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AGRICULTURE AND RURAL DEVELOPMENT
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Growing Gauteng Together

COLOPHON

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ACRONYM LIST

BCA	Benefit Cost Analysis (or Benefit:Cost Analysis). An alternative form of the CBA, but where the ratio >1 is the desired condition.
CBA	Cost Benefit Analysis (or Cost:Benefit Anaysis). A comparison of costs and benefits reduced to monetary values is measured as a ratio. A ratio <1 is the desired condition.
CBD	Central Business District
CMA	Catchment Management Agency
CoJ	City of Johannesburg
DEA	Department of Environmental Affairs
DWAF	Department of Water Affairs and Forestry (now called DWS)
DWS	Department of Water and Sanitation (currently Department of Water, Sanitation and Human Settlements)
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EWR	Environmental Water Requirement. This is the flow rate in a river, stream or drainage line needed to sustain a given quality of habitat and aquatic life. The flow rate may be seasonal and include flood flow requirements.
GDARD	Gauteng Department of Agricultural and Rural Development
MCDA	Multi-Criteria Decision Analysis
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NMT	Non-Motorised Transport. This includes cycle lanes, pedestrian lanes and walkways.
PMC	Project Management Committee
PSC	Project Steering Committee
SAICE	South African Institute for Civil Engineering
SDP	Site Development Plan
SuDS	Sustainable Drainage Systems
WULA	Water Use Licence Application

1 INTRODUCTION

1.1 Research study overview

As part of the project 'Research on the Use of Sustainable Urban Drainage Systems in Gauteng' of the Gauteng Department of Agriculture and Rural Development (GDARD), the Terms of Reference identify this report as 'Cost Benefit Analysis', but during the development of the CBA, the scope changed to compare and recommend on decision support tools or evaluation methods that could be of benefit for implementation of SuDS in Gauteng, therefore the report changed to 'Decision Support Tools for SuDS in Gauteng.

The total list of deliverables of the project is as follows:

1. Inception report and skills transfer plan
2. Literature review on SuDS: definitions, science, data and policy and legal context in South Africa
3. Selection of three specific study areas
4. Data collection on SuDS installations in Gauteng
5. Analysis of study areas with recommendations
6. **Decision Support Tools for SuDS** (in ToR: Cost Benefit Analysis, this report)
7. Best Management Practices
8. Implementation Manual

This report follows **Deliverable 5: Analysis of study areas with recommendations** that identified possible measures in the three study areas in order to investigate what impact and consequences possible Sustainable Drainage Systems (SuDS) could have. This report also follows two stakeholder consultations in July 2019. The outcomes of both these events have had bearing on the objectives and focus of this report as further outlined below.

Deliverables 1 to 7 of this research study are all meant to be input in the formulation of deliverable 8 SuDS Implementation Manual for Gauteng.

1.2 Report Objectives

The original requirement of the ToR for this component of the research study was to undertake Cost Benefit Analyses (CBA) of the various options for each of the study areas. The intention was to highlight constraints of the options and demonstrate the range of benefits that could arise. At the project inception stage, the scope and limitations of traditional monetary value CBA methodologies were discussed, and it was already suggested that a CBA would be too data intensive for this project, and for the application in Gauteng in general, and therefore the analyses needed to be a mix of quantitative and qualitative evaluation of the project options. This approach has been applied to projects of this nature (see **Deliverable 1: Inception report**) and was the intended approach in the tender submission.

As is the nature of research studies, the objectives shifted as the results of the previous deliverables emerged. On review of an early draft of the CBA table of contents consideration was given to focus less on the technical requirements of the CBA and give attention to finding suitable methodologies for comparing options. Subsequent discussions with the client and during stakeholder consultations raised different options that may be considered that pointed more to identifying methodologies that supported decision making.

The following summary of options for Decision Support Methods was presented for discussion at the stakeholder consultations:

1. To adopt the full CBA approach there will need to be substantial effort and investment in building the necessary data.
2. Life-cycle costing is useful for refining a SuDS treatment train.
3. The "Business Case" approach challenges our priorities (e.g. Water security vs healthy systems, or some balance between the two.)
4. The "Trade-off" analysis is qualitative (subjective), but it covers the broader benefits of the scheme.
5. Integrated, strategic Catchment Management Plans[1] are needed which set targets for water resources, ecology, amenity and even catchment economy.

The sentiment taken from the workshop was that presenting decision support methodologies in the Implementation Manual would be more valuable than details of a formal CBA, and in particular the combination of Life-cycle costing and the trade-off methodology may be the best combination for a wider range of users including municipalities, EAPs and EIA case officers, developers and practitioners.

In August 2019, GDARD approved that the title of this report would change to "Decision Support Tools" and that the study areas are used to develop and illustrate the tools rather than a detailed cost benefit assessment for each site.

1.3 Scope of this report

For clarification, the word "decision support tool" as it is used in this report includes ex-ante (based on forecast) evaluation methods. In the context of SuDS applications these methods can be used to decide on whether to implement a SuDS solution instead of a traditional grey infrastructure solution, or to decide between different alternatives. In international literature the word "decision support tools" is often referring to real tools (often software tools) to support ex-ante evaluation methods.

This report acknowledges that using decision support tools for the selection of stormwater infrastructure, and especially those that offer multiple services (e.g. ecological and amenity), are not well developed in South Africa. Research referenced in this report indicates that where these tools are adopted, such as CBA, they are typically tailored to suit the requirements of the organisations concerned.

[1] The "Catchment Management Plan" as referred to in this report is not the same as the "Catchment Management Strategy" (CMS) that is obliged by the National Water Act to be drawn up by the Catchment Management Agencies (CMAs). Once these CMSs are prepared for Gauteng, there should be alignment between Catchment Management Plans and Catchment Management Strategies. There is urgency for both, but municipalities should not delay their preparation of CMPs in the absence of the CMS.

Within this context, the report identifies decision support tools that would be suitable for SuDS related projects. It draws on both CBA based monetary value analysis tools and other analysis tools that are better suited to evaluating environmental and sustainability related criteria.

This report recommends a set of tools that can be applied individually or in some combination as the situation requires. The tools that the research team considers suitable for consideration for decision making on SuDS (**Figure 1**) are:

- **Life-Cycle Analysis**, a form of CBA that is particularly suited to SuDS and local municipal applications;
- **Trade-Off Analysis**, a qualitative Multi-Criteria Analysis method, that has been adapted from the Wet-Services tools for wetlands in South Africa for this SuDS research project, allowing for stronger representation of economic, ecological and social impacts and benefits;
- **Land value assessment**, usually a sub-set of a CBA, it is used here as both an economic evaluation and a measure of social (community) support. This reflects the significance of a key outcome of this study.

While other methods were studied, this report does not go into detail on these different methods, although some alternative methods for economic evaluation are mentioned in Chapter 3. Initial applications of the methods may be tentative but will improve as local experience and locally relevant data sets develop. Provincial government can play an important role in developing and maintaining the data sets, and in particular the cost data sets.

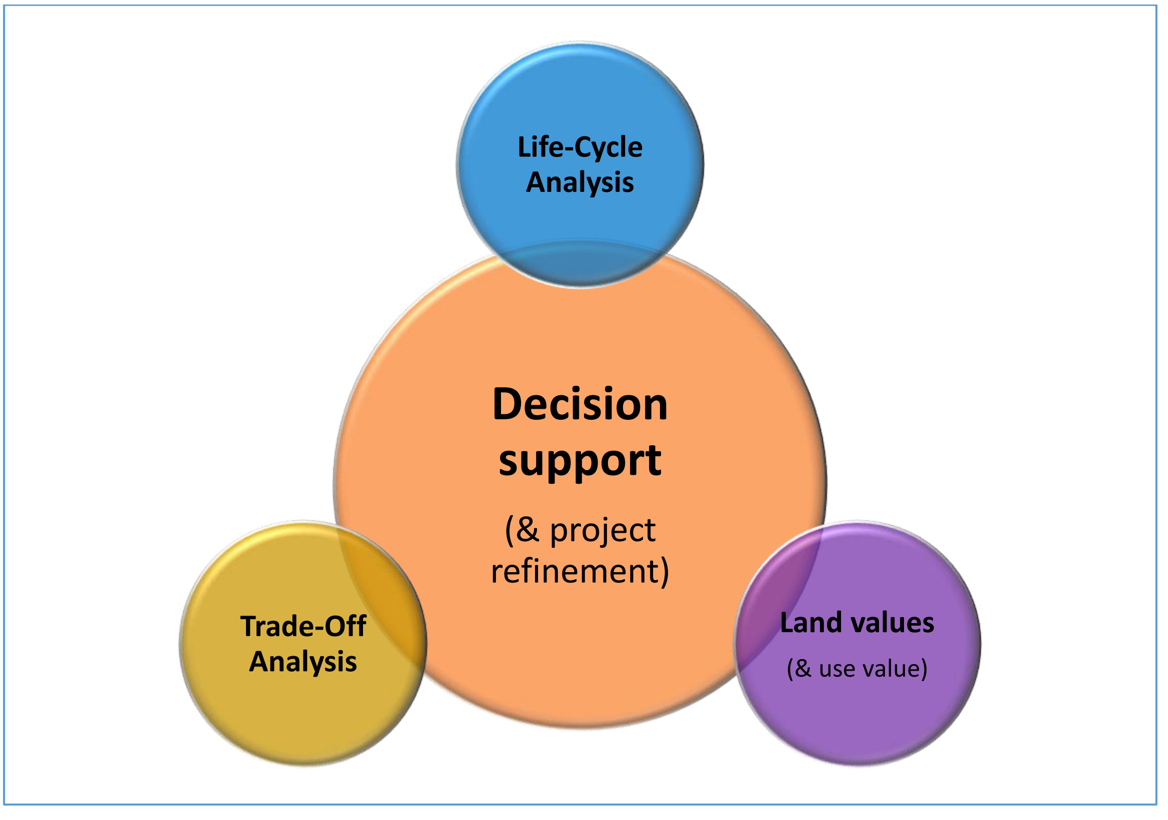

Figure 1: Decision Support Tools recommended in this study.

2 DECISION SUPPORT TOOLS

2.1 Why the need for Decision Support Tools

The provision of municipal services, including stormwater, is not normally supported by formalised decision processes if the required services are within a common standard. In South Africa the standard stormwater services are still largely grey infrastructure systems. These are either public assets, funded through the municipal rates and taxes, or assets on private land funded by landowners and developers. In certain cases, such as on large commercial developments, a bulk services levy may be charged to a developer where municipal services need to be extended or upgraded to accommodate the development, but the standard form of the services (e.g. grey infrastructure) provided would be the same. Usually decisions to invest in this kind of stormwater infrastructure are centred on budget availability, and other decision support tools may be limited to capital cost analysis.

Where project alternatives are contemplated, for example the sizes and locations of one or more regional attenuation facilities, some level of cost comparison may be applied. However, for typical grey infrastructure solutions, the range of costs and benefits will be limited and a simple cost comparison may suffice.

In contrast, SuDS solutions introduce a broader range of treatment measures that may be combined in different treatment train combinations for any given site offering a range of potential impacts and benefits. Instead of providing a single service, they offer multiple services (e.g. ecological and amenity services) and therefore attract a wider stakeholder group. Applying simple cost comparison methods will not address the wider range of services offered by these projects, and different decision support tools need to be considered. The design of a SuDS system will usually be a creative process as the different services and local interests are explored, and there may even be competing objectives. In these situations, there may be multiple possible solutions, and a combination of decision support tools may be needed.

It has to be realized that the decision support tools often try to be all encompassing, while in practice priorities and perspectives may be fragmented between different project owners / decision makers that together have to approve SuDS bearing in mind their own stakes. For example, in a SuDS project stormwater management costs and benefits are evaluated with other services in the green space and equivalent comparisons ("apples with apples") are not always possible. For the larger facilities (further discussed in section 2.3) there may even be different municipalities at play with different priorities of even cost accounting requirements. The decision support tools presented here are an attempt to bridge the range of requirements as well as being open to the participation of a wider stakeholder group.

2.2 Common Decision Points in the Development Process

A typical development timeline is shown in Figure 2. It indicates how the objectives of the development gain in clarity as the certainty in the scale and detail of the design improves. Hence decisions taken earlier in the process must acknowledge higher levels of uncertainty which will affect confidence on the evaluation of any of the decision support tools. Nevertheless, decisions still need to be taken to narrow the alternatives being considered. It is suggested that any of the decision support methods recommended in this report can be applied at any stage to suit the decisions being made by the developer or project team. It is likely that decision support analysis will only be done once or twice in the course of the land development process. Comments on each of the points in Figure 2 may help in selecting the best times.

A Too soon for Life-Cycle analysis, but it may be worth initiating the Trade-off analysis or the Use-value/Land value analysis to start gaining a sense of the broader issues at the site and the potential for developing use-value. This will assist in giving the project direction, rather than the exclusion of alternatives.

B Suitable for any one of the decision support methods, or a combination of them. Treatment train options will usually be ready at this point. Life-cycle analysis will help refine the scale and content of the options, and the Trade-off analysis will help identify preferred options. Use-value/Land-value may incorporated as part of the Life-Cycle analysis, but particular attention should be given to developing the community's perceived benefits of the options.

B1 This may be an update of B, depending on the outcomes of the EIA and WULA processes. The Trade-off analysis should reach close to maximum certainty and will usually reach its peak decision support role in stages B and B1. Life-cycle analysis will be reasonably certain by this point and will assist in confirming the preferred scheme.

C An important costing stage where the details of the treatment train are defined, quantified and costed. Here the Life-cycle analysis will achieve its best certainty before construction. The Use-value/Land-value analysis should be run as part of the Life-cycle as there may be costs associated with developing the use-value of the site. The Trade-off analysis is less likely to be applied at this stage.

D The full costs of the construction and establishment of the scheme are only realised at the end of the construction period. This information will be a useful addition to the costings database for future projects. This could include an update of the Life-cycle analysis, though it is not required for decision support unless there are maintenance related decisions to take.

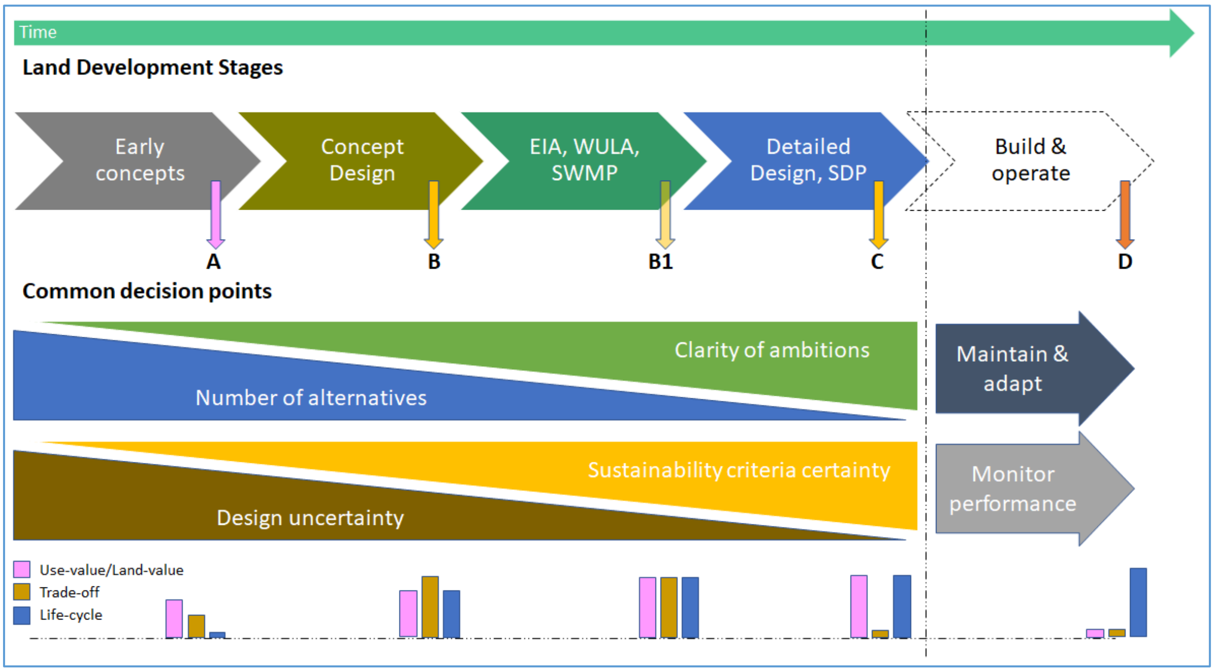

Figure 2: Typical decision points in the development process, with the letters referring to further explanation in the main text

2.3 Decision Support at Scale

It is necessary to first consider how decision support methodologies for SuDS implementation may be applied. In stormwater planning there are two basic scales in play:

> **The site scale**, where a developer proposes to develop (or redevelop) a property and has to apply to the municipality for a permit or council approval of the planned stormwater management system. The developer is legally required to comply with this requirement in terms of the municipal bylaws. Stormwater management guidelines are usually provided by municipalities to assist developers to comply with the bylaws. The primary stakeholders of site scale projects are the occupants of the site. They are ones who will gain the most from the multiple benefits of the system and who will be most interested in its long-term performance. A secondary level of stakeholder will be the downstream properties who may not benefit directly from improved open space, amenity and ecological benefits, but should benefit from the stormwater quantity and quality improvements.
>
> **The "regional" scale**, where stormwater facilities may serve a collection of properties or a wider catchment area. In this case the municipality may waive the specific parts of the bylaw that requires an individual landowner to achieve stormwater management targets on site *en lieu* of the landowner (or developer) contributing to the construction and maintenance of the "regional" facility (e.g. an attenuation pond). The primary stakeholders for regional projects will be a much wider group, especially where the SuDS interventions are in an open space with public access. In these situations, the potential to enhance the ecological and amenity value of the SuDS project is usually seen to be greater than on a site scale. The "Harvestability" potential is also greater at a regional scale than a site scale.

In Gauteng the bylaws (CoJ, 2010) and stormwater design guidelines (CoJ, 2019) of the City of Johannesburg currently point the way for the rest of the province in terms of Best Practice stormwater management on a site. As such the requirement for SuDS measures is virtually enforced by the stormwater discharge limits. In the absence of a wider catchment management plan that may set out alternative discharge limits, the allowable discharge limits revert to a default condition that requires the developer (or landowner) to discharge no more runoff than would have occurred on the site in its natural ecological state. Normal detention facilities on their own will not achieve this target, and neither will a stormwater plan based on traditional grey infrastructure. SuDS will need to be applied. Decision support for the best combination of SuDS measures (the treatment train) will be determined by hydrological and hydraulic analyses. Methodologies such as CBA and Trade-off analyses may only be necessary in rare cases, though CBA may find more application through the Life Cycle Assessment component.

In contrast, the "regional" facilities are not covered in the bylaws and are not directly addressed in stormwater design manuals or guidelines. There are no default performance requirements for these facilities. Instead they would have more strategic performance requirements, to meet the objectives of the wider catchment objectives (e.g. through a Catchment Management Plan). It is in these "regional" facilities that GDARD is expected to have a greater oversight role in SuDS implementation. There will be a much wider stakeholder group for these facilities, possibly even beyond municipal boundaries. The diversity of interests in the services provided by the SuDS facilities may also be much wider than the on-site SuDS, and may even have competing demands (e.g. agriculture vs amenity, habitat vs flood management, etc.). Decision support methodologies such as CBA and Trade-off analyses may be vital in these situations.

SuDS is typically applied under the overarching objectives of sustainability and adaptation. These objectives are best obtained through synergistic responses, rather than trade-offs, between land development and adaptation. However, evidence suggests that trade-offs are the more common approaches to achieve sustainability goals (Hertz, 2016), implying that sustainability objectives are achieved through compromise instead of synergy, and the opportunity for optimum benefit is missed. Therefore, the sustainability criteria for SuDS can be either strong or weak; strong when there is no compromise between the criteria, and weak when there is compromise (Sjöstrand, 2019). The latter is especially the case where there are competing objectives as may occur with the different environmental services offered by SuDS and the decision support tools need to be able to deal with this.

The outcomes of the application of the methods in this study suggest that, if applied in the planning stages of a project, these decision support tools can also be used to enhance the scheme and reduce trade-off compromises.

2.4 Decision Support Tools Available

Two broad categories of decision support tools are considered here:

Economic evaluation is based on the premise that all costs and all benefits of a project can be reduced to the same value system and that if the value of the benefits exceed that of the costs then the project can be approved. This approach is criticised as anthropocentric (centred on human wellbeing) and that the real value of nature is ignored (e.g. Speed, 2006). The methods include Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis and Life-Cycle Analysis (LCA) and despite the criticism parts of these methods are considered useful to municipal infrastructure projects and are outlined in Sections 3 and 4. It is the **Life-Cycle Analysis** that is recommended for application to SuDS projects (Armitage, et al, 2013).

Multi-criteria evaluation allows for the integration of the wider variety of criteria and types of information typically associated with the environmental (including human well-being) aspects that are difficult to value in monetary terms (Sjöstrand, 2019). The approach is best supported by multidisciplinary skills and stakeholder consultation (Cinelli, et al, 2014). This approach is seen to be particularly suitable for the wider range of environmental services offered by SuDS schemes, and it allows for the evaluation of trade-offs. Although synergistic solutions are preferred to trade-off solutions, the latter is particularly important in retro-fit SuDS applications, and where the planning processes have not included sustainable drainage requirements. Hence the trade-off approach is expected to be a common feature of SuDS projects.

The multi-criteria approach is also easy to integrate as part of the existing Environmental Impact Assessment (EIA) process in South Africa, and in particular the stakeholder consultation process. The **Trade-off Analysis** approach is outlined in Section 6.2.

In these early stages of the implementation of SuDS in Gauteng these two categories of assessment and the two methods themselves (Life-Cycle Analysis and Trade-off Analysis) are expected to cover most decision support requirements. They may be applied together or individually depending on the nature of the site, the scale of the project and the expectations of the stakeholders. The Life-Cycle

Analysis method is already well set out for SuDS projects by Armitage, et al (2013), though more current costs and Gauteng based rates are needed for application in the province.

Use-value is a key outcome of the research undertaken in this study. It refers to how communities perceive the value of the SuDS site and whether they will want the SuDS system to be sustained. It is often linked to **land-values** which are a specific aspect of economic evaluation and therefore a subset of a CBA. Hence land-value assessment is proposed here as a useful addition to the Life-Cycle Analysis. However, it is also seen as an important indicator of the sustainability of the system, and as such may be used on its own, or in conjunction with the Trade-Off Analysis (see below).

The Trade-off Analysis is an adaptation of the methodology already available for wetland assessments. It is presented here in concept form and will require further development for direct application to SuDS projects, but it is expected that this should be achieved relatively easily.

An additional method was raised at the August 2019 project Steering Committee. This is **Business Case Assessment** which may be used as decision support for investment in a scheme, for example stormwater harvesting. This introduces an additional opportunity for SuDS based systems in this study. Although an outline scenario is presented in **Appendix 4**, this method has not been investigated in any detail on this assessment. With the development of catchment management plans and increasing attention to the progression to Water Sensitive City status, there may be competing attention for stormwater resources. An example would be balancing the demands of desired future ecological states in urban streams against the stormwater harvest potential to reduce demand on traditional potable supplies. In such cases the "business case" approach may highlight compelling incentives that need to be considered. This approach will need further development in time.

2.5 Simulation models to assist in assessing performance

In this research project the hydrological simulation model MUSIC from eWater was applied to support design development and decision making. Such simulation models basically assess the effectiveness of SuDS in terms of water quantity and water quality performance. Performance measures from MUSIC are assessed with scheme costs from a Life-Cycle Analysis and the cost effectiveness of project options can be compared.

Some simulation models can also provide cost indications, or further assessments of costs and benefits. MUSIC, for example, does provide cost analysis but the data is not set yet up for South African conditions, and this tool was not used in this study. Most simulation models will only quantify part of the criteria to be evaluated, but their advantage is that different scenarios and alternative strategies can be tested for performance regarding the stormwater management impacts. (See Literature Review report and the report on Study Site Case Studies for more information)

2.6 Seeing value in SuDS

Seeing value in SUDS is a discussion about the adoption of SuDS versus traditional grey drainage infrastructure. It is not about a decision to invest in SuDS versus investment in other municipal services. Municipal township establishment and any development sites within an urban township typically require provision of all basic municipal services, including stormwater services. However, in more informally developed areas where a municipality is trying to retro-fit services, any decision made to select one of the basic services over another is outside the scope of this report. However, stormwater conditions will still occur and at some point the municipality will face decisions as to what stormwater system to install. This report will help at that stage.

One of the key outcomes of this study is the importance of the actual or perceived value that a SuDS solution in a community environment. This is not just an important component of the economic evaluation of a project. The placing, and the adoption, of SuDS in the community space is seen to be a key success factor for the long-term sustainability of a SuDS treatment train and is reliant on how the community perceives its value in their environment. The outcomes of the study to date show that the value may take various forms; experience of a green open space (e.g. in CBD areas), conservation value (Bonaero-Atlasville), agricultural potential (Kagiso), flood or water quality performance, etc. However, if the community perception of the SuDS system is indifferent, or even negative, that space may be transformed (e.g. re-landscaped or developed if it is on a private estate) or it may become dumping ground and the municipality will become solely responsible for its monitoring and upkeep and even in the short-term the functioning of the system will degrade.

A common indicator for perceived value in the urban space is land value. Examples have emerged in this study where land owners have indicated the importance green space can bring to the value of a property. The Clearwater Estate (Bonaero case study), for example, is centred on a pan that provides SuDS services has had its amenity value enhanced for the benefit of the estate area as a whole. In the Johannesburg CBD, developers in the city centre have both demonstrated (e.g. Bank City) and others expressed intent to enhance their street front environment as a green space area using SuDS.

However, it is also evident that perceptions of value will vary across communities in the city and in places like Kagiso the value of land may be driven by other factors and proximity to open space areas may even be seen to be a risk (e.g. for security reasons). Hence a section of the report (Section 5) looks into this aspect in some detail. Land value could make an important contribution to the Life-Cycle Analysis of a SuDS project, but it is also a potentially important indicator on its own, and there an additional decision support tool.

3 ECONOMIC EVALUATION AND THE LIFE-CYCLE ANALYSIS

3.1 Economic Evaluation Methods

An economic evaluation method, like the Cost-Benefit Analysis or the Life-Cycle Costing, typically looks at costs and benefits of a scheme, converted to monetary value as far as possible, and all converted to a Net-Present Value (NPV). Converting to Net Present Value means discounting for costs and benefits in the future, because of the uncertainty these costs and benefits have. Often the period over which the evaluation is done is the useful life of a scheme (or the depreciation period). It does not include the full life cycle necessarily, i.e. including possible disposal of the asset after its useful life, which is done in Life Cycle Costing.

When considering an economic evaluation method three key factors are important to realize:

- **Data intensity -** Armitage et al. (2013) in the SA guidelines for SuDS mention that Benefit Cost Analysis (thus also valid for CBA[2]) is "the most comprehensive approach, however it is difficult to undertake. The more complicated and detailed the studies required, the less attractive SuDS may appear to developers." For this reason, where CBA becomes an official tool for project evaluation it is common for municipalities, or governments, to invest in the development of cost and benefit databases that the development community can utilise. Examples include the cost-benefit methodology for flood risk evaluations in the United Kingdom (Penning-Rowsell, et al 2013), and the Green Values National Stormwater Management Calculator (CNT, 2009) for the evaluation of Low Impact Development (SuDS) projects in the United States.

- **Monetary evaluation –** The costs and benefits are monetarized as soon as much as possible, and every Rand at its present value weighs the same. In contrast, methods such as multi-criteria analysis can be used to compare alternatives that are weighed against different aspects of society or nature with different weighting factors. This is still subjective but gives the advantage of judgement of importance. (This is similar in principle to the "Trade-off" approach presented in Section 6.2.)

- **Discount rate –** This approach adopts a standard financial accounting method where all future benefits and costs are converted to a present day value[3]. The method is sensitive to the discount rate applied which should be standardised for a municipality or a province, for example. Ideally the discount rate should be prescribed (e.g. by a municipality or a government). For financial analysis (which is part of CBA) the Treasury of South Africa advises to use the government bond yield, although it could also be at the discretion of the financing institution. It would also apply to 'social discount rate' for economic opportunity costs of capital in a CBA (National Treasury, 2017).

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[2] The Cost Benefit Analysis is sometimes also called Benefit Cost Analysis (BCA). This may be attributed to the use of the ratio, where a benefit:cost ratio ≥1 is a beneficial scheme and is an easier reference number.

[3] For further reading on discount rates refer to http://www.sfu.ca/~heaps/483/discounting.htm .

The US Environmental Protection Agency (USEPA, 2013) lists a number of economic analyses that have been used to assess green infrastructure projects. Those considered relevant to application at municipal level in Gauteng are summarised in Table 1. Investment in municipal stormwater infrastructure is not commonly supported by a formal CBA process in South Africa. Investment in grey infrastructure without a formal assessment of costs and benefits is the norm in township establishment, but the evaluation of SuDS infrastructure is sometimes done by comparison with equivalent grey infrastructure assets (e.g. Armitage, et al, 2013).

Table 1: Economic Evaluation Methods for SuDS compiled from (USEPA, 2013)

Method	Description	Local relevance
Capital Cost Analysist	This is the estimate of the cost of works, cost of land, and any other up-front costs to build a scheme. It excludes operational and maintenance costs.	It is useful in comparing one option against another, and data is more readily available through the planning and design process. It is one of the more common methods applied by municipalities in South Africa.
Cost:Benefit Analysis (CBA) [or Benefit:Cost Analysis]	This typically looks at life-cycle costs and benefits of a scheme, converted to monetary value as far as possible, and all reduced to Net-Present Value (NPV).	The components of the analysis will be determined by the municipality or sector and the objectives of the assessment. For example, life-cycle costs may be narrowed to just capital costs plus operations and maintenance costs over the design life of the scheme. Usually CBAs include costs and benefits that can be easily assigned market values. However, it has long been recognised that there are additional benefits that accrue from schemes that improve the safety and wellbeing of communities, and increasingly CBAs seek to include these components, quantify these values and even monetise them.
Cost-Effectiveness Analysis	In this approach the capital cost or life-cycle cost is reduced to a cost per unit, such as cost per cubic metre of stormwater reduction, or cost per kilogram of sediment trapped. In this way different SuDS options (and grey options) may be compared.	This approach has been effective at municipal level in the US where investment performance on, say, sediment load reduction can be monitored and reported. The system will need to be adapted for South African conditions.
Fiscal Impact Analysis	This approach is linked to land use, land values and therefore land revenues. It assists municipalities evaluate the return on investment of different land types and locations.	This option is relevant to SuDS and green infrastructure projects linked to drainage and watercourses, particularly where land values are influenced by proximity to watercourses and public open space.

Method	Description	Local relevance
Life Cycle Costing Analysis [Whole life costing]	This is the calculation and comparison of all costs from acquisition to disposal of an asset. The method does consider revenues as benefits, but does not necessarily include the value of all ecosystem's goods and services, although they can be economically (not monetary) appraised and then included.	Armitage et al. (2013) find this the most appropriate method for South Africa, as it ensures all stakeholders will have an understanding of their total commitments. Armitage proposes to use "Damage Avoidance Costs", which applies the substitute costs principle to estimate the value of improved water quality and water flows (so the alternative costs of using a grey infrastructure design to get the same benefit). It can also include land values as both costs (e.g. land purchase) and benefits (e.g. improved land values).

Theoretically a complete CBA would involve all environmental and societal costs, but this would entail an extensive economic evaluation exercise. Economic evaluation can go into considerable detail when sufficient data is available, but it usually takes time to develop a sufficiently large database. In fact, for Nature Based Solutions in water, including SuDS, there is often not enough data and only quite theoretical measures to prove their benefits. This is seen to hinder the implementation of a full CBA (WWAP, 2018). The benefits of a SuDS scheme are similarly difficult to quantify. Defining the monetary value of such aspects as ecological services and amenity can be seen to be too subjective and perceptions will vary between communities. Hence the scope of a CBA is typically tailored by the user to suit the objectives of the organisation(s) concerned with funding and approvals of such projects and secondly with the availability of data and the nature of the project.

3.2 Life-Cycle Analysis

Life-Cycle Analysis is the recommended approach for the economic evaluation of a SuDS project in Gauteng for the following reasons:

i. Baseline costs are readily available to users through the SA Guidelines for Sustainable Drainage Systems (Armitage, et al, 2013). This offers a standard by which decisions across the province can be applied. Ideally the standard would be updated and referenced against Gauteng costs in the near future.

ii. It enables comparison between drainage alternatives, including green vs grey, and different treatment train options.

iii. The process of preparing costs for a treatment train (based on a concept design) allows for review and refinement of the system in the context of the site.

Each of the above are important parts of the decision making process by the developer and designers, will be helpful in communicating the costs and benefits of the project to the local communities for their input, and also helpful to authorities for review and authorisation. Hence the timing of the Life-Cycle Analysis will be influenced by decision points in the land development process (Figure 2).

Armitage et al. (2013) propose that the Life-Cycle Costing approach (also known as Whole-Life Costing) is the more appropriate for SuDS evaluation in South Africa. The full scope of a Life Cycle Cost assessment is given in the **Figure 3** which was developed by HR Wallingford (2004) for the Whole Life Cost appraisal for SuDS in the UK. A provisional list of the kinds of costs and benefits that may be associated with a SuDS project is given in Table 3. However, the assessment can also just focus on capital costs and associated maintenance costs, especially in the earlier stages of development planning when details of the SuDS options are still being considered at a relatively high level (Figure 2). Where available it may include revenue streams and improved land values as benefits. Therefore the wider benefits of ecosystem services and public amenity would not normally be considered.

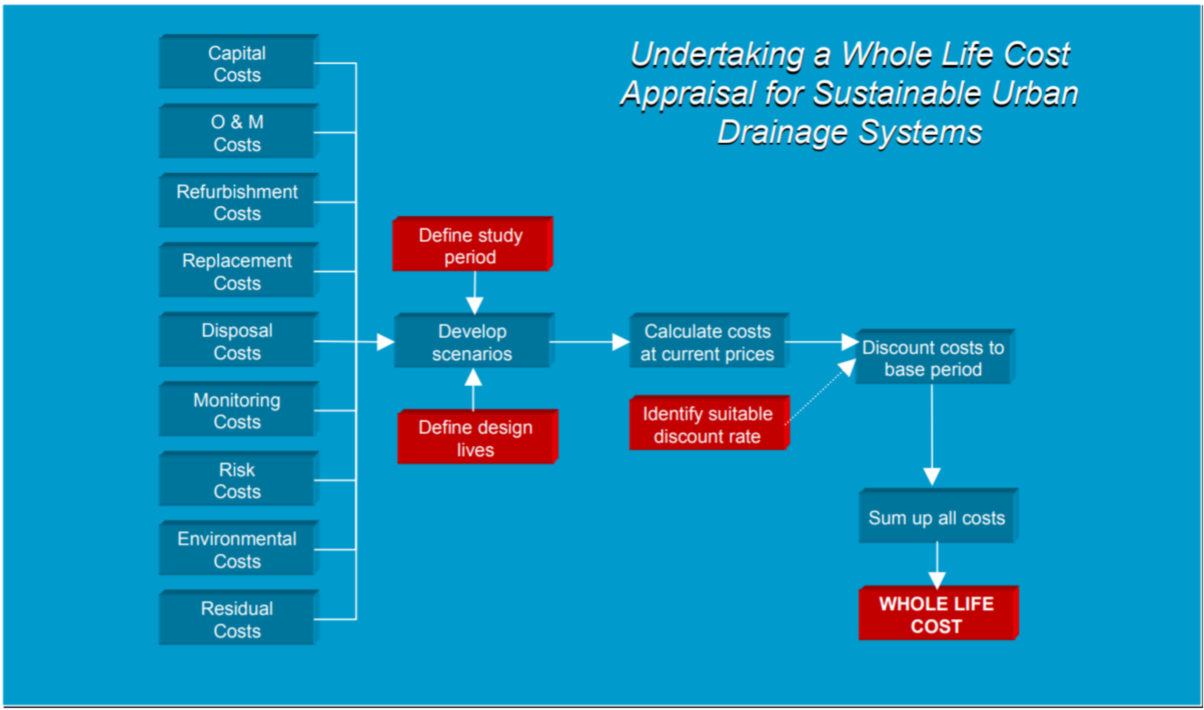

Figure 3: Whole Life Costing for sustainable drainage projects (after HR Wallingford, 2004).

Life-Cycle Analysis is useful in that it provides stakeholders their total cost commitments. In the SA SuDS guideline (Armitage, et al, 2013) it is suggested that some of the benefits of the SuDS scheme may be included where information is available. This may include "Damage Avoidance Costs" where wider environmental damage (e.g. flood damage, erosion, scouring, sediment build-up, water quality, etc.) that may be avoided by implementing the proposed drainage system can be quantified in monetary terms. This option may also assist in comparing grey and green (SuDS) alternatives.

Life-Cycle Analysis with all economic evaluations, the level of detail included in the analysis can be tailored to suit the organisation concerned. Most civil engineering works projects will have a detailed design that breaks down the different components of a project into a Bill of Quantities which can then be costed. However, there are a number of stages in the planning and design process where costs are considered. These are summarised in **Table 2.**

Table 2: Project stages where costs are considered (with stages relating to decision points in Figure 2)

Planning & Design Stage	Description	Certainty
Feasibility stages (Decision point A)	Early consideration of the SuDS scheme within the planning stages of the project. Typically a range of options may be considered with different site layouts.	Very high level SuDS concepts. Indicative costs only. **Cost certainty is low.**
Concept design (Decision point B)	Overall scale of the project is generally confirmed. Components of the treatment train identified with performance criteria to a level of detail suitable for EIA and WULA. Options still being tested. Provisional Bills of Quantities prepared for each option.	First breakdown of the components of each facility in the SuDS treatment train. Costing detail may depend on the developer's requirements but the SA SuDS guideline (Armitage, et al, 2013) will be suitable. **Cost certainty is moderate[4].**
EIA & WULA Stage (Decision point B1)	Environmental and stakeholder input into the SuDS concept(s). Refinements to treatment train and final (preferred) solution selected.	Revision of Concept design costs. **Cost certainty is moderate.**
Detailed design (Decision point C)	Development of the detail of the works, allowing for requirements specific to the site location and specific conditions. A detailed Bill of Quantities is produced.	Detailed cost breakdown. Costs from projects of a similar nature and location are used where possible. **Cost certainty is moderate-high.**
Tender award (Decision point C)	Detailed costing by contractors of the Bill of Quantities.	This is usually the best estimate of scheme cost before construction starts. It draws on actual construction rates and charges relevant for the location. Where a competitive tender process is followed, the range of costs should improve certainty. **Cost certainty will be high**, though there will still be contingency allowances.

[4] All cost certainty is relative to the level of detail of the design and the extent of the current pricing data. Developing and maintaining (updating) a suitable pricing database for Gauteng will be an important asset.

Planning & Design Stage	**Description**	**Certainty**
Construction handover (Decision point D)	Ideally handover occurs a period of time after the actual clearing and rehabilitation of the site. This is to allow for repair of any construction faults and for the rehabilitation works to stabilise. All costs incurred are realised, including, unforeseen costs, weather disruption, etc.	**This is the actual cost of the project.**

Maintenance & inspection costs (including monitoring) are important considerations for SuDS projects. These should reflect regular maintenance activities such as sediment and litter removal, vegetation harvesting (e.g. reeds) and replacement, erosion damage, etc. The frequency of inspections should also be anticipated and should reflect the conditions at the project location. For example, SuDS in public spaces, or on main streams may need to be inspected weekly in the wet season and after large storms to ensure stability and performance. Maintenance and inspection requirements can be estimated from references such as Armitage, et al (2013) at concept design stage, but project specific details should be prepared as part of the detailed design stage.

Two important additional documents should reflect the maintenance and inspection requirements for the SuDS project in some detail:

- The OEMP (Operational and Environmental Management Plan) for the project, prepared for the EIA submission, should set out the detailed maintenance and inspection requirements of the project, or have as a condition of environmental authorisation the need to have them submitted back to GDARD and approved in an updated EMPR before construction can start.
- On private developments the Conditions of Establishment of the site should clearly set out the SuDS facilities areas and include clear maintenance and performance plans.

Inspection activities should be tailored to monitor the performance of the SuDS treatment train that it was designed to achieve. For example, if the SuDS scheme was designed to reduce runoff yield to a given volume per year (m^3/year), or reduce sediment load to a given mass per year (kg/year), there should be some means of measuring this. This is important more for improving designs and knowledge of these systems than it is for policing the performance of the systems. Hence, environmental authorisation should require that site monitoring reflects the developer's stated design performance of the SuDS system.

4 COSTS & BENEFITS

4.1 Scope for costs and benefits

The scope for both costs and benefits is indicated in **Table 3**. This is an indicative list to assist with identifying opportunities and potentially significant costs. It will expand over time as Gauteng based experience with SuDS grows.

Focus is given here to direct costs and benefits as those are usually more readily measured (or estimated) and therefore more suitable for inclusion in the Implementation Manual. As the application of Life-Cycle Assessments and Trade-off analyses gain traction in practice, and suitable data becomes available, the list can be expanded to include indirect and intangible costs and benefits.

Table 3: Provisional list of typical direct costs and benefits associated with SuDS projects.

Costs	Benefits
Planning & design costs Professional fees, surveys & sampling, EIA and WULA, etc.	Multiple services: A treatment train may provide for additional services in the same corridor. For example sewer lines, power lines, NMT, etc.
Land costs: Land purchase, rezoning, servitude establishment, etc.	Ecological services: Increased urban biodiversity and contribution to ecological corridors in the urban space.
Capital costs: Construction costs and any associated services, professional supervision services, site establishment, planting & irrigation, etc.	Amenity services: SuDS may be integrated, and landscaped, into community open space.
Operations & Maintenance costs: Regular maintenance & inspections, irrigation, refurbishment & replacement, damage repair, disposal costs (e.g. contaminated sediment), etc.	Flood mitigation: Decrease in small flash floods, better channel stability and habitat protection. Large flood mitigation if SuDS includes detention.
Monitoring costs: Monitoring inspections, sampling (quantity, quality, habitat, etc.), laboratory testing, etc.	Water quality improvements: Improved water security, instream habitat, amenity, and more.

Costs	Benefits
Decommissioning costs: These are rarely considered for stormwater infrastructure, but with SuDS providing treatment services, and the risk of contamination, the costs may be significant. This is also in line with EIA processes where the impact of decommissioning needs to be considered.	Improved land values: Locations where waterfront properties, including SuDS features, improve rentals and land values.
Residual damages: Many SuDS measures are designed to address the smaller, frequent storm and rain event conditions. Unless detention measures are included there may still be flood risk and damage to be expected during larger storm events. Damages may include damage to property, infrastructure, as well as the physical landscape, ecological systems, etc.	Avoided damages: Measure the cost of damages that have been avoided by implementing a particular SuDS project. See adjacent for the kinds of damages the may be considered. Useful data sources would include insurance claims for previous events, maintenance costs, etc.

4.2 Data sources

Guidelines, rates and data presented by Armitage, et al (2013) in the SA Guidelines for Sustainable Drainage Systems provides a very useful reference for the estimation of costs and some benefits for a SuDS project. It is recommended that this reference, or any subsequent update(s), is adopted for decision support in Gauteng, until a suitable replacement is provided with more relevance to Gauteng rates.

Guideline rates as provided in the reference above are useful for comparing alternatives and refining the scale and concept of the scheme. They are usually applied to concept designs and are therefore an effective part of the planning process. The scheme costs will be refined as part of the detailed design, preferably using local rates where available.

Data for cost and benefit analyses change with location and over time. Hence the rates presented by Armitage, et al (2013) are out of date and applying a rate adjustment (e.g. based on CPIX[5] or the CIPI[6]) is a temporary measure, and even in 2013 they may have been more relevant to the Western Cape than Gauteng. This does not change the recommendations in this report to use this data set as an

[5] Consumer price index excluding mortgage costs. This is officially targeted by the South African Reserve Bank and a primary measure that determines national interest rates, and published by Statistics South Africa.

[6] Construction Input Price Index, published by Statistics South Africa on a regular basis.

interim measure, but it does emphasise the need to develop current data sets relevant to Gauteng. Responsibility for this is sometimes adopted by bodies such as civil engineering and construction institutions, but they will only focus on member requirements and may not cover the full range of costs. This is therefore an aspect the provincial government can initiate and oversee, for example through the provincial Dept. of Public Works (see further Implementation Manual).

5 USE-VALUE AND LAND VALUES

5.1 Land values and SuDS

The evaluation of improvements to land values due to local assets (e.g. river front) can be a helpful addition to CBA. A local example is the study of house prices adjacent to a green infrastructure project in Ekurhuleni just downstream of the Bonaero Park-Atlasville study site. The study indicated a significant increase in riverside properties after the construction of the scheme in a middle income area of the city (Dunsmore, et al, 2019). This proved to be one of the more measurable benefits identified in the CBA where ecological benefits were also clearly identified but were difficult to convert to monetary terms. Hence it was anticipated that land values would be an important component of the Life-Cycle Analysis methodology recommended in this study. However, the outcome of the assessment on land values in the case study sites resulted in different, but equally important results.

Research by NM Associates (Mammon and Paterson, 2019) for this study showed there is very limited South African based research on whether or not investment in Sustainable Urban Drainage Systems (SUDS) and other forms of Open Space has a positive impact on property values in the surrounding areas. Analysing the effect that investment into the kinds of green open spaces that play a role in Sustainable Urban Drainage is challenging and complex, because property values depend on a number of differing contextual factors – only one of which is proximity to landscaped green open space. In South Africa, for example, security plays a large role in informing property values. Security in turn is not only reliant on design factors but also on municipal and community capacity to manage open spaces. Determining the extent to which changes in property values are a direct result of SUDS interventions, and not security or other determinants, is thus difficult. However, the assessment does point to the importance of a broader “use-value” of the site.

A summary of some of the key findings by Mammon and Paterson (2019):

- There is a general international trend that that urban properties adjacent to well managed green open space areas, especially those with “waterfront” positions, will see improved property prices.
- It may be assumed from observations that property values in industrial spaces are likely to be the least responsive to the presence of green open space.
- Developers of commercial property may not always market the benefits of adjacent open space areas and water frontage, but there is evident willingness of commercial property owners to pay more for these areas.
- Residential developments associated with enhanced recreational and ecological open spaces in middle and upper income areas are expected to add a premium to property values.
- The same is not assured in lower income areas. Instead the opposite may be true and open spaces within residential areas can decrease property prices. Security can be a primary concern. How residential areas interface with open spaces and how those spaces are maintained can influence security status.
- There is a strong link between use-value and property value. If the local community see value in using the area this is more likely going to reflect in their property values.

- A key requirement in all cases is that the open spaces need to be well managed. Security, illegal dumping and waste build-up, poor water quality, and overgrown or eroded areas will likely lead to a decrease in property values.

Mammon and Paterson (2019) offer some guidance to estimate property values in the study sites covered in this project (**Appendix 5**). Although preliminary readings of the little research that is available on the relationship between SUDS interventions and property pricing may suggest that such interventions could have a positive impact on the value of property, it is vital to acknowledge the limits of this investigation. The extent to which property values respond to such interventions depends on a number of complex site-specific factors – requiring us to treat each site differently and raising questions about the applicability of international research. Any discussion around the added land value benefit of implementing SUDS strategies on a certain site must also include a discussion on amenity, functionality, land uses in the area and the economic role of the site in the broader city. All of these aspects are interrelated, and thus determining the land value benefit of the SUDS intervention in particular is incredibly challenging.

5.2 Defining Use-value

> Land that is not perceived to offer value to local communities is vulnerable to degradation.

Stormwater servitudes and corridors are already vulnerable to degradation. This is evident in many of the urban stream and river corridors in Gauteng where river front properties have turned their backs on the river corridor by building high walls and security fences. These areas become dumping areas for waste and building rubble, security risks as vagrants move along the corridor, and are vulnerable to the establishment of informal settlements. In addition the rivers and streams suffer from lack of maintenance resulting in erosion and river bank damage. SuDS sites will also be at risk and there is high importance placed on trying to develop a positive community perspective of the value of SuDS sites in their area.

Schäffler, et al (2013) assessed the state of green infrastructure in Gauteng and recorded the perspectives of Gauteng municipalities on the value of green open spaces. The metropolitan areas have larger development pressures and all have policies that encourage the establishment of green open spaces and recreation value is a common theme, but there appear to be subtle differences. The City of Johannesburg (CoJ) places value in the ecological assets of the open spaces in association, but the value of green spaces in general is not shared across all municipal departments. The City of Ekurhuleni (CoE) has driven the "rehabilitation and beautification" of water systems (lakes, dams and pans) for their "eco-recreational" potential (in particular eco-tourism). They also have a strong focus on wetlands as part of protecting water resources. The City of Tshwane (CoT) has a strong conservation focus with the establishment of a number of nature reserves across the city, but particularly in previously disadvantaged areas. Ecological benefits are linked to social and economic functions, and the value of open space should recognise benefits to present and future communities. CoT also identifies sustainable small scale agricultural development as unlocking the "full potential" of open space land in the city area.

Outside the metropolitan areas, in the Sedibeng District Municipality (including Emfuleni, Lesedi, Midvaal Local Municipalities), land cover is largely rural and agricultural. Although environmental policies typically acknowledge the importance of open space, natural areas and ecological value, this does not attract high priority. This is partly due to the lack of experience of municipal officials in this field, but also because community perceptions of the value of ecological services are low. Even tree planting programmes need considerable consultation with local communities before the projects are implemented (e.g. Lesedi). However, strong political commitment can effect changes to these perspectives (e.g. Midvaal), though it is still important to engage with communities and understand their values. For example, Schäffler, et al (2013) record that in Midvaal communities have been persuaded that tree planting is good, but fruit trees were more successful than indigenous trees due to their higher values.

In West Rand District Municipality (including Mogale City, Merafong, Westonaria and Randfontein Local Municipalities) have significant ambitions for greening the district. There are strong links to community needs and values of social wellbeing though it is not clear how this has been "sold" to communities. However, there is interest in looking at creative ways of achieving green space objectives; use of cemetery space, conversion of informal dumping sites to formal parks. Formal, managed park areas are seen to be positive ways to influence public perceptions of open space.

Box 1:

"Although 'community values' feature as a primary motivation in most West rand greening schemes, little detailed work has been done to study the relationship between ecological investments and social value, and in particular, how the specific attitudes of residents affect the success of projects such as vegetable gardens and tree planting. There is a general acceptance that these initiatives are socially beneficial, but officials' experience with greening schemes is that these schemes depend on "levels of interaction between communities and trees and gardens, and whether people actually use green features" ".

(Schäffler, et al, 2013)

There are strong parallels between Green Infrastructure and SuDS projects, and the findings by Schäffler, et al (2013) are reflected in the experiences in the case studies in this study. There is a clear need to investigate the use-value of a project on a site, even if those values are qualitative and don't necessarily emerge through changes in property values of residents adjacent to, or close to, the project. What is also clear from the work by Schäffler, et al (2013) is that although further research is required in this field (**Box 1**), there is a diversity of options for developing use-value to explore at a site. These include formal park and play areas through to activities that offer jobs and economic benefits such as agriculture and stormwater harvesting. The case study site is an example of this, and even demonstrates existing waste recycling and landscaping (paving) business on the site. While these may not usually be the preferred land uses with SuDS, they highlight the variable nature of perceived value that the planning and design of SuDS should be ready to consider.

Deliverable 7: Best Management Practices for SuDS in Gauteng, **Section 8**, presents a range of methods to consider when developing use-value of a site in consultation with the community and stakeholders. The alternative is to use land-values as an indicator of the economic benefits of the SuDS project, as outlines in the section below.

5.3 Land value and SuDS: An index of community adoption?

An important outcome of the analysis of study areas (**Deliverable 5: Analysis of study areas with recommendations**) is that community acceptance, perhaps even their adoption, of a green open space is critical to the sustainability of a scheme. The Bonaero-Atlasville pans and wetland case study is a prime example of this, but there are also important indicators of the same outcome for the developments in the Johannesburg CBD. There is a link between use-value and property value. Property value may therefore be more than an indicator of economic benefit, but an indicator of community adoption, and therefore the sustainability, of a SuDS project.

In some situations, such as Kagiso where land values are not usually associated with proximity to open space, the land value indicators may only respond sometime after a successful project is implemented. Here the consultation process with the community in the planning and design stages (and EIA stage) of the project may be used to infer likely community adoption, and this may be acknowledged in but the Land Value Analysis and Trade-off Analysis decision support tools. This approach will require trial and testing over a number of projects before its value as a decision support tool is realised, but even the process of considering this aspect will be useful in evaluating the benefits and risks of a new SuDS project in a new community.

6 MULTI-CRITERIA ANALYSIS AND INTRODUCTION OF THE TRADE-OFF ANALYSIS

6.1 Overview of Multi-Criteria Analysis

Multi-criteria analysis, or Multi-Criteria Decision Analysis (MCDA) has developed to become one of the preferred methods of sustainability assessments. It is useful where a range of environmental, social and economic factors are inter-connected and must be taken into consideration, particularly in situations where objectives may be competing and trade-offs may be required. It supports a wide variety of information types, and has proved useful where stakeholder participation is an important part of the decision making process (Brinkhoff, 2011, Cinelli, et al, 2014). Evaluation criteria can be quantitative (e.g. monetised values from a Life-Cycle Analysis), semi-quantitative (e.g. expert scorings of environmental services), or qualitative (e.g. value statements from stakeholder participation).

There are an increasing range of methods within multi-criteria analyses, but the approach promoted by Sjöstrand, et al (2018) has strong parallels with the objectives of this study on implementing SuDS in Gauteng. They look at Multi-Criteria Decision Analysis for municipal support for sustainability assessments of regional water supply interventions in Sweden. They look primarily at quantitative and semi-quantitative sustainability criteria that are suitable for water supply (Sjöstrand, et al, 2018). In the approach adopted here for the analysis of SuDS projects, the Trade-Off Analysis set out below, a more qualitative analysis is proposed due to the importance of ecological services in SuDS, and that SuDS projects are an important part of the community space. This is backed up by the Life-Cycle Analysis that provides the quantitative analysis.

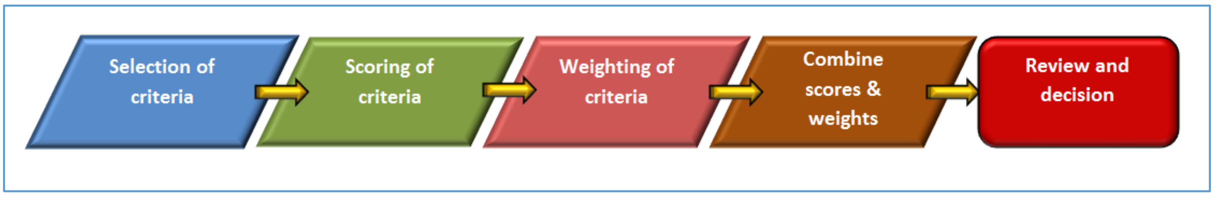

Figure 4: Multi-Criteria Analysis process (after Sjöstrand, 2019)

A simple depiction of the process of a Multi-Criteria Analysis is given in Figure 4. Each of these stages needs to acknowledge the diversity of the issues. The process is ideally undertaken by a multi-disciplinary team of specialists unless the project is small, or the issues around the selection of the treatment train are relatively straight forward. Sjöstrand (2019) suggests the following are important in running a successful Multi-Criteria Analysis:

- Selection of the right criteria is a critical
- Avoid double counting
- Setting weightings for criteria
- Carrying out uncertainty analyses

The first three are addressed in the section below on Trade-off Analysis. The fourth, uncertainty analysis, is a more advanced level of analyses where uncertainties are incorporated into the scoring and weighting of criteria. Uncertainties arise in many forms in these kinds of analyses, and would typically include the lack of suitable data, knowledge to estimate the impacts of the project on aspects of the environment, subjectivity and bias in the experts, etc. At present this is not included in the Trade-Off Analysis method described below, though this should be considered in time to come.

6.2 Introduction of the Trade-Off Analysis

The proposed trade-off analysis method, developed in this research project on SuDS in Gauteng, is an adaptation of the Wet-EcoServices tool that has been developed in South Africa to evaluate the benefits of wetland systems (Kotze *et al,* 2008). It was well received at the Stakeholder Workshop in July 2019 and is part of the recommended set of tools for decision support for SuDS projects. It is still under development, but the principles are described here.

The management and restoration of drainage systems can be undertaken in such a way that it supports and improves multiple objectives, but it requires a good understanding of the values currently provided by the targeted area is critical to inform decision making. The demand for different benefits (both now and projected), also needs to be considered to ensure that restoration efforts make an appropriate contribution to user needs and aspirations. This is particularly important when interventions are being considered which involve a substantive trade-off amongst different user groups. An analysis of ecosystem services provides a useful framework for better understanding competing needs and the trade-offs that will be made when evaluating the desirability of potential rehabilitation interventions.

There may be a range of competing objectives that need to be considered when developing a management and/or restoration plan for a particular reach of river or wetland system. These may include:

- Enhancing flood attenuation functions to reduce flood risks for downstream communities;
- Enhance pollutant uptake to help address water quality concerns;
- Securing biodiversity values for species of conservation concern;
- Creating space for small business and local enterprises for members of the local community;
- Attenuating and harvesting water for re-use or other purposes;
- Creating opportunities for urban agriculture or livestock grazing;
- Enhancing aesthetic values for local homeowners; or
- Improving access or quality of open space for recreational or educational purposes.

A preliminary set of generic criteria for the evaluation of SuDS projects is presented in Table 4 and Table 5. These will be refined as the method is developed. The process of selecting criteria is set out in Section 6.3.

The application of the Trade-off analysis to a project site entails three stages of analysis as indicated in **Figure 5**. In simple terms, the aim of each stage may be described as follows;

State: This requires a frank evaluation of the site as it is before the SuDS intervention, as well as the anticipated condition after the proposed SuDS treatment train is implemented. The post-SuDS condition will emerge from the concept design of the proposed SuDS scheme. [Note this method therefore inherently includes the “Do nothing” option.]

Supply: This is assessment of the potential of the site to provide a range of services in both the pre-SuDS and post-SuDS intervention.

Demand: A frank analysis of how these services are used in the pre-SuDS condition, and whether they will actually be used in the post-SuDS condition. This last stage is a critical evaluation of the community buy-in to the scheme and therefore whether the project will be sustainable. This is a key issue in the planning the implementation of SuDS.

Figure 5: Stages in the Trade-off Analysis method

Table 4: Preliminary set of generic criteria for rating the supply of SuDS services

Category	Values	Selected attributes affecting supply
Regulating and Supporting Services	**Quantity** (Flood attenuation, stream flow regulation)	• Attributes affecting flood attenuation functions: ○ Channel characteristics affecting overtopping frequency; ○ Longitudinal slope and accommodation space for floodwaters; ○ Roughness of wetland and riparian vegetation; ○ Features (e.g. dams) imposing restrictions to flow
	Quality (Water Purification, Sediment trapping & erosion control)	• Attributes affecting the potential of ecological infrastructure to improve water quality: ○ Condition of wetlands and rivers; ○ Low flow patterns; ○ Vegetation cover and roughness; ○ Longitudinal slope; • Presence and quality of buffer zones.
	Climate Regulation	• Current contribution to climate regulation and carbon sequestration functions: ○ Presence of wetlands with high organic soils; ○ Presence of riparian forests or other robust vegetation acting as a carbon store. ○ Presence and effect of tree shade on local communities
Biodiversity Maintenance	**Habitat & biota**	• Attributes affecting biodiversity values: ○ Threat status of habitat; ○ Habitat condition; ○ Diversity of habitats; ○ Presence of threatened plant and animal species; ○ Process value in terms of connectivity with other intact habitats.
Provisioning Services	**Water supply** (Harvestability)	• Attributes affecting the potential for abstraction and use of water: ○ Water availability (ephemeral, seasonal or perennial) ○ Presence of open water (including impoundments) ○ Prevailing water quality conditions

Category	Values	Selected attributes affecting supply
	Agriculture & economy	• Attributes affecting the contribution to local livelihoods and economy: ○ Suitability for grazing; ○ Suitability for cultivation; ○ Plant material for fuel, medicinal plants or building material
Societal Services	**Public Amenity** (Aesthetics, recreation) **Education & cultural use** **Site accessibility** (including pedestrian) **Use-value** **Economics – land value** **Economics – tourism, etc.** **Others?**	• Current contribution to social role: ○ Levels of disturbance and pollution; ○ Presence of safe open water; ○ Diversity of habitat and shade for people; ○ Facilities for recreation for a range of ages Personal Safety risks ○ Accessibility to subject green open space for pedestrians ○ Integration of subject site with surrounds. ○ Condition of landscaping ○ Space for cultural events • Current contribution to increased property values ○ Adjacent buildings' response to site • Intensity of use by local residents and workers • Current contribution to amenity values: ○ Levels of disturbance and pollution; ○ Presence of open water; ○ Diversity of habitat and shade for people; ○ Accessibility & safety risks

Table 5: Preliminary set of generic criteria for rating the demand for SuDS services

Category	Values	Selected attributes affecting demand
Regulating and Supporting Services	**Quantity** (Flood attenuation, stream flow regulation)	• Flood risk posed by catchment activities ○ Level of urbanization; ○ Prevailing stormwater management challenges; • Flood risks experienced in downstream areas: ○ Presence of infrastructure susceptible to flooding; ○ Presence of communities in flood risk areas; • Risk to infrastructure, property and communities.
	Quality (Water Purification, Sediment trapping & erosion control)	• Need for improved water quality: ○ Prevailing water quality; ○ Local and downstream communities or users with a demand for improved water quality; ○ Sensitive features downstream (e.g. priority wetlands / protected areas); ○ Catchment management plans and associated water quality management objectives; • Gazetted resource quality objectives indicating any required improvements in water quality.
	Climate Regulation	• Priority of climate regulation in local policies and practices • Existence of direct climate related risks to local communities (floods, water security, heat)
Biodiversity Maintenance	**Habitat & biota**	• Priority for protection based on regional context: ○ Threat status of vegetation types; ○ Priority in regional conservation plans (PA, CBA / ESA).
Provisioning Services	**Water supply** (Harvestability)	• Need for improved water security: ○ Availability and capacity of municipal infrastructure; ○ Need for abstraction for various uses.

Category	Values	Selected attributes affecting demand
	Agriculture & economy	• Demand for agricultural and other direct use values: ○ Economic status of nearby communities; ○ Number and dependence of people using the site for cultivation.
Societal Services	**Public Amenity** (Aesthetics, recreation)	• Priority for public access and use: ○ Location in relation to residential development and / or offices and other employment hubs; ○ Existing provision of existing parks and recreational areas; ○ Level of interest and use of open spaces by local communities. ○ Presence of Schools ○ Tourism routes and activities in the area ○ Desire for access to nature for cultural activities • Priority for property value increases • Affordability levels of local land owners to invest in their properties • Priority for public access and use: ○ Location within a residential area; ○ Provision of existing parks and recreational areas; ○ Level of interest and use of open spaces by local communities.
	Education & cultural use	
	Site accessibility (including pedestrian)	
	Use-value	
	Economics – land value	
	Economics – tourism, etc.	
	Others?	

6.3 Process towards selection of evaluation criteria

The criteria provisionally selected for the trade-off analysis of SuDS projects are represented in the first two columns of **Table 4** and **Table 5**. They are indicative of the range of benefits, and possible impacts, of SuDS projects on the environment. They will typically vary from site to site, and an important step in the process of undertaking a Trade-Off Analysis will be selecting the most appropriate evaluation criteria for the project. This step will include:

- Input from specialists in the project team,
- Consultation with stakeholders, including the local community.

The Dept. of Communities and Local Government (DCLG), 2009, published a useful reference for undertaking Multi-criteria analysis. They suggest the following steps to selecting evaluation criteria:

Step 1: Establishing the decision context

Key questions to be asked are: What is the single high level objective of the decision to be made? Who are the decision makers? Who are the beneficiaries (or those impacted)?

The high level objective could be simply “sustainable stormwater management”, or “SDP (Site Development Plan) approval”, and there would be a number of location specific sub-objectives that would emerge through the early consultation stages. Or there could be more targeted objectives, such as “flood hazard reduction” or “water quality improvement” that would give more focus to the decisions to be made.

Step 2: Identifying options

In the land development process (Figure 2) these would be explored in the early concepts stages and refined in the concept design stage. The exploration of early concepts can be an iterative process as site investigations progress and consultation with communities and other stakeholders takes place. It often takes some time for communities, in particular, to understand the scope of SuDS projects and for concepts to be formed that integrate their issues.

Step 3: Identifying criteria and sub-criteria

The criteria and sub-criteria are the measures of performance that will be used to judge between options and the overall suitability of the SuDS project. Hence the criteria selected should have some degree of measurability within the options being considered.

The selection of criteria is ideally undertaken in a group context, such as the project team together with the developer, who will distil a set of criteria that can be discussed further with local communities and municipal officials. Criteria selection will be informed by the site conditions, the objectives of the scheme and the options being considered. Vague criteria (e.g. 'Climate Regulation' in Table 5) will need to be refined to achieve a level of measurability, and the selection process may also be somewhat iterative.

The selection of evaluation criteria may also be informed by policies and plans relevant to the project area, for example; catchment management plans, Integrated Development Plans, GDARD C-Plan, bylaws, etc.

The number of criteria selected should be kept small. This helps keep the decisions focussed on the main objectives, it reduces the risk of double counting, and it is easier to communicate the decision process and the outcomes to stakeholders. For example, Sjöstrand, et al (2018), have a total of 13 generic criteria for sustainability assessments of regional water supply projects. These are made up of four social criteria, one economic criterion and eight environmental criteria. Water supply projects may be more complex than local SuDS projects, suggesting perhaps that the number of criteria in Table 5 could be reduced when applied to a particular site.

The EIA and WULA processes can provide a test of the suitability of the criteria, and the coordination of the decision support analysis with these processes should be an important consideration.

Another criterion that doesn't frequent the list but may be relevant in local applications is the capacity to implement SuDS projects (Knopman & Lempert, 2019). These are infrastructure projects and will be subject to the same limitations in operation and maintenance as other infrastructure unless there are backup measures such as the adoption of SuDS systems by local communities. Perhaps these criteria, capacity to implement and community adoption, should both feature in the list of evaluation criteria.

As the Trade-off Analysis method is developed the criteria presented in **Table 4** and Table 5 will be refined to a more suitable set of generic criteria as a reference for SuDS projects. Project teams and developers will still be expected to adapt the criteria to the local site and social conditions.

6.4 Assessing Performance: Scoring and Weighting

There are a number of techniques for scoring and weighting the evaluation criteria, some of which are supported by software applications (see Department for Communities and Local Government, 2009). The proposed approach for use in the Trade-off Analysis is drawn from the relatively simple approach in the Wet-EcoServices method (Kotze, et al, 2008).

The scoring system in **Table 6** is an example of the scoring system for the Supply and Demand of the pre and post-SuDS conditions of a SuDS project. The scoring is subjective and therefore best undertaken by a subject expert. Its simplicity, however, enables communication and discussion with a wide range of stakeholders including both subject specialists and local residents.

The first stage is to set the scores based on knowledge of the site, the community and the potential performance of the SuDS project. This should be closely followed by an integration session with all the scorers (specialists) to review and challenge the scores relative to each other. This is an effective means of checking the consistency of scoring across all criteria. Consistency is key to ensuring valid and defendable results.

This consultative element is a critical part of both developing confidence in the scoring and in building support within the community and municipal departments. Scoring may initially be undertaken by an experienced practitioner, but the multidisciplinary nature of the services and benefits provided by SuDS systems would point to a group of specialists undertaking the early scoring as part of best practice. This will also encourage early discussion of the potential for trade-off considerations to be built into the description of potential SuDS scheme alternatives.

Adapting the methodology to SuDS projects may see the evaluation of supply and demand criteria of a SuDS scheme as demonstrated in the hypothetical scenario in **Table 7**. The scores are prepared for each of the services provided by the SuDS project, based on the scoring system in **Table 6**. The criteria are then weighted as determined by the expert team in consultation with stakeholders and a total score is calculated for the supply and demand for the criteria for each of the options (**Table 7**). The Supply and demand scores may be further integrated as shown. The 60:40 weighting shown in Table 7 is drawn from the Wet-Ecoservices tool for wetlands. The value of this final step may be reviewed as the Trade-Off Analysis method is fully developed.

As indicated above, the weighting of the criteria is determined through consultation between the expert team, developer and stakeholders. This is also where spatial characteristics of the SuDS benefits and impacts of the criteria can be applied to the scoring. This approach has been effective in the environmental evaluation and decision support for development options such as powerline route selection (ref[7]).

[7] Spatial weighting and scoring processes were applied to large power line route selection in EIAs for Eskom power lines. The work was not published, but became an effective decision support, environmental motivation and authority (DEA) review tool.

Table 6: Provisional scoring for SuDS services that may be supplied, and in demand, at a project site. (From Wet-EcoServices tool, Kotze et al, 2008)

Score	Guidance for Supply	Guidance for Demand
0: Very Low	Benefits provides are inconsequential at any scale	Inconsequential to users
1: Low	Limited benefits provided at a site scale	Low importance to users (few users and low dependence)
2: Moderate	The site provides some benefits, important at a site level	Moderately important to users (large numbers but limited dependence OR few numbers with high dependence)
3: High	The site provides important benefits at a local level	Very important to users
4: Very High	The site provides critically important benefits that are important at a regional or national level.	Critically important to users (large number & high dependence)

Table 7: Example of scoring and weighting of criteria in a trade-off analysis

		Supply of Services				Demand for Services			
Category	Values	Status Quo	SuDS1 (WQ obj.)	SuDS2 (Flood obj.)	Weighting 100%	Status Quo	SuDS1 (WQ obj.)	SuDS2 (Flood obj.)	Weighting 100%
Regulating and Supporting Services	Quantity (Flood attenuation, stream flow	1	3	4	10%	0	2	1	10%
	Quality (Water Purification, Sediment trapping & erosion control)	0	3	2	20%	1	3	2	20%
	Climate Regulation	0	1	1	2%	0	0	0	2%
Biodiversity Maintenance	Habitat & biota	2	4	3	10%	0	0	0	10%
Provisioning Services	Water supply (Harvestability)	0	3	2	15%	1	4	2	15%
	Agriculture & economy	1	3	2	15%	3	4	3	15%
Societal Services	Public Amenity (Aesthetics, recreation)	0	2	1	5%	0	2	2	5%
	Education & cultural use	0	2	1	2%	0	2	1	2%
	Site accessibility (including pedestrian)	2	3	3	15%	3	3	3	15%
	Use-value	2	3	2	2%	0	2	1	2%
	Economics – land value	0	2	1	2%	0	3	1	2%
	Economics – tourism, etc.	0	0	0	2%	0	0	0	2%
Weighted scores		0.79	2.91	2.3	100%	1.25	2.69	1.86	100%
Integrated scores *(0.6 x supply + 0.4 x demand)*		0.974	2.822	2.124					

6.5 Further development of the Trade-Off Analysis method

The Department of Communities and Local Government (DCLG, 2009) lists the following advantages of Multi-criteria analysis over less formal judgement methods:

- It is open and explicit,
- The choice of objectives and criteria that any decision making group may make are open to analysis and to change if they are felt to be inappropriate,
- Scores and weights, when used, are also explicit and are developed according to established techniques. They can also be cross-referenced to other sources of information on relative values, and amended if necessary,
- Performance measurement can be sub-contracted to experts, so need not necessarily be left in the hands of the decision making body itself,
- It can provide an important means of communication, within the decision making body and sometimes, later, between that body and the wider community, and
- Scores and weights are used, it provides an audit trail.

The proposed approach is relatively simple and an adaptation of similar applications in EIAs and the Wet-Ecoservices analysis for wetlands. However, it requires further development for application to SuDS projects, and trialled and refined on new SuDS projects.

7 APPLICATION OF THE METHODS

7.1 Opportunities to apply the methods

Selection, use and adaptation of the methods will ultimately be determined by the user, stakeholder and funder requirements, and requirements of the reviewing and permitting authorities. The methods can be used individually or collectively and can be applied at different stages of the planning and design of a SuDS project. **Table 8** offers some examples on how the methods can be applied and who may use them. Much will depend on when the methods are applied in the project cycle:

- Application of one or more of the methods early in the planning stages of a project will help identify opportunities and synergies with SuDS and associated services at the site. This will support a more holistic solution.
- Application late in the project cycle will enable all impacts and benefits of the project to be accounted for and will be an important reference for the “sign-off” and handover of the project.

Application of the methods as part of the EIA and WULA processes will benefit each of the processes. In particular, it will reinforce consultation with communities and stakeholders, and address one of the important outcomes of this study that community support for the project is a key success factor. **Table 8** describes examples of the users and applications of the decision support tools in this report. **Table 9** offers a more detailed guide to the suitability of the different methods for a wide range of requirements. Apart from the methods discussed in this report, in **Table 9** in this chapter also the method of ‘business case’ is added (see also Appendix 4), which is the primary method for an investor to judge whether to invest in a project. Business cases do not only about direct financial gain, but also about the branding of an investor. In the example of SuDS in Gauteng, SuDS have been implemented by private developers as part of landscaping and to brand the developments as ‘green’ (e.g. Steyn City).

Table 8: Examples of the users and application of the decision support tools discussed in this report on a SuDS project

Method	Users	Application
Life Cycle Costing (with or without land value assessment)	Developer and designer	Site assessment for SuDS interventions. Comparison of alternatives, including the "Do nothing" option, and with grey infrastructure options. Refinement of concept design.
	Municipal officials (especially stormwater departments).	Evaluation of system performance as well as maintenance requirements and costs.
Use-value or Land value assessment	Developer and planner (urban designer)	Critical assessment of benefits of different SuDS and grey infrastructure options, including "Do nothing" to a community and how these may be converted to perceptions of use-value and land value.
	Municipalities	Assessment of changes in land-values and rates. Consideration of aspects such as incentives, bulk levees, etc., to optimise benefits.
	Developer and planner (urban designer)	Quantify the potential economic benefits of a SuDS projects to and values.
Trade-off analysis	Developer and planner (urban designer)	Assessment of community uptake and support. Community consultation.
	EAP's and environmental specialists supporting EIAs. GDARD and municipal officials reviewing EIAs	Reviewing (and confirming) impacts and benefits. The "Do nothing" option is inherent in the method.

Table 9: Guide to application of the Decision Support Tools

Selection of Decision Support Tools	Evaluation Tools					Indicator / Index assessment
	Business case	Multi-criteria Analysis	Trade-Off Analysis (this report)	Cost Benefit Analysis	Life Cycling Costing Analysis	Land and Use Value Assessment
1. Role in Development phases						
Analytical phase						
Research and Analysis at regional scale	1	3	3	1	1	2
Research and Analysis at local scale	2	3	3	1	1	3
Broad Programme Development	2	3	3	1	1	1
Design Phase						
Concept design	3	3	3	2	2	3
Design Development	3	3	3	3	3	3
Environmental Authorisation	3	3	3	3	3	1
Heritage Authorisation	3	3	3	3	3	3
Finalisation of Design and Site Planning	3	1	1	3	3	3
2. Role in decision making process with stakeholders						
Is useful for the following goals:						
Informing and framing	1	3	3	1	1	3
Engaging with community	1	3	3	2	2	3
Engaging with other stakeholders	2	3	3	3	3	2
Convincing investors	3	1	1	2	2	3
Convincing authorities (ESIA)	1	3	3	1	1	2
3. Other use / application						
3.i Ability of proposal to deal with alternatives						
Many	1	2	2	1	2	1
A few (<5)	3	2	2	3	2	3
Only one	3	1	1	3	1	3
3.ii Ability of proposal to deal with unclear ambitions	1	2	2	3	1	3
3.iii Ability to be used to explore performance						
Exploring expected performance	3	3	3	1	1	3
Evaluating expected performance	3	3	1	3	3	3
3.iv Ablity to be done in a limited period of time and with limited budget	2	2	3	1	2	2
3.v Ability to be used to cover the following aspects of sustainability						
Ecology	2	3	3	2	2	1
Economy	2	3	3	3	3	2
Equity / social	2	3	3	1	1	2
Finances	3	3	3	3	3	2
Amenity	2	3	3	2	2	3
3.vi Ability to deal with non-monetary methods						
Exclusively monetary	3	1	1	3	3	2
Also non-monetary	2	3	3	1	1	3
3.v Ability to deal with different weightings of indicators, chosen by stakeholders	3	3	3	1	1	2

Key:

3	Is suitable
2	Can be made suitable / provide insights
1	Is not suitable

Notes:

1) *None of the evaluation methods compared here evaluate indicators that determine the capacity of implementation, which we consider crucial in the SA context.*
2) *None of the evaluation methods compared here are really useful for the initiation phase, for developing (municipal/private) climate change adaptation programmes, in which rather climate change adaptation exploratory tools are used (but none really available yet for the Gauteng environment)*

7.2 Expertise and Good Practice in Decision Support Analysis

It is intended that the Decision Support tools presented in this report are accessible to practitioners, developers and authorities who are involved in the planning, design and implementation of SuDS projects. It is important, however, that those applying the methods develop an understanding of the assumptions, data limitations and expert knowledge required to apply the methods such that bias and uncertainty is minimised and balance is achieved. Some of the inherent risks in applying the methods include:

- Limited expert knowledge of the multidisciplinary aspects of the project could lead to bias by giving greater attention to those aspects more in line with the expertise of the team.
- Limited data may lead to generalised assumptions with unknown levels of uncertainty in the results that may lead to a distorted outcome.
- Limited expert knowledge, and stakeholder consultation, may miss important costs (damages) and benefits, again leading to an unbalanced outcome.

The structure of the project team for SuDS projects is discussed in **Deliverable 7: Best Management Practices for SuDS in Gauteng**. Officials involved in the respective permitting processes for SuDS projects will be able to review the project team undertaking the decision support analysis against these lists.

Understanding the uncertainty in the scores or evaluations is an important part of applying and using the decision support methods. These are best managed by using economic data from good data sets (see Section 4.2), and by employing expert knowledge in applying the qualitative scoring in the Trade-Off Analysis (see Sections 6.3 and 6.4). Consultation with stakeholders, and particularly with local communities, is also an important means of reducing uncertainty, and the EIA and WULA processes will offer useful input.

Uncertainty generally reduces as the detail of the project is investigated in increasing detail. This coincides with the reduction in number of project alternatives and increased clarity of ambitions for the project over time (see Figure 2).

Training of users of the decision support tools recommended in this report is not envisaged at this stage. However, it is suggested that future training on SuDS should include use of decision support tools. It is intended that the technical level of the methods is still relatively simple and most practitioners will be able to adapt to the requirements of the analyses by ensuring there are sufficient subject experts on the team. Additionally, the EIA, WULA and municipal development controls will offer important check points. However, it is noted that the need for expert training is not uncommon. An example is the newly developed water management decision support analysis methods for municipalities in Sweden. Here is it anticipated that some of the larger municipalities may develop their own specialist teams and the smaller municipalities will outsource the service for experienced consultants (Sjöstrand, 2019). In time this may become a requirement for Gauteng municipalities, but the methods proposed in this report are generally simpler than those in the Swedish systems and a trial period of implementation is recommended before this is reviewed.

It is also relevant that the methods presented here may be applied as much for planning support as they may be for development and investment support. Support during the planning stages assist in directing the development of the SuDS solutions (and alternatives). These will be done at a higher level of assessment where the focus may only be on one aspect of the development (e.g. land values, or ecological systems). Here only one of the decision support tools, and perhaps only one aspect of that tool, may be used. In these situations, degrees of uncertainty will be less of a concern, the outcomes will be exploratory and the need for checks and consultation is relatively low.

7.3 Capacity to implement SuDS

None of the evaluation methods compared here evaluate indicators that determine the capacity of implementation, which we consider crucial in the SA context. Knopman & Lempert (2019) highlight this as a critical consideration for the evaluation of climate adaptation programmes. SuDS are infrastructure projects and they will be subject to the same limitations in operation and maintenance as other infrastructure. This is one of the reasons why the need to secure the adoption of SuDS systems by local communities is seen as an important success factor. As indicated in Section 6.3, perhaps these criteria, capacity to implement and community adoption, should both feature in the list of evaluation criteria.

7.4 "The process is as important as the result"

The value of these decision support tools; Life-Cycle Analysis, Land Value assessments and the Trade-Off Analysis, is not just in having a means to justify decisions on projects and investment, but also in developing and refining the project, and communicating it to stakeholders. When applied during the planning and design stages of a project, these support tools can result in an iterative process of design adjustment and decision support review. The early stages of this are indicated in the worked example of the Life-Cycle Analysis in Appendices 1 to 3. Hence the decision support tools are also used to help decisions during planning and design.

A similar argument can be made about the wider benefits of the EIA process. If applied as part of the planning and design stages of a project, instead of an authorisation process once the preferred development has been decided, the outcome is more likely to demonstrate synergy between development and the environment, rather than compromise.

For site projects were a Consultants team advises a developer, the team leader will need to confirm the preferred solution and prepare a defendable argument (motivation) for the decision towards the developer and the reviewing authorities. This process should include challenging the weighting factors offered by the different team members, and even the decisions being made in the group integration process. Experience in integration processes is beneficial, and a demonstrated understanding of the wider issues will be important. It can be that the team leader delegates this task. An in-house EAP who is not tasked with the independent EIA, or the engineer or the expert closest to the critical issues on the site (ecological, flooding, social, etc.) could be best suited for the role. While the developer will have critical input to make to the identified preferred option, a motivation prepared by the developer may be challenged as being biased. However, circumstances will differ between sites. An important check on the selection of the preferred solution is the presentation of the defendable argument for the proposed solution to the community and stakeholders. For more complex projects, like stormwater plans for suburbs where a transition to SuDS is intended, or for a strategic SuDS, the appointment of an independent process manager is recommended to facilitate the process of decision making and integrate the input from decision makers (politicians, council members, financiers), experts (design team) and the stakeholders (local inhabitants, local companies, civil society groups), and prepare the defendable argument.

8 WAY FORWARD

The implementation and testing of the framework for decision making on SuDS related projects, as well as the tools (methods) described in this report is seen to be the important next step. While some of the methods still need some development, there is sufficient detail to begin applying them on the next SuDS project where justification of the project, or the make-up of the project, is needed.

The suggested next steps will include:

1. Update the items, costs and rates in the Life-cycle analysis presented by Armitage, et al (2013) to reflect more current and local (Gauteng) based rates. This may be undertaken by specialist cost consultants (e.g. quantity surveyors), or it may be developed over time through the collation of data from projects as they go to construction and operation. This process should be closely associated with the development and maintenance of an asset register (see report on Best Management Practices).
2. An outcome of (1) should be the publication (and regular update of) a cost database of typical SuDS civil works, maintenance and monitoring costs.
3. Refine the stages and parameters involved in the Trade-off Analysis as applied to SuDS projects. The EIA process may be a particular driver of this approach and EAPS and GDARD officials should be proactive in overseeing this development. Regular feedback can be provided through the likes of the Gauteng EAP Forum.
4. Over time the requirements of the decision support process will be tailored to suit decision makers such as developers and municipalities, and practitioners such as designers and EAPs. This may lead to the replacement of this report with a manual of good practice.

The drive for the implementation of SuDS will be led by municipalities and GDARD in the province. It is recommended that between them the development and adoption of the decision support methods and associated databases is managed. This will include the identification of the keeper of the database(s) which may include research organisations such as the Water Research Commission and or the GCRO (Gauteng City Region Observatory), or institutions such as the civil engineering (SAICE) or landscape architect (ILASA) professional institutions.

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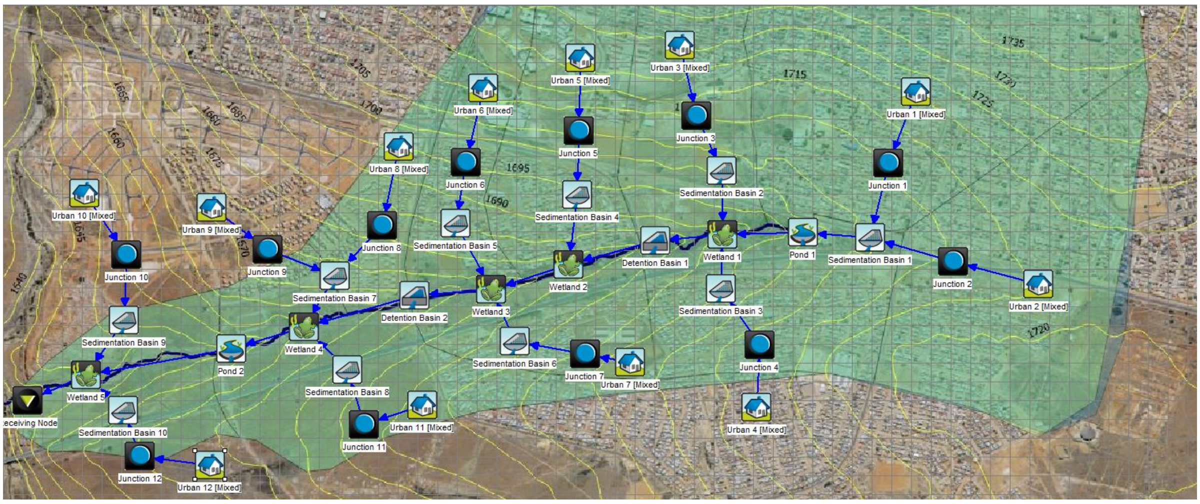
APPENDIX A: LIFE-CYCLE COSTING EXAMPLE: KAGISO SITE

A.1 SCHEME LAYOUT



NOTES:

The scheme is as developed in **Deliverable 5: Analysis of study areas with recommendations.** This represents a **Concept Design** with **moderate certainty** of project content, scale and detail.

Components considered in the Life-Cycle costing were limited to:

- Capital costs (cost of construction)
- Maintenance costs for the design life of the project.

Other potential costs such as damage avoidance costs and land value costs were not available at this stage of the project development cycle.

All cost items and rates were obtained from Armitage, et al, 2013. All rates were converted to 2019 rates by applying an annual cost increase of 6.5%.

The costs presented here are based on the criteria applied to the MUSIC model; surface areas, weir and dam wall heights, storage volumes, etc. As such this is a very high level of concept design.

Breakdown and costing for a sample of the overall scheme is presented here in detail (Tables 1 to 4), and a summary of the Life-Cycle costs for the overall scheme is presented in Table 5.

A.2 TREATMENT TRAIN CONCEPT FOR KAGISO

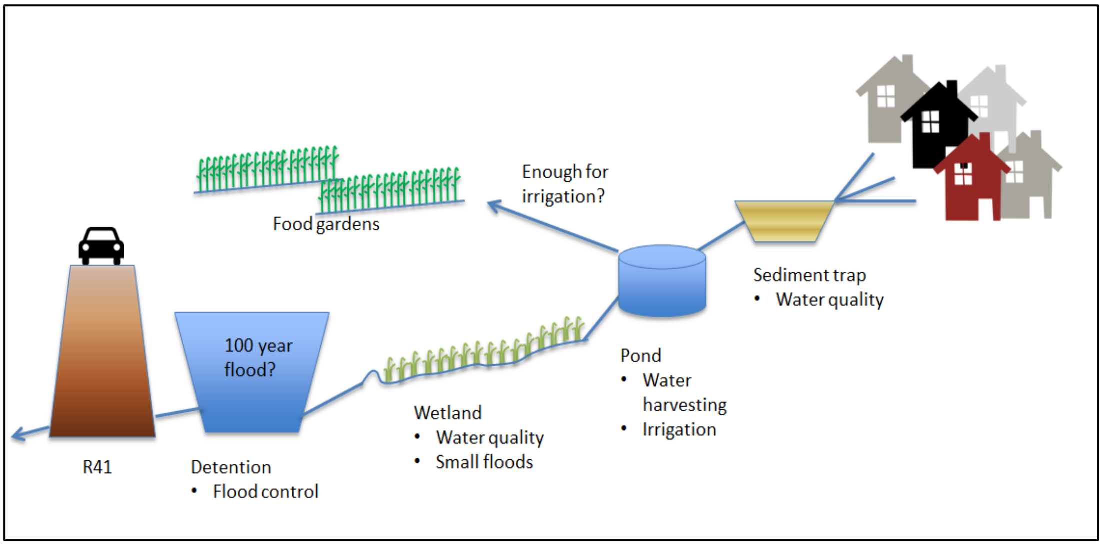


Table A.2a: Sample of Treatment Train - Sizing & Performance

SuDS Unit	Sed 1	Sed 2	Sed 3	Wetland 1	Pond 1	Detention 1
ID	S1	S2	S3	W1	P1	D1
Sources	U1, U2	U3	U4	S1, S2, S3	U1, U2	W1
Catchment (ha)	180.54	34.06	64.12	278.72	180.54	278.72
Impervious area (ha)	137.92	27.30	38.58	203.80	137.92	203.80
Area (sqm)	800	280	160	13627	2164	17669
Initial Volume (m3)	800	280	160	20440.5	4328	0
Extended detention depth (m)	0.5	0.5	0.5	1.5	1	3
Total volume (m3)	1200	420	240	40881	6492	53007
Area per Impervious Catchment (m2/ha)	5.80	10.26	4.15	66.86	15.69	86.70
Volume per Impervious Catchment (m3/ha)	8.70	15.38	6.22	200.59	47.07	260.09
IN - Mean Annual Flow (ML/yr)	818	233	161	1180	812	1090
IN - TSS Mean Annual Load (kg/yr)	129000	36500	25300	133000	105000	65200
IN - TP Mean Annual Load (kg/yr)	289	82.1	56.9	336	253	194
IN - TN Mean Annual Load (kg/yr)	2150	612	422	2920	2050	2250
IN - Gross Pollutant Mean Annual Load (kg/yr)	30200	9380	5850	0	0	0
OUT - Mean Annual Flow (ML/yr)	812	232	160	1090	794	1050
OUT - TSS Mean Annual Load (kg/yr)	105000	28900	20600	65200	83500	28200
OUT - TP Mean Annual Load (kg/yr)	253	70.8	49.9	194	215	151
OUT - TN Mean Annual Load (kg/yr)	2050	580	403	2250	1940	1900
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0	0	0	0	0	0
Flow In (ML/yr)	817.53	233.41	160.71	1184.85	812.35	1085.80
ET Loss (ML/yr)	1.19	0.42	0.24	32.75	4.48	9.85
Infiltration Loss (ML/yr)	4.18	1.47	0.83	69.17	12.09	22.90
Low Flow Bypass Out (ML/yr)	0.00	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out (ML/yr)	0.00	0.00	0.00	0.00	0.00	0.00
Orifice / Filter Out (ML/yr)	236.44	76.32	49.01	741.81	167.96	1008.79
Weir Out (ML/yr)	575.99	155.26	110.69	343.99	625.74	44.25

Table A.2b: Sample of Treatment Train - Detailed Performance

SuDS Unit	Sed 1	Sed 2	Sed 3	Wetland 1	Pond 1	Detention 1
ID	S1	S2	S3	W1	P1	D1
Sources	U1, U2	U3	U4	S1, S2, S3	U1, U2	W1
Performance						
Flow load reduction per facility (%)	0.73%	0.43%	0.62%	7.63%	2.22%	3.67%
TSS reduction per facility (%)	18.60%	20.82%	18.58%	50.98%	20.48%	56.75%
TP reduction per facility (%)	12.46%	13.76%	12.30%	42.26%	15.02%	22.16%
TN reduction per facility (%)	4.65%	5.23%	4.50%	22.95%	5.37%	15.56%
GP reduction per facility (%)	100.00%	100.00%	100.00%	N/A	N/A	N/A
Flow load reduction per Imp. Area. (Ml/ha.yr)	0.04	0.04	0.03	0.44	0.13	0.20
TSS reduction per Imp. Area. (kg/ha.yr)	174.02	278.37	121.82	332.68	155.89	181.55
TP reduction per Imp. Area. (kg/ha.yr)	0.26	0.41	0.18	0.70	0.28	0.21
TN reduction per Imp. Area. (kg/ha.yr)	0.73	1.17	0.49	3.29	0.80	1.72
GP reduction per Imp. Area. (kg/ha.yr)	218.97	343.56	151.63	0.00	0.00	0.00

Table A.2c: Sample of Treatment Train - Quantities & Maintenance

SuDS Unit		Sed 1	Sed 2	Sed 3	Wetland 1	Pond 1	Detention 1
ID		S1	S2	S3	W1	P1	D1
Sources		U1, U2	U3	U4	S1, S2, S3	U1, U2	W1
Design life		40	40	40	40	40	40
Surface area (A)	(m2)	800	280	160	13627	2164	17669
Ops depth (D)	(m)	1.5	1.5	1.5	1.5	3	3
Length (L)	(m)	80	40	32	360	65.8	190
Top width (B)	(m)	20	14	10	75.71	65.78	185.99
Base width (b)	(m)	14	8	4	69.71	65.78	173.99
Wall area (a)	(m2)	25.5	16.5	10.5	109.06	215.33	539.97
Full storage vol, incl. detention storage (V)	(m3)	1020	330	168	19630.5	7084.2	51297
Full storage vol, excl. detention storage (V0)	(m3)	800	280	160	20440.5	4328	0
Settlement depth (d)	(m)	0.25	0.25	0.25	0.375	0.2	0
Settlement vol. (v)	(m3)	145	42.5	18	4755.75	435.43	2564.85
GP vol. (@10% sed.vol.)	(m3)	14.5	4.25	1.8	475.575	43.54	256.49
Wall height, top width 1m (pond, detention pond)	(m)					1	4
Wall base width @ 1:3 (pond, detention pond)	(m)					7	25
Wall length	(m)					165	186.0
Wall volume (pond, detention pond)	(m3)					660	4840
Sediment load	(kg/yr)	24000	7600	4700	67800	21500	37000
Gross pollution load	(kg/yr)	30200	9380	5850	0	0	0
Rel.density sediment	(kg/m3)	1700	1700	1700	1700	1700	1700
Density GP	(kg/m3)	95	95	95	95	95	95
Sediment volume	(m3/yr)	14.12	4.47	2.76	39.88	12.65	21.76
GP volume	(m3/yr)	317.89	98.74	61.58	0.00	0.00	0.00
Sed.maintenance freq.	(yrs)	11	10	7	120	35	118
GP.maintenance freq.	(weeks)	2.4	2.3	1.6	0	0	0

A.3 COSTING AND LIFE CYCLE ANALYSIS FOR KAGISO

Table A.3a: Sample of Treatment Train - Costing (Capital & Maintenance)

Capital Costs		2019 @	2019 @	2019 @	2019 @	2019 @	2019 @	2019 @
(Armitage, et al, 2013)		0.065	0.065	0.065	0.065	0.065	0.065	0.065
Description	Units	Rate (R)	Cost (R)	Cost (R)	Cost (R)	Cost (R)	Cost (R)	Cost (R)
SuDS Unit			Sed 1	Sed 2	Sed 3	Wetland 1	Pond 1	Detention 1
ID			S1	S2	S3	W1	P1	D1
Sources			U1, U2	U3	U4	S1, S2, S3	U1, U2	W1
Design life			**40**	**40**	**40**	**40**	**40**	**40**
% Volume excavated			1	1	1	0.05	1	0.1
Cut to fill	m3	71	72420	23430	11928	69688	307288	364209
Excavate detention ponds 1-2m deep	m3	32						
Overhaul	m3.km	15						
Excavate material	m3	177	180540	58410	29736	173730	766056	907957
Gabion lengths	m		50	35	25	910	0	50
Gabion mattress areas	m2		53	30	15	2730	0	150
Surface bed preparation for bedding of gabions	m2	124	6510	3720	1860	338520	0	18600
Gabions (2 x 1 x 1) PVC coated gabio boxes 2.7mm diar	m3	2292	57300	40110	28650	1042860	0	57300
Geotextile (Filter fabric - Bidim)	m2	36	3690	2340	1440	131040	0	7200
Reno mattresses (3 x 1 x 0.3 PVC boxes)	m3	2803	49053	28030	14015	2550730	0	140150
Gabions, reno mattress, stone Pitching	m2	582						
Pond inlet/outlet	No	41421					82842	41421
Topsoil supplied by contractor (150mm deep)	m2	284				3870068		
Grassing	m2	36	36000	12600	7200		77904	795105
Vegetating (mix supplied & planted by contractor)	m2	82				1117414		
Total			**405513**	**168640**	**94829**	**9294050**	**1234090**	**2331942**
Maintenance (annually)								
Inspections	No. (@6/ann)	318	1908	1908	1908	1908	1908	1908
Litter and vegetation management	visit.m2	2	9600	3360	1920	163524	25968	212028
Sediment removal	m3	277	3911	1238	766	11047	3503	6029
Irregular/Corrective maintenance								
Gabion repair @ 2 gabions/yr	m3	2292	4584	4584	4584	4584	4584	4584
Erosion repair & planting (@10% of area)	m2	36	2880	1008	576	49057	7790	63608
Total annual maintenance budget			**22883**	**12098**	**9754**	**230121**	**43754**	**288157**

Table A.3b: Overall Scheme Life-Cycle Cost Summary for Kagiso

Unit	Capital Cost (2019)	Ann. Maint. (2019)	Maint. PV Rate 6.5% Design life 40	Summary	TSS removal (kg/ha.yr)
Sediment1	R405 513	R22 883	R 323 686		174.0
Sediment2	R168 640	R12 098	R 171 138		278.4
Sediment3	R94 829	R9 754	R 137 973		121.8
Sediment4	R94 829	R9 770	R 138 203		165.7
Sediment5	R52 456	R8 336	R 117 916		170.3
Sediment6	R54 048	R8 108	R 114 695		189.0
Sediment7	R59 598	R8 508	R 120 353		180.0
Sediment8	R91 775	R9 041	R 127 884		N/A
Sediment9	R36 009	R7 280	R 102 984		96.1
Sediment10	R48 433	R7 732	R 109 376		680.1
	R1 106 129		**R 1 464 209**	**R2 570 338**	
Wetland1	R9 294 050	R230 121	R 3 255 177		332.7
Wetland2	R4 457 178	R111 329	R 1 574 803		89.8
Wetland3	R5 986 615	R146 113	R 2 066 838		83.0
Wetland4	R10 816 331	R257 952	R 3 648 863		91.3
Wetland5	R27 674 536	R640 352	R 9 058 110		31.8
	R58 228 710		**R 19 603 791**	**R77 832 501**	
Pond1	R1 234 090	R43 754	R 618 918		
Pond2	R1 664 478	R52 708	R 745 580		
	R2 898 568		**R 1 364 499**	**R4 263 067**	
Detention1	R2 331 942	R288 157	R 4 076 136		181.5
Detention2	R2 764 646	R386 434	R 5 466 306		19.2
	R5 096 587		**R 9 542 441**	**R14 639 028**	
TOTALS	R67 329 993	R2 260 428	R31 974 940		
TOTAL PV COST			**R99 304 934**		

A.4 DECISION SUPPORT COMMENTS ON KAGISO CASE STUDY

Tables 1 & 2 — These present the basic scale and performance of this sample section of the treatment train as determined from the trial model runs for the site. They provide the basis of the setting out the capital costs of the scheme and the maintenance requirements for the design life of the project.

Table 3 — This presents the conversion of Tables 1 & 2 to a preliminary Bill of Quantities for the treatment train. Quantities are linked to the scale and terrain conditions on site.

Table 4 — The costing of the treatment train is guided by the line items and rates (updated to 2019) presented in Armitage, et al (2013).

This offers a first look at the relative costs of the components of the treatment train. For example, attention is drawn to the constructed wetland facility:

- It comprises almost 70% of the total cost of the works for this section of the treatment train. Is this expected? Is this reasonable?
- It offers the best treatment performance (Table 3), but is it worth this cost?
- Do other benefits (e.g. ecological function) help off-set these costs? (Is the Trade-Off analysis needed?)
- Can the design of the scheme be revised? The primary cost items include
  - excavation (levelling, terracing, etc.),
  - gabion & reno mattresses (terracing, hydraulic control, erosion protection), and
  - rehabilitation (top soil and planting).

  Can these quantities be changed? Can the design be altered? Can the construction methods be changed (e.g. use more manual labour based methods and enhance community benefits?).

Similar questions can be raised about the other components of the treatment train.

Table 5 The assessment of the cost of the whole scheme shows a similar pattern. The questions raised for Table 4 will apply.

It provides an early estimate of annual maintenance costs. These are dominated by the wetlands again, and the detention facilities. Is there double counting in these?

The table also shows where the best gains are in terms of TSS performance. This will help guide a more detailed assessment of the 'value-for-money' of each of the components of the system.

Hence this early application of the Life-Cycle Analysis, using high level concept design and generic cost data, provides an important opportunity for a critical review of the scheme.

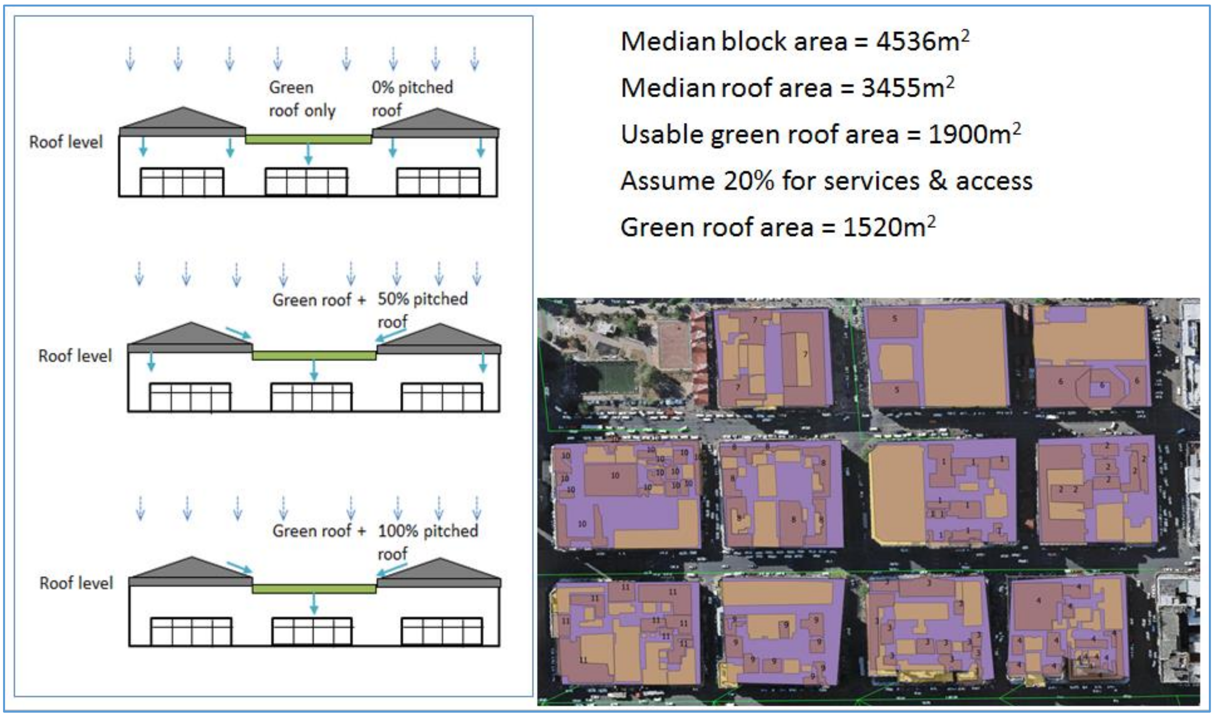
APPENDIX B: LIFE-CYCLE COSTING EXAMPLE: JOHANNESBURG CBD

B.1 OVERVIEW OF JOHANNESBURG CBD CASE STUDY SITE

NOTES:

1. All cost items and rates were obtained from Armitage, et al, 2013. All rates were converted to 2019 rates by applying an annual cost increase of 6.5%.
2. The costs presented here are based on the criteria applied to the MUSIC model; surface areas, weir and dam wall heights, storage volumes, etc. As such this is a very high level of concept design.

B.2 GREEN ROOF SIZING AND COSTING



GREEN ROOF

Roof area/block (m^2)	1518
Perimeter (m)	156
Expected useful life (yrs) (10 to	40
Aggregate 50mm (m^3)	75.9
Top soil 100mm (m^3)	151.8 @ 150mm

Capital Costs

(Armitage, et al, 2013)

Description	Units	Qty	Rate (R) 2010	Rate (R) 2019	Cost
			Rate (ann.)	6.5%	
Land Acquisition Cost					R0
Capital cost					
Derbigum SP4 waterproof layer	m^2	1518	R174	R307	R466 026
Aggregate	m^3	75.9	R215	R379	R28 766
Geotextile (Filter Fabric - Bidim)	m^2	1518	R21	R38	R57 684
Inspection eyes	No.	8	R102	R180	R1 440
Top soil supplied by contractor, spread in 100-200 m	m^3	151.8	R161	R284	R43 111
Plants supplied & planted	m^2	1518	R46	R82	R124 476
Supply and add mulch to shrub areas (20mm)	m^2	1518	R62	R110	R166 980
(Van der Walt, 2018)			2018	2019	
Crane hire	once off		R36 000	R38 340	R38 340
Building permit	once off		R23 000	R24 495	R24 495
Sub-total					R951 318
Contingency				10.0%	R95 132
Green Roof cost					**R1 046 450**
Green roof estimate (without consideration for height)	**m^2**	**1518**	**R444**	**R783**	**R1 188 594**
Maintenance costs (annual)					
Inspections	No.	6	R210	R371	R2 226
Litter and vegetation management	visit.m2	3036	R2	R4	R12 144
Irrigation					R0
Total Annual Maintenance cost					**R14 370**
Irregular/Corrective maintenance (provisional annual budget)					
Soil replacement	m^3	7.59	R161	R284	R2 156
Repair of water proof layer	m^2	75.9	R174	R307	R23 301
					R25 457
Total Maintenance Budget (annual)					**R39 827**
Present value of annual maintenance					**R563 371.92**

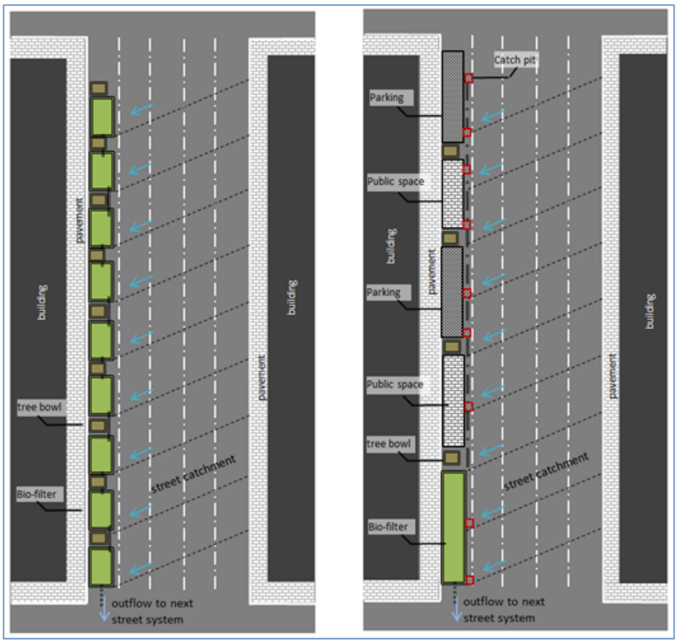
B.3 BIORETENTION CELLS SIZING AND COSTING

Typical lengths / areas of blocks in CBD	Number (see unit on left)
Median block street length (m)	67
Street width (m)	15
Total street catchment area (m^2)	1005
Bio-filter sub-catchment area (m^2)#	126
No. Lanes	5
Width of lane (m)	3
Surface area of cell (m^2)*	7.5
Dimensions of cell (m x m)	2.5 x 3.0
Filter depth (m)	2

Notes

 # Dependent on number of cells. Given area is based on 8 cells

** for multi-cell systems*



BIORETENTION CELL

Bio retention surface ar	60	
Length of unit (2.5m wid	24	
Perimeter (m)	53	
Surface area of volume	166	(incl. base)
Expected useful life (yrs	40	
Volume (m^3)	120	@ 2m
Rate (ann.)	6.5%	

Capital Costs

(Armitage, et al, 2013)

Description	Units	Qty	Rate (R) 2010	Rate (R) 2019	Cost
Land Acquisition Cost					R0
Capital cost					
Remove road surface and sub-base	m^2	60		R130	R7 800
Clear and remove topsoil	m^2		R7	R13	R0
Cut to spoil	m^3	144	R82	R145	R20 880
Overhaul (0-5km)	m^3-km	144		R23	R3 374
Impermeable liner (HDPE), installed	m^2			R307	R0
Impermeable liner (concrete, 75mm sides, 100mm base), insta	m^3	14		R5 310	R74 341
300 x 300 stone drain covered in geofabric (110 mm drainex pip	m	27	R160	R283	R7 641
Backfilling with selected material	m^3	120	R120	R212	R25 440
Top soil supplied by contractor, spread in 100-200 mm thick lay	m^3	9	R160	R283	R2 547
Plants supplied & planted	m^2	60	R45	R80	R4 800
Supply and add mulch to shrub areas (20mm)	m^2	60	R60	R106	R6 360
Kerb finish around bio-retention unit	m	53		R323	R17 103
Road reinstatement, incl. kerbing	m.lane	4		R1 955	R7 821
Sub-Total					R178 107
Contingency				10.0%	R17 811
Total Capital Cost					**R195 918**

Maintenance costs (annual)					
Inspections	No.	4	R210	R371	R1 484
Litter and vegetation management	visit.m2	720	R2	R4	R2 880
Sediment removal	m^3	0.089	R71	R126	R11.16
Irrigation					R0.00
Total Annual Maintenance cost					**R4 375**

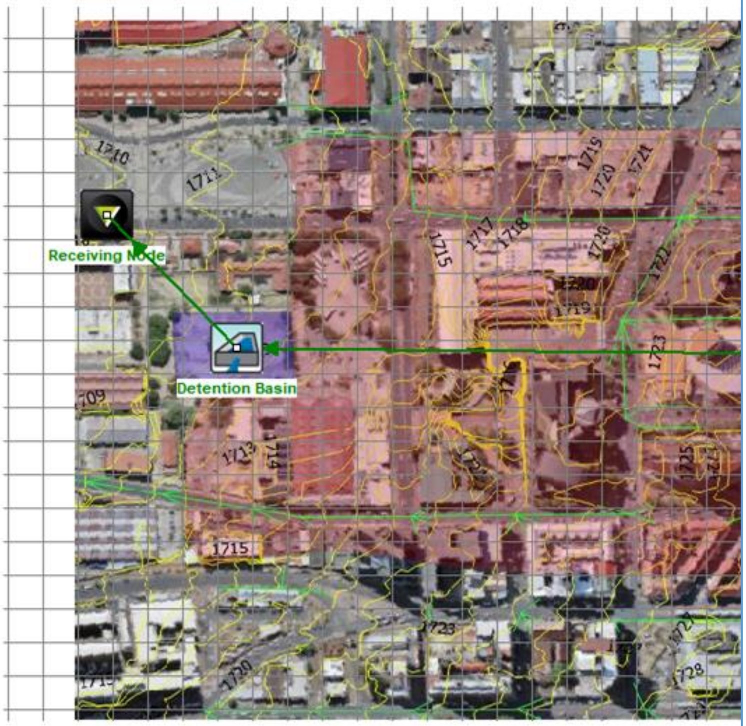
Irregular/Corrective maintenance (provisional annual budget)				
Clear and remove filter medium and vegetation	m^3	12	R145	R1 740
Replace filter medium	m^3	12	R212	R2 544
Replace vegetation	m^2	6	R80	R480
Repair of water proof layer	m^2	6	R307	R1 842
Total annual corrective maintenance (provisional)				**R6 606**
Total Maintenance Budget (annual)				**R10 981**

Present value of annual maintenance	**R155 334.32**

B.4 DETENTION BASIN SIZING AND COSTING

Use public park area at Sci-Bono.

Area = 6300 m^2
Detention depth = 0.5m
Filling time ~30min
Draining time ~6h



DETENTION BASIN

Surface area (m^2)	6298
Expected useful life (yrs) (20 to 50)	40
Detention Volume (m^3)	18894 @ 3m
Rate (ann.)	6.5%

Capital Costs

(Armitage, et al, 2013)

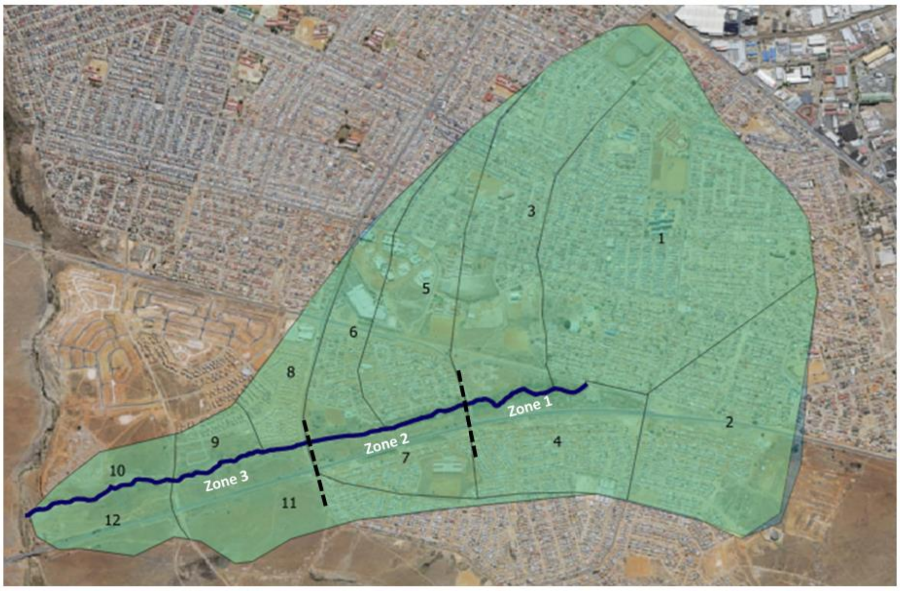
Description	Units	Qty	Rate (R) 2010	Rate (R) 2019	Cost
Cut to fill	m^3	1889.4	R40	R71	R134 147.40
Excavate detention ponds 1-2m deep	m^3	0	R18	R32	R0.00
Overhaul	m^3.km	0	R8	R15	R0.00
Excavate material	m^3	1889.4	R100	R177	R334 423.80
Surface bed preparation for bedding of gabions	m^2	18	R70	R124	R2 232.00
Gabions (2 x 1 x 1) PVC coated gabio boxes 2.7mm diamet	m^3	0	R1 300	R2 292	R0.00
Geotextile (Filter fabric - Bidim)	m^2	18	R20	R36	R648.00
Reno mattresses (3 x 1 x 0.3 PVC boxes)	m^3	6	R1 590	R2 803	R16 818.00
Gabions, reno mattress, stone Pitching	m^2	0	R330	R582	R0.00
Pond inlet/outlet	Sum	2	R23 500	R41 421	R82 842.00
Topsoil (150mm deep)	m^2	944.7		R284	R268 294.80
Grassing	m^2	944.7	R20	R36	R34 009.20
Sub-total					R873 415.20
Contingency				10.0%	R87 341.52
Total Capital Cost					**R960 756.72**
Maintenance (annually)					
Inspections	No.	6	R180	R318	R1 908
Litter and vegetation management	visit.m^2	5668.2	R2	R4	R22 673
Sediment removal	m^3	16.2	R157	R277	R4 497
Total Annual Maintenance cost					**R29 078**
Irregular/Corrective maintenance (provisional annual budget)					
Erosion control & replace vegetation	m^2	314.9		R36	R11 336
Repair of inlet & outlet structures	Sum			R8 284	R8 284
Total annual corrective maintenance (provisional)					**R19 621**
Total Maintenance Budget (annual)					**R48 699**
Present value of annual maintenance					**R688 867.02**

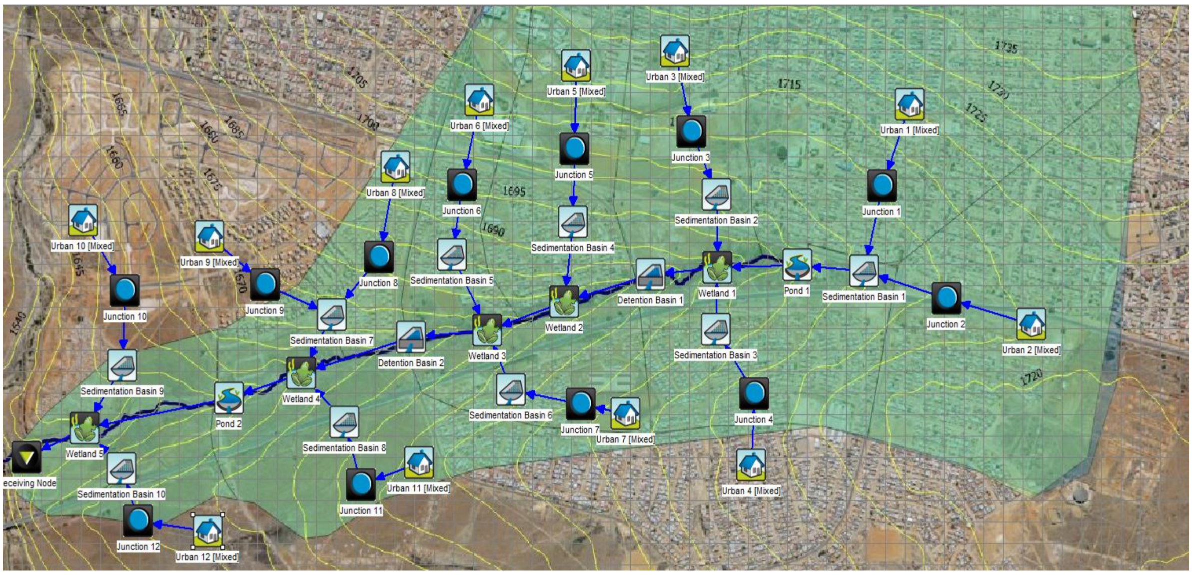
B.4 CBD INTEGRATED CATCHMENT SCHEME COSTING

CBD Integrated Catchment Scheme	Cost estimate (2019)	Useful life (years)	Present value (2019)	Catchment No. units
Green Roof		40		13
Land aquisition	nil		R0	R0
Capital cost	R1 188 594		R1 188 594	R15 451 722
Annual maintance (incl. corrective maint.)	R39 827		R563 372	R7 323 835
			R1 751 966	R22 775 557
Street bio-retention unit		40		13
Land aquisition	?		?	?
Capital cost	R195 918		R195 918	R2 546 935
Annual maintance (incl. corrective maint.)	R10 981		R155 334	R2 019 346
			R351 252	R4 566 282
Detention basin		40		1
Land aquisition	?		?	?
Capital cost	R960 757		R960 757	R960 757
Annual maintance (incl. corrective maint.)	R48 699		R688 867	R688 867
			R1 649 624	R1 649 624
Total acquisition cost				**?**
Total capital cost				**R18 959 414**
Total maintenance (PV)				**R10 032 048**
Grand total				**R28 991 462**

APPENDIX C: TRADE-OFF ANALYSIS EXAMPLE: KAGISO

C.1 Scheme Layout Kagiso Case Study





C.2 Application of Wet-EcoServices methodology

The trade-off methodology is not yet fully developed for application to SuDS projects. However, a sense of its potential is demonstrated by applying the Wet-EcoServices methodology to the Kagiso project site, where a substantial area of the scheme will be converted to treatment wetland systems.

The importance of benefits provided by the wetland systems along the drainage line at the Kagiso case study site are indicated in **Error! Reference source not found.** below. This enables pre-intervention c onditions (Present state) to be compared against the anticipated outcomes if planned SuDS interventions are implemented at the site (Future state). The following points are worth noting in this case:

- The demand for most regulating and supporting services was assessed as being moderate-to-low. This is informed largely by the limited use of water resources downstream (linked to the poor water quality conditions), and the limited number of people that are likely to be affected by flooding;
- The provision of cultivated foods and cultivated foods was highlighted, although such use is moderate in relation to that in other wetlands;
- Considerable improvements in water quality functions are anticipated under a post-rehabilitation scenario, whilst a moderate improvement in flood attenuation is expected;
- If targeted for SuDS interventions, the site is expected to provide good opportunity for education and research.

Table C.2a Integrating scores for supply & demand to obtain an overall importance score. (From Wet-EcoServices tool, Kotze et al, 2008)

Importance Score = Supply Score x 0.6 + Demand Score x 0.4		**Supply**				
		Very Low	Low	Moderate	High	Very High
Demand		0	1	2	3	4
Very Low	0	0.00	0.60	1.20	1.80	2.40
Low	1	0.40	1.00	1.60	2.20	2.80
Moderate	2	0.80	1.40	2.00	2.60	3.20
High	3	1.20	1.80	2.40	3.00	3.60
Very High	4	1.60	2.20	2.80	3.40	4.00

Table C.2b Table used to interpret importance scores. (From Wet-EcoServices tool, Kotze et al, 2008)

Importance Category		**Description**
Very Low	0-0.79	The importance of services supplied is very low relative to that supplied by other wetlands.
Low	0.8 – 1.29	The importance of services supplied is low relative to that supplied by other wetlands.
Moderately-Low	1.3 – 1.69	The importance of services supplied is moderately-low relative to that supplied by other wetlands.
Moderate	1.7 – 2.59	The importance of services supplied is moderate relative to that supplied by other wetlands.
Moderately-High	2.6 – 2.99	The importance of services supplied is moderately-high relative to that supplied by other wetlands.
High	3.0 – 3.49	The importance of services supplied is high relative to that supplied by other wetlands.
Very High	3.5 - 4.0	The importance of services supplied is very high relative to that supplied by other wetlands.

Table C.2c Outcomes of the Wet-EcoServices Assessment for the Kagiso Site

	ECOSYSTEM SERVICE	Present State Supply	Present State Demand	Present State Importance Score	Present State Importance	Future State Supply	Future State Demand	Future State Importance Score	Future State Importance
REGULATING AND SUPPORTING SERVICES	Flood attenuation	1.0	1.2	1.06	Low	1.5	1.2	1.34	Moderately Low
	Stream flow regulation	1.7	1.3	1.53	Moderately Low	2.0	2.0	2.00	Moderate
	Sediment trapping	2.0	0.5	1.40	Moderately Low	4.0	0.5	2.60	Moderately High
	Erosion control	1.0	1.5	1.21	Low	2.3	1.5	2.02	Moderate
	Phosphate removal	1.7	1.5	1.60	Moderately Low	4.0	1.5	3.00	High
	Nitrate removal	1.0	1.5	1.20	Low	3.3	1.5	2.60	Moderately High
	Toxicant removal	1.4	1.0	1.25	Low	3.9	1.0	2.75	Moderately High
	Carbon storage	0.9	2.0	1.37	Moderately Low	1.4	2.0	1.65	Moderately Low
	Biodiversity maintenance			2.00	Moderate			2.50	Moderate
PROVISIONING SERVICES	Water supply	0.0	0.3	0.12	Very Low	2.0	0.3	1.32	Moderately Low
	Harvestable natural resources	0.5	0.0	0.30	Very Low	1.0	0.0	0.60	Very Low
	Food for livestock	2.8	0.6	1.92	Moderate	2.4	0.6	1.68	Moderately Low
	Cultivated foods	2.3	1.5	1.96	Moderate	1.7	1.5	1.59	Moderately Low
CULTURAL SERVICES	Tourism & recreation	0.4	0.0	0.23	Very Low	1.9	0.0	1.13	Low
	Education and research	0.8	0.0	0.45	Very Low	3.0	2.5	2.80	Moderately High
	Cultural significance	0.0	0.3	0.12	Very Low	0.0	0.3	0.12	Very Low

The results of the assessments can also be portrayed by means of spider diagrams that help to illustrate the change in ecosystem service values that are anticipated across a broad suite of services (**Figure C.2a**).

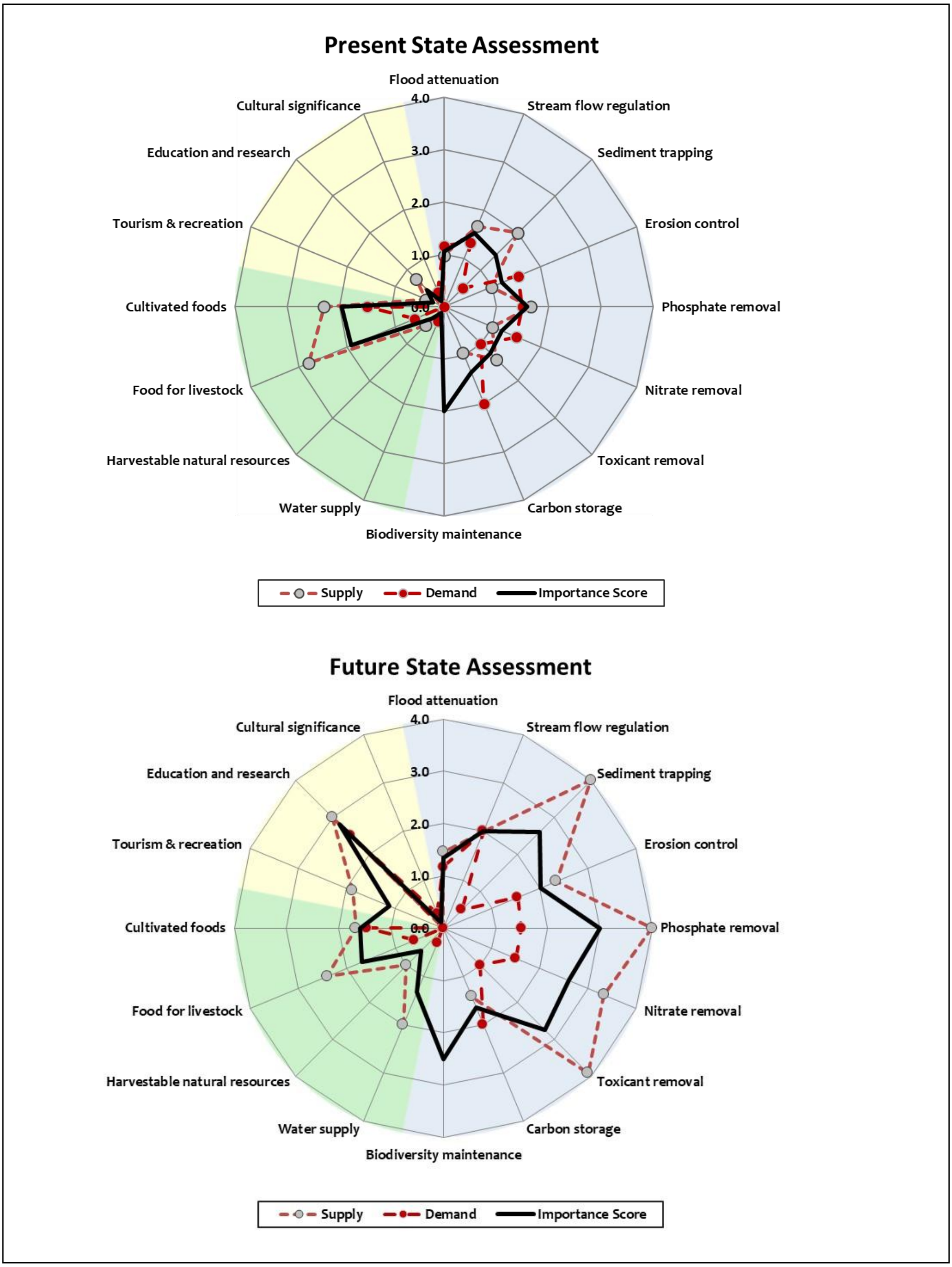


Figure C.2a: Spider diagrams indicating the anticipated change in ecosystem service values under each scenario.

The Trade-off approach highlights that when the primary services provided by SuDS; runoff quantity, quality, amenity and ecology (Armitage, et al, 2013), are analysed in more detail the services hierarchy may be revised as per **Figure C.2b.** This suggests that a greater diversity of services should be considered in case of a "regional' SuDS project. Good practice suggests the order of the hierarchy needs to be debated within the specialists of the expert team for each project. It may be that in many cases around Gauteng the priority services will be quantity and quality, but the principle that all services start with equal weighting should be the starting point in each new case.

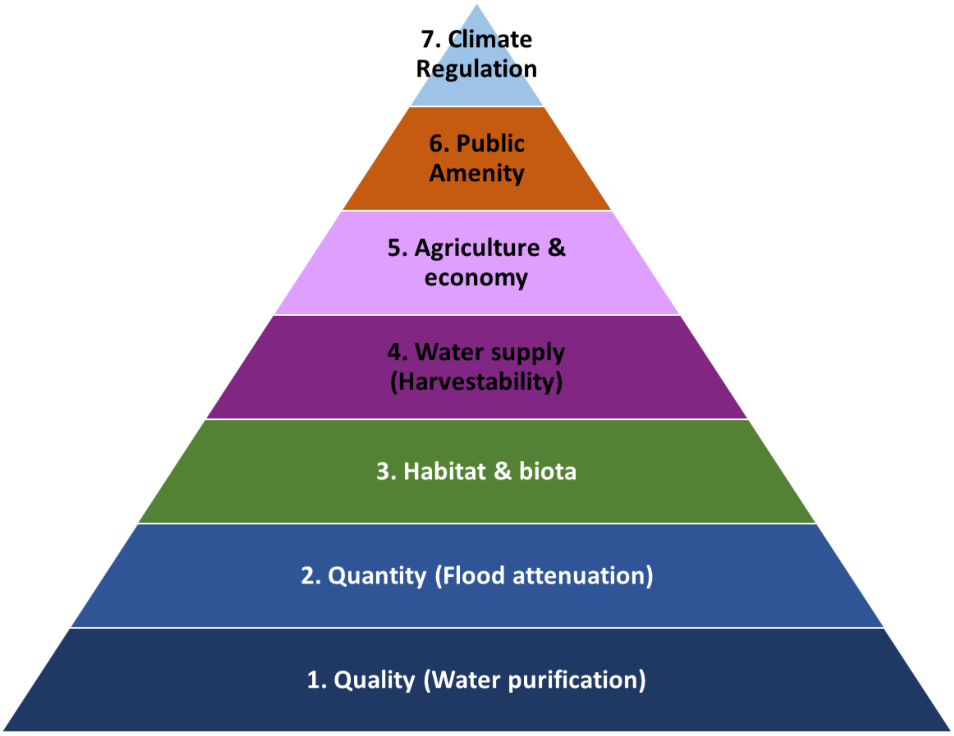


Figure C.2b: An adaptation of the SuDS services hierarchy (Armitage, et al, 2013) to reflect the services addressed in the Trade-off process as applied to the Kagiso site.

APPENDIX D: BUSINESS CASE ASSESSMENT – OUTLINE EXAMPLE ON THE BASIS OF HARVESTABILITY

A Business Case approach to "harvestability" of stormwater was proposed as an alternative to the CBA approach at the July 2019 Project Steering Committee meeting. This was in the context of water security considerations which is an increasingly important issue in the context of stormwater management in South Africa. It is also an important climate change adaptation measure.

The principle is that stormwater is considered in terms of its "harvestability" and its potential contribution to meet local demand requirements. This places additional performance criteria to be considered when planning SuDS treatment trains, and SuDS implementation strategies. For example, retained stormwater runoff may improve streamflow for ecological habitat establishment but is may reduce the harvestable resource. As such, concerns about the widespread implementation of SuDS may have implications on strategic water resources management. Examples raised during recent consultation include:

- Legislation for the Vaal catchment places a moratorium on local storage of rainfall-runoff so that runoff to important water resources reservoirs (Vaal Dam, Vaal Barrage and Bloemhof Dam) is maximised. *[Note: the reference for this legislation is still being investigated. It is understood to date back to the 1950's or earlier. This must be finalised by the time the final version of this report is prepared.]*
- The middle and lower Crocodile West system has become reliant on return water (treated sewage) and stormwater in the upper catchment areas, including West Rand, City of Johannesburg and City of Ekurhuleni (DWAF, 2008).

If successful, the role out and retrofit of SuDS in Gauteng could have important implications for the regional water resources balance. This is beyond the scope of this study, and it will take time (decades) before impacts are likely to be experienced. Catchment Management Plans should be responsible for assessing this in more detail to support decision making in the long-term.

However, the principle also raises questions on how local water resources are managed within a municipal catchment. For example, will local harvesting improve the resilience of the communities in the catchment? What should the balance be between environmental water requirements, local harvesting targets and regional water resource reconciliation objectives? This too is beyond the scope of this study, and should be addressed in municipal Catchment Management Plans. Again, any impact of SuDS projects in the short-term will have little impact on the receiving systems and catchment water balance. Instead, the need for SuDS projects as case studies for the province will be more important in the short-term.

- Therefore, at this stage the detail of the Business Case methodology as a potential decision support tool has not been explored. An example of the kind of data that may be evaluated is given in **Error! Reference source not found.**. This will no doubt develop as the methodology d evelops. The sample data is drawn from one of the Kagiso site sub-catchments. In summary the data shows:
- The theoretical (average) annual harvestable stormwater yield from the urban catchment is 1470 Ml.
- This is sufficient to supply 5595 households (47% of total) @ 120 litres/pers.day (for a year), OR
- To supply 3052 households (26% of total) @ 220 litres/pers.day (for a year).

- The value of this water is in excess of R12 million/annum (@ CoJ rates).

Table D.1: Baseline data required for developing a water resources Business Case

Feature	Amount	Unit	
Catchment area	448	ha	
Urban area	373	ha	
% impervious	62.0%		
Stands per hectare	32	Samples from aerial images (Google Earth)	
Stands per catchment	11936	Estimate	
Persons/stand	6	Assumed, based on discussions with municipal representatives. This is a variable for scenario testing.	
Est. population	71616		
Household consumption	0.2628	Ml/yr (@120l/pers.day)	
	0.4818	Ml/yr (@220l/pers.day)	
% Runoff	56.7%	From model simulation.	
Runoff	1678	Ml/yr (model simulation)	
Natural runoff @7%	207	Ml/yr (based on typical annual yield for the quaternary – WR2012). This adopted as the default EWR.	
Estimate of annual "harvestable" yield			
Harvestable (Ml/yr)	**1470**	**Ml/yr**	
Estimate of supply potential (this ignores storage limitations)			
5595	47%	households @ 120 l/pers.day	
3052	26%	households @ 220 l/pers.day	
An estimate of the value of the "harvestable" water.			
Water costs (based on CoJ rates)	8.28	R/kl	R12 174 597
	8.79	R/kl	R12 924 481
	15	R/kl	R22 055 429
	21.83	R/kl	R32 098 001

The analysis ignores water losses, water quality treatment costs, and storage and reticulation costs. It also ignores off-set transmission, storage and treatment costs of the water that would need to be supplied (by Rand Water) in its place over the design period.

However, the net present value (NPV) of the value of the water (at the basic CoJ rate) over a 25 year design life, at a rate of 6.5% is R297 million. If the true value of the Rand Water delivered is more than this the NPV would be higher.

This is a simplistic analysis, but it provides a first-pass assessment of the potential value of the stormwater available from this catchment. Especially if it supplies almost half the population of the catchment.

Therefore, this high level overview of the Business Case approach suggests it will add value to the suite of decision support tools for SuDS projects. However, it will need a Catchment Management Plan to develop more accurate estimated of harvestable yield. This methodology should be developed further.

APPENDIX E: GUIDE TO ENHANCED LAND VALUES IN THE CASE STUDY SITES CBD, BONAERO-ATLASVILLE AND KAGISO

E.1 CBD: Green roofs

- Consensus from international studies is that green roofs have a positive effect on property value. Data suggests values are improved anywhere between 2% to 16%.
- Green roof accessibility trends towards the upper end of the range.
- Adjacent buildings with views of green roofs may also see improved property values (2% to 7%).
- Intensive roof gardens, though more expensive to install (deeper soils, larger plants, more weight), tend to show higher increases in property values than extensive gardens. However, extensive green roofs are anticipated to be more likely to be applied in the CBD area.
- Applicability of this data to South Africa, or even Johannesburg, conditions needs to be tested by case studies.
- Stakeholder consultation in the CBD shows there is interest in converting roof space to a rentable space. This may place green roofs in competition with roof-top hydroponic farming. However, combining smaller areas of more intensive green roof systems and integrating this with accessible relaxation areas (perhaps with café style catering) may offer competitive rentable space while still providing SuDS performance (the potential for which is limited with hydroponic farming).
- It is proposed that as a guide for general CBA purposes a conservative value of between 2% to 5% increase in property values may be assigned to properties that establish extensive green roofs in the Johannesburg CBD. This should be kept under review.

E.1 CBD: Ground level SuDS

- The general international trend that green infrastructure in city areas adds to property values can be extrapolated to inner city areas.
- International research suggests that inner city properties next to green open spaces may see property values increase by as much as 14%, particularly where there is a scarcity of green open space.
- There is evidence of this already in the Johannesburg CBD where private developers have invested in landscaped street areas in parts of the city. This also supports international data that points to increases in commercial trading (up to 40%) for properties adjacent to well-planned open space environments in city centres.
- However, accessibility and active use is important; people need to benefit from the experience of being in the green space. Size of the area is important, so restricting motor traffic will be part of the trade-off that needs to be considered in the CBD.
- Tree cover is an important part of the experience, and this will support combining SuDS with tree shading as part of heat island mitigation.
- It is proposed that as a guide for general CBA purposes a conservative value of 7.3% increase in property values may be assigned to properties adjacent to open green spaces in the Johannesburg CBD. This should be kept under review.

E.3 Bonaero-Atlasville: The pans and wetland

- Current land use around the three pans present three very different perspectives of the possible benefits to land values; Blaauwpan is a municipal open space that has allowed private development to encroach in an uncoordinated manner and the "waterfront" value is not well utilised; Pan 1 is in a more industrial context and efforts to protect the pan are not necessarily linked to land value (interface with the pan appears limited); Pan 2 is a mixed commercial and residential site that has specifically used the "waterfront" concept to improve property values.
- In contrast the wetland area attracts very little attention from surround development, even around Pan2. There is an industrial property between Pan 1 and 2 that overlooks the wetland and has located the building with a view over the wetland, but there is no knowledge whether the wetland is the reason for this.
- Although trends for industrial property are not known, a general guide for residential and commercial property with "waterfront" locations on assets such as these pans is to work with a 10% increase in property values, though in many locations (probably including Pan2) it may be much higher than this.
- An important factor will be placing development close to the water and wetland interface, and enabling employee (and even community) access to these areas (i.e. improving the use value of the area). However, there may be some conflict with conservation objectives. The balance (or compromise) between community access and ecological objectives for a site will need to be achieved in each case.
- It is anticipated that the wetland area may provide similar value to edge properties if the use-value is recognised. This may require some initiative, perhaps by the municipality, to raise the profile of the wetland. Perhaps the establishment of the proposed integrated conservation area identified in **Deliverable 5: Analysis of study areas with recommendations** will provide the impetus for this. Under these conditions, Mammon and Paterson (2019) propose a guideline 5% increase in property values may be considered.

E.3 Kagiso

- There is little evidence to suggest that desirability and location in proximity to a managed SUDS site directly increases property values in township areas.
- There is evidence that factors affecting property values in the lowest portion of the property market are related more to proximity to schools, jobs, familial networks and affordability criteria.
- In addition, as indicated above, green open space systems in poor South African townships is often experienced negatively due to the lack of resources to ensure they remain clean and safe.
- Research suggests the role of public spaces and places in highly dense and poorer urban contexts is mostly functional and psychological and related directly to the reality of living in overcrowded spaces with little access to basic services (NM & Associates, 2010). It is not related necessarily to the future needs of the city in the context of Climate Change and environmental challenges. With on-going densification of poorer townships on the periphery

of the urban areas, green open spaces as places for relaxation, contemplation and recreation are becoming all the more necessary (Mammon and Paterson, 2019).

- Some use value is already demonstrated in the project site area in the form of an established waste recycling centre, subsistence arable farming (food gardens) and livestock grazing. The possibility of developing the SuDS treatment train to enhance, or even increase, these land uses will surely improve the overall use-value, and therefore potentially the same for adjacent property values.
- In conclusion, while other contextual factors may play a role, it is fair to say that the presence of a safer, well-utilised green open space with community involvement in management may well have a positive effect on property values. However, further research will need to be conducted in order to verify this.
- At this stage it is not reasonable to propose a guideline for increases in value for properties adjacent to the SuDS development area. However, to ensure a positive change in property values it is proposed that the following need to be provided as a minimum:
    - A SUDS intervention in low income areas should be accompanied by other public investment that addresses functional requirements (providing psychological, social and recreational opportunities) and creates and supports economic opportunities such as agriculture, and
    - There is continued and sustained upkeep by the municipality, or even an organised community group with municipal support.