INVESTIGATION OF THE REHABILITATION POTENTIAL OF THE BAAKENS RIVER
PART 3: COST BENEFIT ANALYSIS

A Uys, J MacKenzie & A Bok

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Report to the
Water Research Commission

by

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This report forms part of a set of five reports emanating from WRC project no. C2022/2023-01121. The other reports are:

- An investigation of the rehabilitation potential of the Baakens River, Gqeberha. Part 1: Current state of the river. (WRC Report No. TT 910/1/23)
- An investigation of the rehabilitation potential of the Baakens River, Gqeberha. Part 2: River rehabilitation scenarios. (WRC Report No. TT 910/2/23)
- Rehabilitation Potential of the Baakens River, Gqeberha. Part 4: Recommendations. (WRC Report No. TT 910/4/23)
- Rehabilitation potential of the Baakens River, Gqeberha. Part 5: Summary Report. (WRC Report No. TT 910/5/23)

EXECUTIVE SUMMARY

In its current state, the delivery of ecosystem services by the Baakens River Catchment to the residents and municipality of Nelson Mandela Bay is severely impaired. This report provides an economic justification for undertaking a range of interventions identified in the broader study, proposed to address aspects of this situation.

The three sets of interventions, structured as three scenarios, proposed by Uys et al. (2022b) are evaluated to assess their relative costs and benefits. This assessment finds scenario one to be the most cost effective, and imperative for the effective implementation of scenarios two and three. Scenario three is found to be the next most compelling, aligning with the development and climate change objectives of the NMB Metro.

A description of the process of ecosystem service valuation is outlined to provide the reader with sufficient background information to interpret the methodology employed and the findings of the report.

A benefit transfer method is applied to arrive at reference values for the range of ecosystem services identified as being delivered by the Baakens River Catchment. These values are applied at a detailed level according to the observed level of ecosystem functioning at each site, as assessed by the project team, to provide an indication of the value of the services currently being enjoyed.

The recommended ecological conditions derived for each site are used to calculate the expected change in benefits that can be expected from implementing the scenarios developed to arrive at these conditions.

Costs associated with each scenario are estimated through a review of relevant literature and the inputs of the project team.

The findings of this analysis show that it makes economic sense to undertake a rehabilitation programme for the Baakens River Catchment, as this will result in an increase in the delivery of ecosystem services to the municipality and its residents that exceeds the costs associated with such a programme, at a ratio greater than 1-to-1, and up to 3-to-1 specifically for interventions aimed at improving the water quality of the Baakens River.

ACRONYMS

AIV - Alien invasive vegetation

BCR - Benefit-Cost Ratio

CA - Conjoint Analysis

CBA - Cost Benefit Analysis

CO - Carbon monoxide

CO_2 - Carbon dioxide

ES - Ecosystem Services

GHG - Greenhouse Gases

Ha - Hectare

HVM - Hedonic Valuation Method

IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

Km - Kilometre

MEA - Millennium Ecosystem Assessment

NCP - Nature's Contribution to People

NMB - Nelson Mandela Bay

NPV - Net Present Value

OECD - Organisation for Economic Cooperation and Development

PES - Present Ecological State

REC - Recommended Ecological Category

TCM - Travel Cost Method

TEEB - The Economics of Ecosystems and Biodiversity

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1. INTRODUCTION TO ECOSYSTEM SERVICES

Natural ecosystems provide environmental, health, social and economic benefits to humans. The value of healthy ecosystems in providing these free services to a range of formal and informal beneficiaries has been vigorously demonstrated and there is ever growing recognition of their importance to human well-being at multiple scales (Perrings, 2006; Freeman, 2003; Pearce et. al., 2006; Dasgupta, 2008 and 2021; Mäler, 1991; MEA, 2005; TEEB, 2010; WAVES, 2012).

Impacts or changes to ecosystems (which are also known as Natural Capital or Ecological Infrastructure) alters the ability of that ecosystem to supply valuable services to beneficiaries. Ecological infrastructure refers here to functioning ecosystems that deliver to people valuable services such as fresh water, flow and climate regulation, cultural services, and soil formation (SANBI, 2014). Ecological infrastructure is the nature-based equivalent of built or hard infrastructure, and includes features such as wetlands, rivers and other watercourses, forests and entire catchments.

The analysis of the cause-and-effect relationships (or linkages) between ecological infrastructure and beneficiaries of ecosystem services is vital to appropriately manage natural resources in a sustainable manner. Informed appropriate natural resource management, in this case rehabilitation, maximises natural benefits and opportunities towards contributing to optimal socio-ecological and economic well-being.

An established approach to analysing these linkages is through the use of Ecosystem Services Frameworks as formalised and refined through initiatives such as the Millennium Ecosystem Assessment (MEA, 2005), The Economics of Ecosystems and Biodiversity (TEEB, 2010), the Final Ecosystem Goods and Services Classification System (Landers and Nahlik, 2013) and the Natures Contribution to People (NCP), as per the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services or IPBES (IPBES, 2019; Diaz et al., 2015). This approach is refined through the use of complimentary economic tools and methodologies such as environmental economic accounting (UN, 2014).

Functioning ecosystems are the foundation of human well-being and most economic activity, as nearly all resources that humans use on a daily basis depend, directly or indirectly, on nature. The benefits that humans derive from nature are called ecosystem services. Since the inception of the Millennium Ecosystem Assessment (MEA) in 2005, a number of frameworks have been developed to further disaggregate the benefits that people derive from ecosystem services and enable a thorough assessment of the economic value of those benefits. These include the Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (Haynes-

Young & Potschin, 2013), and the framework developed by the IPBES (IPBES, 2019). These frameworks are described in Table 1-1.

While each of these frameworks attempt to build upon one another, they essentially follow a similar logic, where ecosystem services and the benefits derived from them are classified into three or four broad categories, namely:

- **regulating services**, where direct and indirect benefits are derived in the form of regular flows of biotic and abiotic elements which allow for the regular, effective functioning of ecosystems;
- **provisioning services**, where humans derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials); and
- **cultural services**, where an intangible benefit is received in terms of intellectual, spiritual and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure.
- A fourth category is added in some cases to distinguish between regulating and **supporting services** in a specific delineated ecosystem, and in the global system as a whole. This category may include the maintenance of options (in IPBES) which refers to the ability of an intact ecosystem to maintain a diversity of potential benefits, such as genetic resources, which have not yet been identified, but may become useful at a future time; genetic diversity, biodiversity, and habitat (in MEA, TEEB, IPBES); and largescale planetary processes, such as nutrient cycling and soil formation (in MEA) and evolutionary or biological processes (in IPBES). These frameworks contain essentially the same services and processes, differing only slightly in where or how these processes are classified.

In the valuation of ecosystem services, all of the above frameworks are useful and provide insight. For the purposes of this study we have used a blend of the categories of ecosystem services laid out in the Millennium Ecosystem Assessment (MEA) and The Economics of Ecosystems and Biodiversity (TEEB).

Table 1-1: Summary of ecosystem service frameworks

Ecosystem Services Typology as per MEA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES, 2019; Diaz et al., 2018, Kadykalo et al., 2019)
Focus on framing Ecosystem Services	*Focus on framing Ecosystem Services*	*Focus on framing Ecosystem Services in hierarchical system*	*Focus on framing the benefits. This drives the consideration of variation in benefits between groups of beneficiaries.*
Provisioning Services - Food - Fresh Water - Fibre - Fuelwood - Genetic resources - Biochemicals	**Provisioning Services** - Food - Fresh water - Raw materials - Genetic resources - Medicinal resources - Ornamental resources	**Provisioning** - Nutrition o biomass o water - Materials o biomass, fibre o water - Energy o biomass based energy sources o mechanical energy	**Material NCP (includes non-material elements)** 11. Energy 12. Food and feed 13. Materials, companionship and labour 14. Medicinal, biochemical and genetic resources
Regulating Services - Climate Regulation - Disease Regulation - Water Regulation - Water Purification	**Regulating Services** - Air quality regulation - Climate regulation - Moderation of extreme events - Regulation of water flows - Waste treatment - Erosion prevention - Maintenance of soil fertility - Pollination - Biological control	**Regulation and Maintenance** - Mediation of wastes, toxics, and other nuisances o mediation by biota o mediation by ecosystems - Mediation of flows o Mass o Liquids o gaseous/airflows - Maintenance of physical, chemical and biological conditions o lifecycle maintenance, habitat and gene pool protection o pest and disease control o soil formation and composition o water conditions o atmospheric composition and climate regulation	**Regulating NCP** 1. Habitat creation and maintenance 2. Pollination and dispersal of seeds and other propagules 3. Regulation of air quality 4. Regulation of climate 5. Regulation of ocean acidification 6. Regulation of freshwater quantity, location and timing 7. Regulation of freshwater and coastal water quality 8. Formation, protection and decontamination of soils and sediments 9. Regulation of hazards and extreme events

Ecosystem Services Typology as per MEA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES, 2019; Diaz et al., 2018, Kadykalo et al., 2019)
			10. Regulation of detrimental organisms and biological processes
Cultural Services - Aesthetic values - Spiritual/ religious values - Educational - Recreation and ecotourism - Inspirational - Sense of place - Cultural heritage	**Cultural and Amenity Services** - Recreation, mental and physical health - Tourism - Aesthetic appreciation - Spiritual experience and sense of place	**Cultural Services** - Physical and intellectual interactions with ecosystems and land-/seascapes o Physical and experiential interactions o Intellectual and representational interactions - Spiritual, symbolic and other interactions with ecosystems and land-/seascapes o Spiritual and/or emblematic o Other cultural outputs	**Non-Material NCP (includes material elements)** 15. Learning and inspiration 16. Physical and psychological experiences 17. Supporting identities
Supporting Services - Nutrient Cycling - Soil Formation - Primary Production - Habitat - Biodiversity	**Habitat Services** - Habitat for species - Maintenance of genetic diversity		**Material, Non-material and Regulating NCP** 18. Maintenance of options **Nature (Intrinsic) E.g.:** - Genetic Diversity, Species diversity - Evolutionary and ecological processes - Gaia, Mother Earth - Animal welfare / rights

2. SYSTEMS DESCRIPTION

2.1. Overview

The Baakens River bisects the suburban areas of Gqeberha, running from west to east from its source in the wetland area of Hunters Retreat and the suburbs of Sherwood and Rowallan Park, to its discharge in the Port of Gqeberha. The river drains quaternary catchment M20A, and is approximately 23 km long. According to the "Water Resources of South Africa, 2012 Study" (WR2012), average flow rate is low, with a mean annual runoff of 5.3 million cubic meters, or approximately 170 litres per second (0.17 m^3/s). The lowest flows are associated with the summer months, while the highest are generally in the later winter and early spring months of August and September, as indicated in (WR2012; Uys et al., 2022a). The river is considered to be largely modified from its natural state, with a number of weirs along its course, the highly urbanised nature of its catchment, and the lower reach (approximately 2 km) being canalised before discharging into the ocean.

Table 2-1: Average monthly naturalised total (WR2012) and separated baseflows (according to Hughes and Watkins, 2002) for the Baakens River catchment (Source: Uys et al., 2022a-unpublished)

Month	**Mean (m^3/s)**		**% zero months**
	Total	**Baseflow**	
Jan	0.051	0.01	17
Feb	0.038	0.007	28
Mar	0.162	0.022	8
Apr	0.102	0.016	8
May	0.183	0.026	3
Jun	0.191	0.028	2
Jul	0.198	0.03	1
Aug	0.311	0.045	0
Sep	0.297	0.045	0
Oct	0.191	0.032	1
Nov	0.161	0.027	1
Dec	0.118	0.021	0
Annual	**0.167**	**0.026**	

The river has experienced several extreme flooding events over its history, with reports of flooding going all the way back to 1867. Most recently floods occurred in 2006 and 2015. The most severe flood event is generally accepted to be that of 1968, when an estimated R40 million damaged was sustained (approximately R3.5 billion in 2022 rands) and at least 14 lives were lost. Damage costs for subsequent events are not as readily available.

2.2. Ecological and socio-economic context

The Baakens River is the primary asset of note in this study, however, connected to the river intrinsically and extrinsically are a number of sub-systems which all play a role in the ecological functioning of the system. In the Draft Present Ecological State report (Part:1 of the series - Uys et al., 2022a-unpublished) the river is divided into six river reaches. This division is based on natural physical characteristics, as well as urban features and boundaries such as roads, as shown in Figure 2-1.

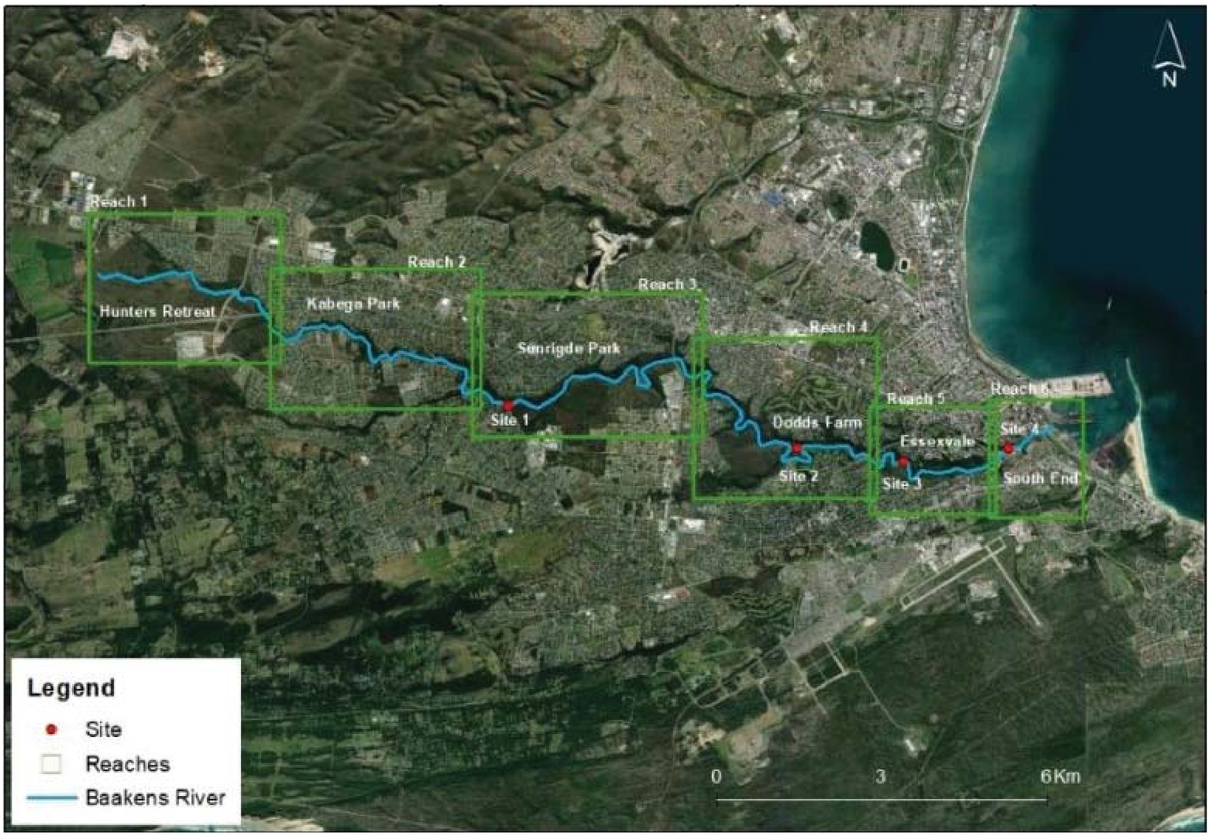

Figure 2-1: Map of the Baakens River showing river reaches and sites (from: Uys et al., 2022a)

No site assessments were done for Reaches 1 and 2. Reach 1 is the source area of the river, consisting of seep and depressional wetlands and rocky outcrops. This area is host to the last remaining populations of the Eastern Cape endemic species *Cyclopia pubescens*, or Cape Honeybush, and is dominated by fynbos vegetation. It is extensively invaded by *Acacia saligna* (Port Jackson willow), which threatens its ecological functioning. Like all of the reaches in the study area, this reach is impacted by urbanisation, although a significant area of the floodplain remains undeveloped. The seep wetlands in this reach represent an important ecological asset in that they function as sponges which regulate water flows, attenuating floods during high rainfall periods, and holding and releasing water to maintain the base flow in the upper reaches of the river during drier periods.

Reach 2 is highly urbanised, consisting of residential land, with a narrow band of public open space along the immediate vicinity of the river. Alien trees, largely wattle and well-established bluegum, are present along much of the green space along the river, and in many instances have invaded. The public open space is mostly cleared and maintained for recreational activities. The recreational services associated with this reach may represent some value to the overall ecosystem services value.

The details of the remaining reaches, for which site assessments were conducted by Uys et al. (2022a), are presented in Table 2-2

Table 2-2: Ecological asset descriptions based on site assessments for the current state of the Baakens River by Uys et al. (2022a)

Site 1: Hawthorne Ave (Reach 3)	
Water Quality	- The flow at the site was low, but if the fine sediment were to become mobilized during strong flows, there is a possibility of elevated turbidity levels. - E. coli levels were very high (with an average value of 1,026,410 cfu/ml) and serve as an indicator of pollution by sewage discharges. - Elevated nutrients from sewage spills, high quantities of litter in the stream - Instream water is affected by non-compliance with discharge standards by the sewerage pump station as well as litter in the surrounding urban areas - The water quality model (Physicochemical Assessment Index or PAI) scores result for water quality was a low C category (64.1%). Primary contributors are high nutrient levels, elevated salinity, anoxic fine sediments and a low toxicant load. - Failing infrastructure, with load-shedding putting additional strain on an already constrained system.
Riparian Vegetation	- Most of the area upstream and downstream of the site has been invaded by perennial alien species comprising dense shrubs and tall trees. - A portion of the channel has been landscaped by landowners and substrates are mostly non-alluvial. - Large stretches of the reach have been shaded by tall woody aliens and support no marginal zone vegetation. - The riparian vegetation at this site has been critically altered, with an overall PES score of 13.7% (category F), which is critically modified from reference condition. This is attributed to a lowered species richness and an absence of intolerant and moderately tolerant species.
Fish	- The distribution and population density of alien fish appear to be increasing. - Rapid spread of alien fish leads to an increased disturbance of catchment (impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder).

	- Increased pollution and escalating changes in natural hydrology and increase in numbers and distribution of aggressive, predatory alien fish species all contribute to a PES score of 44.2% (category D).
Aquatic Invertebrates	- Poor habitat resulting from modifications to the stream bed and banks in this section. - The presence of largely non-alluvial sediments and fines smothering the natural habitat. - The naturally high Electrical Conductivity or EC (attributed to the underlying Table Mountain Sandstone group geology) and the low dissolved oxygen, together with the poor instream habitat and regular sewage spills in this area, provide some context for the low diversity and sensitivity of the invertebrate fauna. - Water quality will continue to deteriorate with forecast loadshedding; instream habitat is unlikely to recover without intervention. - Significant habitat and flow alteration, coupled with water quality deterioration, sedimentation, and the presence of alien fish species provide a PES score of 49% (category D).
Overall	- **Ecostatus**: Category E (29.2%); **EIS**: High
Site 2: Dodd's Farm (Reach 4)	
Water Quality	- The odour and visible water quality clues at the weir on Dodd's Farm indicated poor water quality. - A pipe built into the weir was discharging effluent which coated the weir downstream of the discharge point with a white layer; later explained to be toilet paper discharging down the system. - It has been reported that when the Mangold Park pump station stops working, waste effluent is discharged directly into the river. - Elevated nutrients from sewer spills promotes primary productivity of aquatic and marginal zone vegetation. - Water quality PES is scored as 66.5% (category C).
Riparian Vegetation	Marginal Zone: - The two main habitat forms in the marginal zone in the vicinity of Site 2 are pools or backup zones and natural channel forms, mostly runs with a linear nature. - Most of the pool areas are artificial and associated with weirs or river crossings, but natural pool areas do exist. Non-Marginal Zone: - Characterised by high aerial cover and dense vegetation, both woody and non-woody. - Open areas are dominated by grasses. - Alterations to the aquatic and marginal zone vegetation with an increase in productivity due to nutrient loading and barriers to flow.

	- Overall PES score for riparian vegetation at this site is 66.7% (category C).
Fish	- Habitats consisted of slow-deep and slow-shallow habitats with dense marginal and overhanging vegetation with soft sand and mud substrate. - No indigenous fish species found at this site, with low numbers of alien species. - Impact of alien fish species, including competition for food and space and predation, particularly on eggs and larvae by banded tilapia and southern mouthbrooder. - PES score of 45.3% (category D).
Aquatic Invertebrates	- The naturally high electrical conductivity (attributed to the underlying TMS Group geology) and the low dissolved oxygen, together with the lack of leafy marginal vegetation habitat, and the regular sewage spills in this area, provides some context for the low diversity and sensitivity of the invertebrate fauna. - PES score of 43.5% (category D).
Overall	- **Ecostatus**: Category C/D (57.8%); **EIS**: Very high
Site 3: Essexvale (Reach 5)	
Water Quality	- Discharges from Essexvale Pump Station are reported to overflow directly into the river in this reach. - Low oxygen levels even in fast-flowing water. - E. coli levels were very high (averaging 2,458 cfu/ml) and serve as an indicator of pollution by sewage discharges. - Rupture in Essexvale pump station of the rising line (which is the line that pumps sewerage away), at the time of sampling. - Six sewage lines at Little Walmer Golf Course would also impact in this river segment. - This site PES score of 26.5% (category E), the lowest score for water quality of all sites surveyed.
Riparian Vegetation	Marginal Zone: - Similar to site 2, the habitats consist of pools or backup zones and natural channel forms, mostly runs with a linear nature. - Riparian and aquatic vegetation is mostly indigenous, with exotic species starting to encroach, with potential to invade. Non-Marginal Zone: - Characterised by woody and non-woody dense vegetation and high aerial cover. - Mowing and clearing maintains patchiness of woody to non-woody vegetation. - Wide variation in vegetation, with fynbos as well as perennial alien species; the latter pose a long-term threat to integrity of natural vegetation.

	- PES score of 62% (category C).
Fish	- Marginal and instream vegetation were limited, but large rocks and cobbles provided good fish cover in water depths up to 60 cm. - Endangered indigenous and endemic species (Eastern Cape redfin *Pseudobarbus afer* and longfin eel, *Anguilla mossambica*) present at this site, along with invasive species (*Tilapia sparrmanii* and *Pseudocrenilabrus philander*). - PES score of 59% (category C/D).
Aquatic Invertebrates	- Extremely poor sample despite increased effort, with only four taxa collected. - The only taxa collected were river crabs, notonectid hemipterans, and chironomid and culicid dipteran larvae. - Poor water quality due to raw sewage inflows is the likely cause of this. - The lowest PES score of for aquatic invertebrates is observed at this site, at 14.5% (category F).
Overall	- **Ecostatus**: Category D (53.8%); **EIS**: Very high
Site 4: Alchemy (Reach 6)	
Water Quality	- The river water appears clear in this section. - E. coli levels are very high and serve as an indicator of pollution by sewage discharges, this is in part attributed to the site being at the lower end of an urban catchment. - The poor water quality, which is linked to sewage discharges rather than industrial waste, is of primary concern. - PES score of 68.8% (category C).
Riparian Vegetation	**Left Bank:** - The marginal zone comprises a linear bank along a concrete canal, broken in places, with seeps into the zone from the upland areas. - Aerial cover is 100%, dense vegetation that is mostly non-woody with overhang from woody shrubs - The canal has some snags and a pulse of sediment moving through the system - The non-marginal zone is characterised by high aerial cover and dense vegetation, both woody and non-woody and comprises a linear bank along a cliff or urban area **Right Bank:** - Landscaped for public use and comprises mown lawns with some scattered plantings of Fig trees - Little ecological value due to loss of ability to function as a corridor or for flood attenuation and virtually no contribution to biodiversity. - Overall PES score of 35.9% (category E)
Fish	- Single indigenous species captured (freshwater mullet, *Myxus capensis*)

	- This catadromous species likely uses Site 4 as a migration corridor due to lack of preferred slow-deep habitats. - PES score of 46.3% (category D).
Aquatic Invertebrates	- Marginal vegetation on either side of the channel was leafy and dense, serving as good habitat and cover for invertebrates with a preference for this type of habitat. - Some indication of the ability of the river and its biota to recover over a short distance, assisted by riparian and instream vegetation. - Taxa present in the sample were lower scoring ones, including Oligochaetes, Potamonautid crabs, leeches, Baetid and Caenid mayflies, Coenagriid, Lestid and Gomphid odonates (dragonflies/damselflies), Gerrid and Veliid hemipterans (bugs), and a number of Dipteran (fly) larvae. - The lack of more sensitive taxa is attributed to the overall paucity of good habitat in this section of the river, and to the water quality condition of inflows. - PES score of 40.9% (category D).
Overall	- **Ecostatus**: Category D/E (39.8%); **EIS**: Very high.

3. ECOSYSTEM SERVICES MAPPING AND PRIORITISATION

3.1. Hazard Statement

A range of hazards have been identified in the Current State of the River report (Uys et al., 2022a) from direct observations at the four sample sites included in this study. While these sites are situated in four of the six reaches, hazards such as alien vegetation invasion and increased urban developments also apply to the upper reaches of the river catchment.

3.1.1. Alien vegetation invasion

A wide range of alien invasive vegetation (AIV) species were identified by Uys et al. (2022a), each affecting the natural ecology of the river in different ways. Broadly, AIV species encroach on the evolutionary niches of indigenous species, displacing the indigenous plant species, while also altering the habitats they provide, and generally requiring more water than indigenous species. The overall effect is a disturbance to the natural balance of the ecosystem.

3.1.2. Alien fish invasion

The presence of alien fish species poses significant risk to the indigenous fish species, particularly those which have a high sensitivity and are at risk of extinction, such as *Pseudobarbus afer (*Eastern Cape redfin*), Sandelia capensis* (Eastern Cape Rocky) and *Enteromius pallidus* (Goldie Barb). This may take the form of predation, competition for resources such as food and habitat niches or refugia, and potentially the introduction of pathogens. The main alien fish species identified in the study include *Tilapia sparmanii* (Banded Tilapia) and *Pseudocrenilabrus philander* (southern mouthbrooders).

3.1.3. Failing infrastructure

This relates primarily to the failure of the sewerage system, and particularly, of sewage pump stations to operate effectively and/or to retain sewage overflows during times of loadshedding and storm events. In many instances these pump stations are not functioning effectively, and do not have capacity (in the form of sumps) to capture these overflows. These issues are recently compounded by loadshedding which further reduces their capacity to function as intended. Damage to related infrastructure, such as broken reticulation pipes, also has a negative effect on the health of the river. Multiple sites were found to have raw sewage flowing directly into the river.

3.1.4. Increase in urban developments

The proliferation of impermeable surfaces, such as tarmac and paving, associated with urban development, and the linked stormwater drainage systems, impacts significantly on the capacity of the river to regulate natural processes. Infiltration of precipitation is reduced due to the replacement of natural ground and vegetation by hardened surfaces in the catchment. This causes an increase in runoff, and a higher probability of flooding. The increase in hardened and impermeable surfaces and the loss of infiltration to groundwater can also have the effect of reducing baseflow.

Extensive urbanisation within the Baakens River catchment has also led to increased impacts on the river ecology. Water transferred from other catchments (in the form of urban water supply) can enter the river in the form of sewage inflows. Further growth in urban development results in greater population and economic activity, which also leads to the likelihood of increased flows of contaminated run-off reaching the river.

The increasing population and proliferation of groundwater abstraction (boreholes) during the drought are likely to have also lowered groundwater levels and affected baseflows, although these effects have not been quantified.

3.2. Ecosystem Service Screening

The valuation of ecosystem services is intrinsically linked to the benefits derived by humans. As such, each ecosystem service must be linked to the beneficiaries who derive the benefits associated with that service, based on both the presence of that service and the realisation of the benefits through utilisation of the service. This screening process is presented in Table 3-1.

Table 3-1: Screening of Ecosystem Services in the Baakens River system

Category of ecosystem services	Type of service	Typical beneficiaries	Notes
Provisioning services	Food	Households	Due to the urban nature of the Baakens River, coupled with the dearth of large edible fish species, this service is not expected to be a priority, and is thus not valued.
	Fresh water	Households	Due to the urban nature of the river, with all adjoining communities serviced with piped water, this service is not a priority, and is thus not valued.
	Fibre and fuelwood	Households	The urban nature of the study area means that there is likely no reliance on this provisioning service, and it is thus not valued.
	Biochemical/ medicinal/ pharmaceutical resources	Households Industry	The Cape Honeybush present in Reach 1 of the river is an important species in terms of its medicinal use, however there appears to be little to no exploitation of this resource, and thus no final use value flowing from it.
Regulating Services	Air quality regulation	Households Local Industry Local Municipality	Wetlands and vegetation in the catchment can absorb carbon dioxide and other pollutants, resulting in better air quality. This service should be evaluated.
	Climate regulation	Households Local Industry Local Municipality	Rivers and urban green spaces can have a significant impact on local micro-climate regulation. This service should be evaluated.
	Water quantity regulation	Households Industry Local Municipality	The role of the wetlands, floodplains, riparian vegetation other features of the river ecosystem in regulating floodwater is important, especially given the historical flood damage and threat to life associated with this river. This service should be evaluated.
	Erosion regulation	Households Industry Local Municipality	Riparian vegetation assists in preventing riverbank erosion, and relates to the above service of flow regulation. This service should be evaluated.

Category of ecosystem services	Type of service	Typical beneficiaries	Notes
	Water purification & waste management	Households Industry Local Municipality	Wetlands, aquatic vegetation and instream habitat elements (cobble, rock etc) assist in slowing the flow of water, trapping sediments, and allowing plants to utilise the excess nutrients, resulting in cleaner water. Due to the significant volume of wastewater flowing into the river, this service may be considered as important.
Cultural Services	Spiritual/ religious; Cultural values	Households	The river has been historically linked to the indigenous Khoi-Khoi people of the area. This is no longer the case. Xhosa spiritual ceremonies are however performed at certain parts of the river (e.g. Mermaids pool at Dodd's farm).
	Aesthetic/ Inspirational/ Sense of place values	Households	The establishment of the original settlement at Algoa Bay has been linked to the presence of the fresh water supplied by the Baakens River. Although it is widely enjoyed by users of the space, and likely contributes towards the identity of the city, time and resource constraints hinder the valuation of this service as it is not suited to the rapid valuation method applied.
	Recreational and amenity values	Households	This service is widely enjoyed by the surrounding community in the form of cycling, hiking, and jogging in the public open space areas along the river. It should be evaluated.
	Education	Households Local institutions	Evidence of educational use being made of the river and surrounds exists. For instance, a local school has assisted in collecting data for the river, and a number of tertiary-level studies and reports have been done on the river. This service should be evaluated if possible.

4. ECOSYSTEM SERVICES VALUATION

4.1. Background

The evolution of ecosystem service valuation techniques is characterised by a historically increasing demand for precise quantification of the values of these services, and is driven by various incidences of environmental disasters.

Ecosystem services can be valued using a variety of techniques. Every method has advantages and disadvantages, and certain approaches are better suited to particular circumstances depending on the information sought. There are approaches with revealed preferences and approaches with stated preferences. The former focuses on analysing available data on behaviour, usually based on spending patterns, while the latter relies on surveys which elicit people's feelings and attitudes, thus 'stated' preference.

By analysing the decisions that an individual makes within a market, the revealed preference approaches **extrapolate** the person's willingness to pay for a certain good or service, or accept compensation for the removal or reduction of a certain good or service (Carson and Bergstrom, 2003). Only the environment's quality or the commodities and services the ecosystem offers can be used to differentiate between options or scenarios, therefore the various scenarios show how valuable those qualities are. The most common revealed preference approaches are the hedonic valuation method (HVM) and the travel cost method (TCM). The stated preference approaches of ecosystem valuation survey individuals to find out what they state as their value of the ecosystem attributes, goods, and services. The most common measures of value in the stated preference approach are willingness to pay and willingness to accept. The stated preference approaches are the contingent valuation method and the conjoint analysis (CA). These methods are described in Table 4-1.

Table 4-1: Summary of ecosystem service valuation methods

ESS Valuation Method	Method Description
Hedonic Pricing Method	The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It can be used to estimate economic benefits or costs associated with: • environmental quality, including air pollution, water pollution, or noise • environmental amenities, such as aesthetically pleasing views or proximity to recreational sites. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes.
Travel Cost Method	The main principle of the travel cost method is that the time and travel costs visitors pay to reach a site serve as a reference for the cost of access. Thus, depending on the number of visits people take at various travel prices, it is possible to assess how willing people are to pay to visit the place.

ESS Valuation Method	Method Description
Contingent Valuation Method	In this technique, the value that a person places on something is calculated. Instead of assuming people's readiness to pay for or give up their desire for a specific commodity based on observed behaviours in open markets, in this technique they are asked directly. One disadvantage of the contingent valuation method is that bias may be introduced by practitioners who have interests other than guaranteeing the accuracy of the results.
Conjoint Analysis	With the conjoint analysis approach, respondents are asked to rank their preferences between two groups of environmental services or features, each of which has a different price or cost to the respondent. Contingent choice is particularly well adapted to policy decisions where a collection of potential actions might have varying consequences on natural resources or environmental services, since it focuses on trade-offs across scenarios with distinct features.
Benefit Transfer	Where data is sparse, or resource constraints do not allow for detailed primary data collection and analysis, the benefit transfer method may be used. Benefit transfer methodologies make use of valuations done for similar services in similar circumstances in more data rich localities. The values identified may be transferred, adjusting for temporal and geographical differences.

The benefit transfer approach is the method most suited to this study. The main objective of benefit transfer is to translate an estimate of benefits from one context into an estimate of benefits for another. When there isn't enough time to undertake an original valuation assessment but there is a need to measure benefits, benefit transfer is frequently used. Meta-analyses from around the world can be used to identify reference values for similar sites. As the river sites included in the study were described in terms of their significant biological and physical characteristics (Uys et al., 2022a), this information can be used to identify similar studies from which reference values may be sourced and transferred to this study using a benefit transfer methodology.

The values thus derived may be used to compare various scenarios in a Cost-Benefit Analysis (CBA) framework in order to provide insight into the feasibility of implementing a certain set of interventions aimed at improving the flow of ecosystem services. The CBA methodology was formalized in 1958 with the publication of the "Green Book," a document intended to provide federal agencies in the USA with a consistent conceptual framework for doing benefit-cost analysis. The Green Book recognized three types of benefits delivered by ecosystems: market goods, non-market goods and intangibles such as temperature and air quality regulation. It contained rigorous treatment of key economic concepts and an emphasis on developing measurable indices for valuing goods and services. Consumer and producer surplus as measures of value, and not price, began to be emphasized (drawing on Dupuit, 1844; and Hotelling, 1931). Moreover, non-market goods and intangibles were not measured, but rather treated qualitatively, as no proven valuation methods for these existed. Thus, it is used in this context to compare the costs of the actions proposed to improve the delivery of ecosystem services with the increase in the value of those services derived through the benefit transfer method.

4.2. Valuation of ecosystem services associated with the Baakens River

As has been demonstrated in the previous paragraphs, the ecosystem services linked to the Baakens River system are more in line with an urban green space incorporating significant hydrological components than would be the case for a generalised river system providing basic provisioning needs of a rural community, such as fresh water, food, and raw materials. The ecosystem services supplied by the surveyed reaches were found to be largely related to the regulating services including storm water reticulation, recreation, air quality regulation, local temperature regulation, and the positive health effects associated with the enjoyment of these services. Such regulating services are by their very nature hard to quantify and value, requiring resource-intensive data collection to arrive at a reasonable estimate. Many such studies have been conducted globally however, facilitating the use of benefit transfer methods to estimate the value of these services in the local context.

A meta study conducted by Elmqvist et al. (2015) evaluated a range of such valuations from across the United States of America and various sites in China, which they standardized using statistical and economic standardisation methods to arrive at a standard average for each. These figures represent a standardised per hectare value range for urban green spaces incorporating hydrological features across a global level, thus making them suitable for benefit transfer. For the purposes of this study, these standard average values were used to estimate the value of each of the relevant ecosystems in the local context.

The standard values were converted from the 2013 international values calculated in the study by first using the Purchasing Power Parity conversion factors (which is a measure of prices in different countries that facilitates the direct comparison of the purchasing power value of countries' currencies) available from the OECD (2022) to estimate the equivalent rand values. These values are then adjusted for inflation using historical inflation data from South Africa for 2013 to 2021 (Macrotrends, 2022). Each service is discussed below, with an indicative value calculated on a per hectare basis using the Benefit Transfer method. A summary of the values estimated for each ecosystem service is presented in Table 4-2.

An indication of the total annual value of ecosystem services provided by the Baakens River Catchment is provided in Table 4-3. This is calculated by multiplying the mean value associated with each ecosystem service by the area of the urban green space surrounding the river in the study area.

Table 4-2: Reference values for ecosystem services using the benefit-transfer method (the figures are expressed in the ranges identified in the Benefit Transfer methodology)

	Ecostatus			REC		
	Lower estimate	Mean	Upper estimate	Lower estimate	Mean	Upper estimate
	ZAR/ha/year					
Pollution and air quality regulation	215	2 325	7 546	266	2 876	9 331
Carbon sequestration (annual flow)	208	1 415	2 515	257	1 750	3 110
Storm water reticulation	2 204	3 303	9 101	2 725	4 085	11 254
Energy savings/temperature regulation	122	5 059	6 836	151	6 256	8 454
Recreation and other amenity services	7 642	22 662	37 682	9 451	28 025	46 599
Positive health effects	-	67 610	-	-	83 609	-
Total (excl. health effects and carbon storage)	**11 508**	**34 758**	**63 676**	**14 232**	**42 983**	**78 744**

Table 4-3: High level estimate of the total value of selected ecosystems associated with the Baakens River Catchment under current circumstances and recommended ecological category (REC) conditions.

	Ecostatus	REC
	Mean	Mean
	ZAR/year	
Pollution and air quality regulation	897 000	1 371 000
Carbon sequestration (annual flow)	546 000	835 000
Storm water reticulation	1 274 000	1 947 000
Energy savings/temperature regulation	1 950 000	2 982 000
Recreation and other amenity services	8 734 000	13 356 000
Positive health effects	26 055 000	39 844 000
Total	**39 456 000**	**60 335 000**

4.2.1. Storm water reticulation

Arguably one of the most vital services provided by the Baakens River system is the regulation of water flows, particularly as related to the conveyance of storm water. The highly compacted nature of the Baakens catchment due to urban development not only impedes the ability of the river system to provide this service, but also places the surrounding residential and commercial properties at risk from flooding.

The presence of trees, other vegetation, and permeable soils in open areas reduces the pressure on constructed drainage systems by absorbing and slowing the flow of excessive precipitation associated with storm events. It has been estimated that in urban areas with over half of the surface area being impermeable, 40 to 80% of rainfall is lost to surface runoff, this being directed to storm water drainage systems (Pakati et al., 2011). In the case of the Baakens, the buffer areas around the river, and importantly the wetlands at the source of the river perform this role, to some extent reducing the volume of water reaching the river. However, with many stormwater drains directing the runoff away from urban areas, and discharging directly into the river channel, pressure is exerted on the river channel to serve as a conduit for this excessive runoff. The ability of the riverine ecosystem (including buffers and wetlands) to regulate storm flows cannot be truly realised.

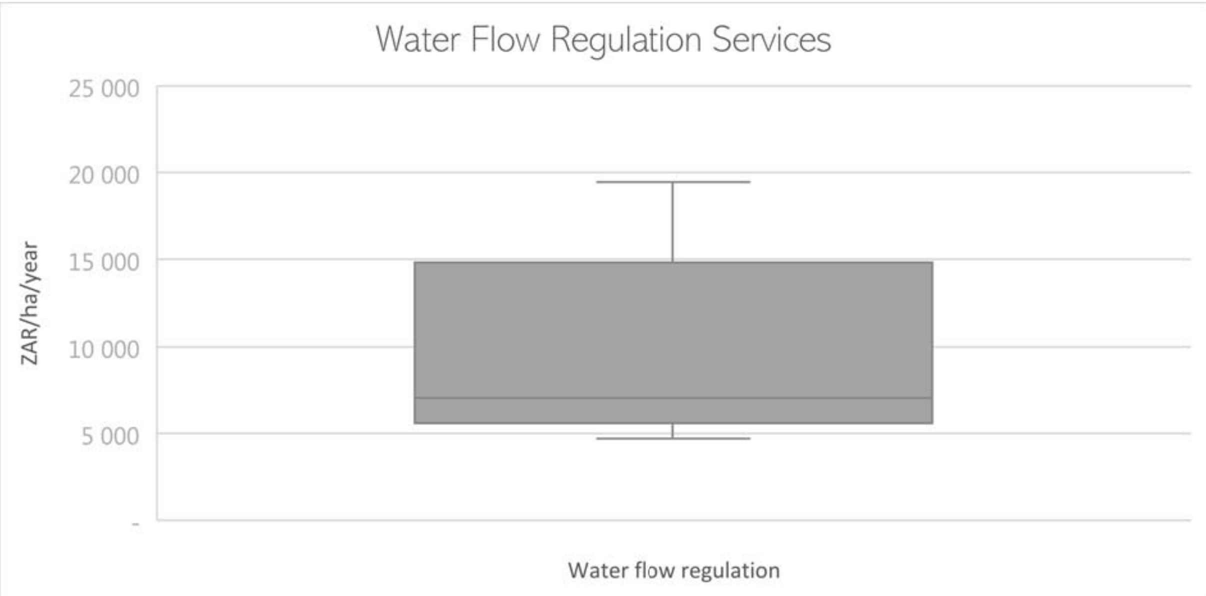

Figure 4-1: Benchmark value for water flow regulation ecosystem services

Globally the average value of flow-regulating ecosystem services associated with urban green spaces incorporating hydrological components, depicted in Figure 4-1, is estimated to be around R7,000 $ha^{-1}yr^{-1}$, with a possible range between R4,700 to R19,500 $ha^{-1}yr^{-1}$. Considering the relative importance of flow regulation services in the Baakens River valley, the upper quartile value of R15,000 $ha^{-1}yr^{-1}$ has been chosen as the reference value for evaluation in this study, indicating the value of this service in an optimal condition.

Using the assessment of the condition of the river (Uys et al., 2022a), the ecostatus for each site is multiplied by the value of the ecosystem service to arrive at an estimated value for water flow regulation in the Baakens River of approximately around R7,000 $ha^{-1}yr^{-1}$ in the current ecological state.

Rehabilitation or restoration of the system that achieves an increase in the ecological functioning of the system such that the REC is achieved, modelled here as an improvement at each site of one class from its current state, i.e. from category E to category D for site 1, and D/E to C/D for site 4, is estimated to increase the value of this ecosystem service to around R8,700 $ha^{-1}yr^{-1}$.

4.2.2. Recreation and other amenity services

Recreation is one of the most tangible and visibly important ecosystem service provided by the Baakens River and its surrounding green space. The use of the Public Open Space by cyclists, joggers, hikers and dog walkers confers a significant benefit to the surrounding community in terms of health and human wellbeing. 'Green views' from commercial buildings have been linked to lower stress levels and increased levels of work satisfaction in the workplace (Lee et al., 2009). The presence of this green space may also be linked to higher property values in land parcels adjacent to the river and its surroundings (Brander & Kotze, 2011). The realisation of this is dependent on not only the ecological state of these areas, but also their effective management in terms of safety and security. There is, however, evidence that the realisation of benefits associated with these ecosystem services is linked to biodiversity, therefore for the purposes of this study the ecological state is used as an indicator of the extent to which these services are currently being conferred. It may also be assumed that any improvements in the ecological state could be associated with improved management of these spaces, linked to enforcement of improvement measures, possibly through the introduction of community safety officers being deployed to monitor the appropriate use of the site.

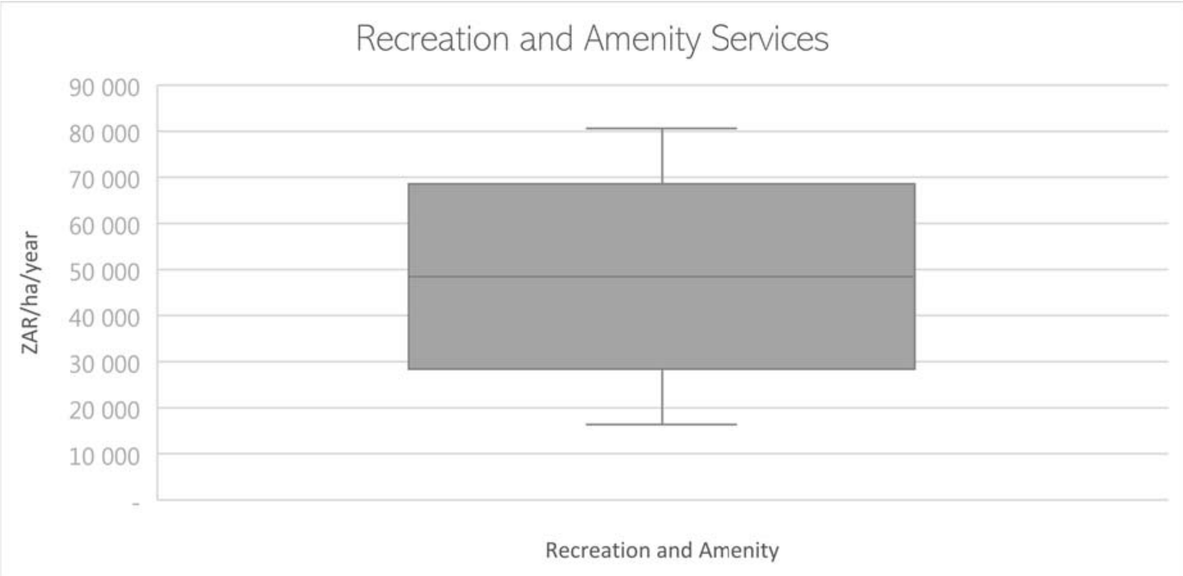

Figure 4-2: Benchmark value of recreation and amenity ecosystem services

The value of this ecosystem service is estimated to range between R16,300 and R81,000 $ha^{-1}yr^{-1}$, with an average value of R48,600 $ha^{-1}yr^{-1}$ (Figure 4-2). Given the current state of the ecological assets, as indicated by the Ecostatus associated with each site, and assuming that the average benchmark value of this ecosystem service is indicative of the value derived from recreation and amenity services in the Baakens River valley, the current value of this service is estimated to approximately R22,700 $ha^{-1}yr^{-1}$. An improvement in the ecological state to the REC, as described for the previous service, would theoretically see an increase in the value of these ecosystem services of approximately R5,400 $ha^{-1}yr^{-1}$ increasing the average annual benefits to R28,000 $ha^{-1}yr^{-1}$.

4.2.3. Temperature regulation and potential energy savings

The presence of vegetation and water (particularly running water) in urban areas plays an important role in microclimate regulation, reducing temperatures and consequently potentially reducing energy consumption associated with mechanical air cooling. The benefits of this service therefore also potentially include a reduction in greenhouse gas (GHG) emissions due to reductions in energy consumption. The Baakens River valley in this instance may also act as a conduit for cool sea air to penetrate further inland, compounding the benefits associated with this ecosystem service.

Globally, the benchmark value of this ecosystem service as it pertains to urban green spaces is estimated to be in the range of R260 $ha^{-1}yr^{-1}$ at the lower end, up to R14,600 $ha^{-1}yr^{-1}$ at the upper end, with an average value of R10,800 $ha^{-1}yr^{-1}$ (Figure 4-3).

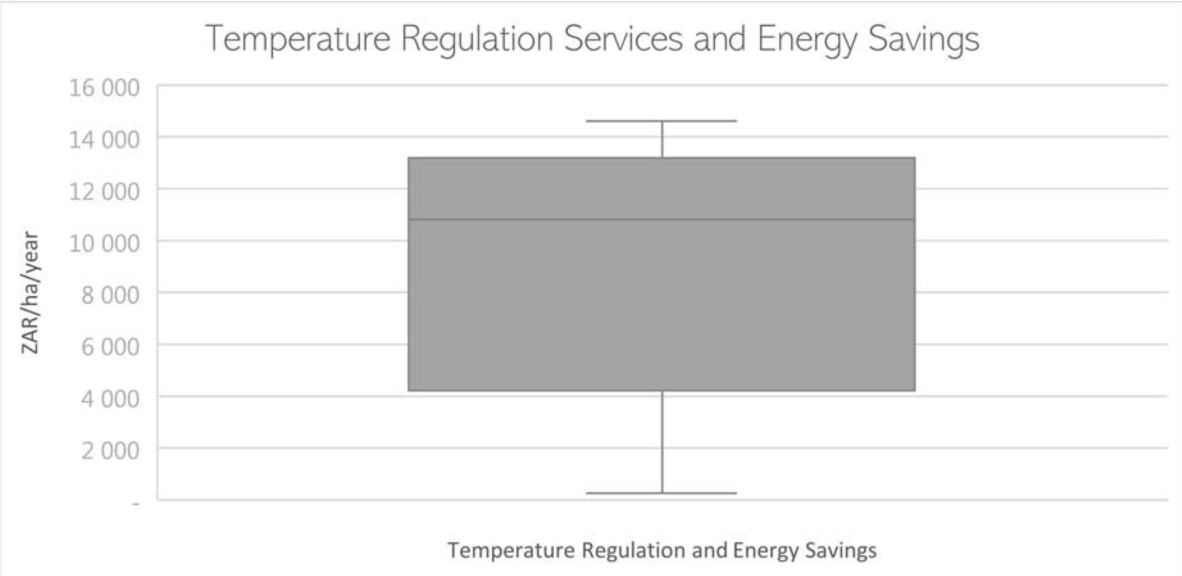

Figure 4-3: Benchmark value for microclimate regulation ecosystem services

Applying this value to the Baakens River and associated urban green space, through multiplying the reference values by the ecostatus of each site across the study area, the average value associated with the river in its current state is estimated to be around R5,100 $ha^{-1}yr^{-1}$.

An improvement in the ecological state of the study area up to the REC is expected to increase this value to an average of approximately R6,300 $ha^{-1}yr^{-1}$.

4.2.4. Pollution and air quality regulation

Vegetation associated with urban green spaces acts like a lung to a city, filtering a range of pollutants and particulate matter from the air, reducing the level of pollutants like carbon monoxide (CO) and carbon dioxide (CO_2,) and increasing the level of oxygen available. Healthy riverine ecosystems also have the capacity to effectively process low levels of waterborne pollutants. While the high levels of

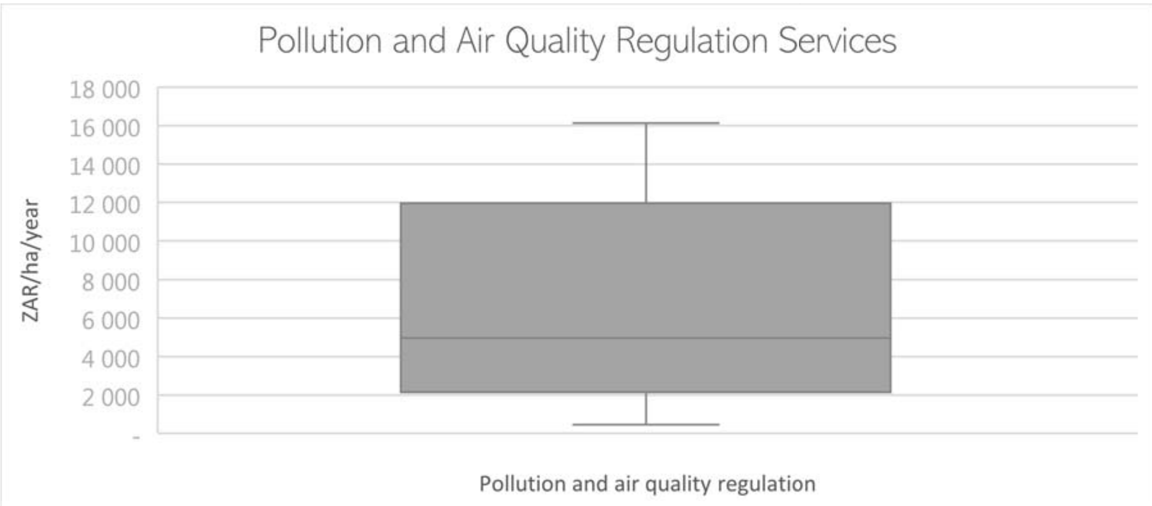

Figure 4-4: Benchmark value of pollution and air quality regulation ecosystem services

wind associated with Gqeberha likely carry much of the air pollution away from the city, it is likely that the surrounding communities are still positively impacted by this function of the Baakens River system. There is no question that that river itself is heavily impacted by a range of pollutants, most notably through wastewater discharged from failing infrastructure. Not only does the level of pollution impact on the river's ability to support a healthy habitat and biota, but the impacted ecological state of the water impedes the river's ability to self-regulate and remove pollutants. In some extremely impacted rivers systems a negative health benefit (or a cost) may be experienced, but these are extreme cases, and the positive health benefits associated with the Baakens River and its associated green spaces in their current condition are likely to be more in line with the lower range of the values discussed below.

The average benchmark value for this ecosystem service is estimated to be just below R5,000 $ha^{-1}yr^{-1}$ (Figure 4-4). Applied to the Baakens River in its current state it is estimated that the annual value of this ecosystem service is approximately R2,300 $ha^{-1}yr^{-1}$. It is further estimated that rehabilitation of the river and its surrounding green spaces along the lines recommended could increase this value to R2,900 $ha^{-1}yr^{-1}$.

4.2.5. Carbon sequestration

The value of carbon sequestration in a given ecosystem may be thought of in two ways – in terms of annual flows associated with the ongoing removal of carbon from the atmosphere, or in terms of stocks which relate to the carbon stored in above- and below-ground biomass and in soil organic carbon.

It is widely understood that trees account for the bulk of terrestrial carbon sequestration by vegetation. This is just as true for urban trees as it is for those found in natural non-urban forests. Shrubs and other types of vegetation also play a role, although to a lesser extent. Vegetation removes carbon from the atmosphere through the process of photosynthesis and stores it either in the woody biomass of its stems, leaves, and roots, or feeds it into the soil through complex interactions between plants and microorganisms.

While all vegetation sequesters carbon to a certain degree, the woodier vegetation is associated with higher rates of carbon removal and storage. The nature of the indigenous vegetation that occurs in the study area, and the shallow sandy soils, points to lower levels of carbon sequestration than may be expected from more productive ecosystems associated with more densely wooded vegetation. There is evidence that the introduction of alien species may in fact release more carbon than would be if an area were maintained with its indigenous vegetation (Waller, 2020). This facilitates the linkage of the ecological state of the study area to this ecosystem service.

The average benchmark value of carbon sequestration services by urban ecosystems is estimated to be around R3,000 $ha^{-1}yr^{-1}$, as shown in Figure 4-5. In the case of the Baakens River system, based on its ecostatus values, the carbon sequestration service value is estimated to be R1,400 $ha^{-1}yr^{-1}$. Improving the ecological state to the REC may increase this value to R1,700 $ha^{-1}yr^{-1}$ over the longer term.

4.2.6. Positive health effects

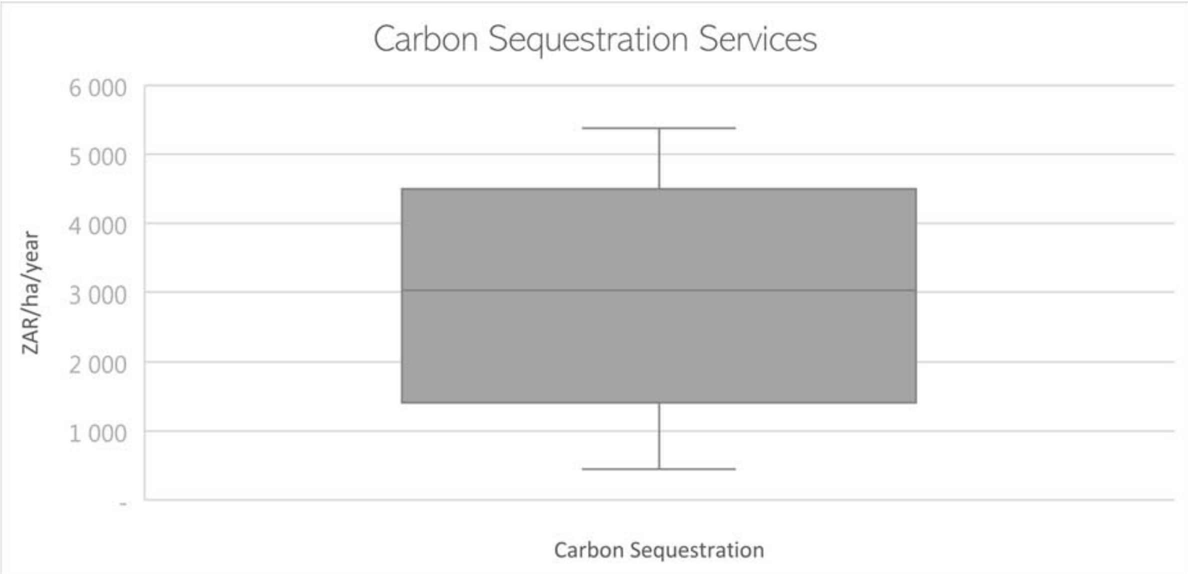

Figure 4-5: Benchmark values of carbon sequestration services

Healthy green areas in urban spaces are often associated with improved physical and mental health. This can be attributed directly to a range of ecosystem services, including improvements in air quality, water quality, and increased levels of exercise observed in communities that live adjacent to such green spaces, as well as the indirect perceived benefits people may associate with access to nature, and along with the spiritual benefits and an improved sense of place.

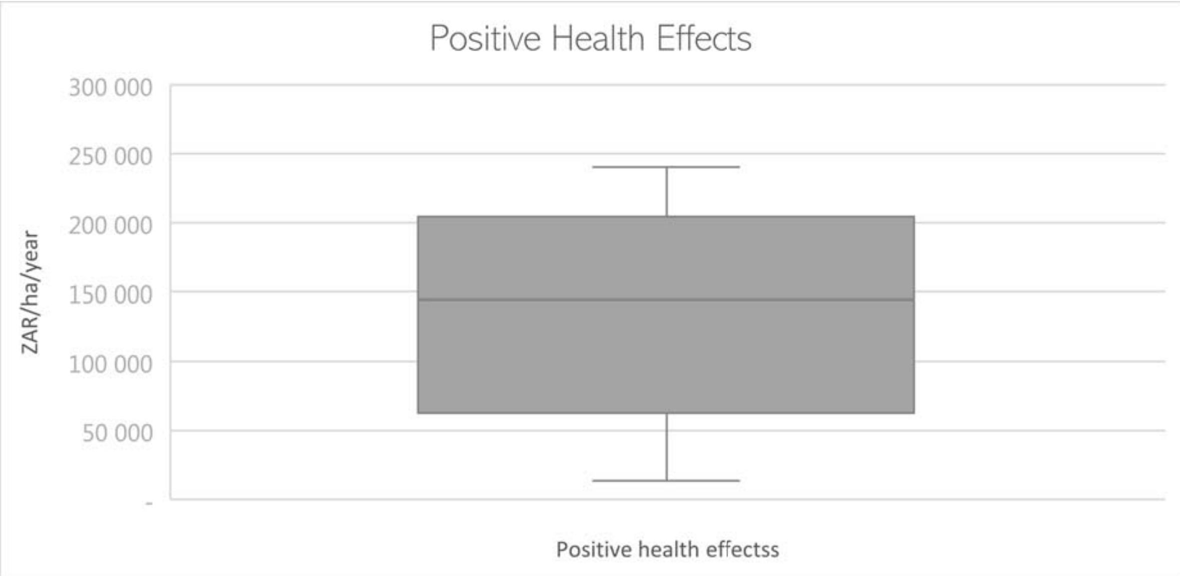

Figure 4-6: Benchmark value of the positive health benefits

Internationally these positive health benefits have been valued at R145,000 $ha^{-1}yr^{-1}$. Such benefits may also largely be related to the condition of these green spaces, with healthy, biologically diverse areas being seen to be conferring higher levels of health benefits. Linking this benefit to the ecostatus and REC of the study sites provides us with an estimate for this service of around R68,000 $ha^{-1}yr^{-1}$ and R84,000 $ha^{-1}yr^{-1}$ respectively.

5. COST BENEFIT ANALYSIS

The valuation of the ecosystem services provided by the Baakens River provides a starting point for the calculation of Benefit-Cost Ratios (BCRs) associated with rehabilitation activities aimed at improving the functioning of the ecological assets and shifting the associated ecosystems to an improved condition. In order to conduct such an analysis, a set of scenarios must be constructed to simulate the activities that may be undertaken in this rehabilitation programme. Indicative costs must be calculated for these scenarios, based on the envisaged activities to be undertaken, which can then be compared to the change in benefit flows expected from the improvement in the condition of the system. The scenarios have been developed in a separate report (Uys et al., 2022b-unpublished) which thoroughly details the proposed interventions. This report thus only provides a basic summary of those interventions in order to contextualise the costs and benefits associated with the scenarios.

5.1. Framing of restoration scenarios and costing of interventions

The proposed interventions for the rehabilitation of the Baakens River are grouped into three primary areas or scenarios, as detailed in the scenarios report of this project (Uys et al., 2022b). A cooperative approach is suggested which incorporates the planning and implementation already presented by a range of stakeholders. Broadly the three scenarios envisioned can be categorised into three areas, namely water quality interventions aimed at addressing the water quality deterioration observed in the river, water quantity interventions aimed at improving the ability of the catchment to more effectively regulate water flow during times of both high and low flows, and connectivity and habitat interventions aimed at reconnecting ocean, estuary, river and wetlands, and improving the biodiversity, and ecological functionality and overall health of the system. .

The costing of these interventions is based on estimates from the project team, related reports and expert inputs. The actual costs involved in the implementation of the proposed interventions may vary significantly, with the figures indicated representing a high-level estimate. The costs under each scenario are aggregated into capex (capital expenditure) costs to denote the major up-front costs, which are usually spread over the first five years, and opex (operating expenditure) costs consisting of ongoing expenditure associated with maintenance and the employment of relevant staff for the various programmes.

Due to the interconnected nature of ecosystems, improvement in any area of the natural system is likely to have knock-on effects which improve the delivery of all other ecosystem services to some extent. The model constructed for this analysis provides a feasible estimate of the change in ecosystem services linked to improved functioning of the system achieved through the proposed interventions.

This difference between the values of the ecosystem services under the current conditions, and their values under improved conditions, is referred to as the marginal benefits. Under each scenario, the primary ecosystem services affected by the interventions are noted.

To complete the CBA, the flow of costs and benefits are estimated over the project time horizon, and discounted to arrive at their net present value (NPV) to allow for comparison under each scenario. NPV is a measure of the current value of a future stream of payments, accounting for the time value of money, which is the concept that a given amount of money today is worth more than that same amount money in the future. This is done by discounting all future payments by a given discount rate, which, in the case of social projects such as those proposed in this study, is recommended to be 10% by the National Treasury guidelines (NT, 2021). In this way significant costs incurred in the near future may be compared with ongoing, but comparatively smaller benefits that may be experienced over a longer time horizon. For this study, a time horizon of 20 years is used.

This method can be used to effectively compare benefit-cost ratios (BCRs) and rates of return for different projects. Benefit-cost ratios indicate the ratio between net present benefits and net present costs. A ratio of between 0 and 1 represents benefits being lower than costs, otherwise referred to a negative net benefit, while a BCR of higher than 1 indicates that the benefits outweigh the costs, i.e. a positive net benefit. Higher BCRs indicate greater ratios of benefits to costs. For instance, a BCR of 3 would indicate that benefits outweigh costs by a factor of three-to-one. A rate of return provides an indication of the net gain or loss over time of a given investment.

5.2. Scenario 1: Water quality improvement

The primary problems associated with water quality deterioration relate to the maintenance and effective functioning of sewer infrastructure, particularly sewage pump stations and wastewater treatment works, and the accumulation of litter in the river.

5.2.1. Interventions

Seven interventions have been identified under Scenario 1: Water Quality, presented in Uys et al. (2022b). These are listed below:

- Commission a Sewerage Situation Assessment and Management Plan to address the problems identified.
- Plan the implementation of those interventions required to upgrade the sewerage infrastructure (particularly the pump stations and sewerage network)

- Ensure Department of Water and Sanitation (DWS) involvement and ongoing water quality monitoring and biomonitoring.
- Foster community action and citizen science.
- Manage catchment litter.
- Employ additional staff and Institute training of all sanitation technical staff and management.

5.2.2. Costing

Commissioning a Sewerage Situation Assessment and Management Plan is estimated to cost around R250,000, while the implementation of the Management Plan is expected to involve significant costs. These would likely include refurbishment and/or upgrading of the Cape Receife Wastewater Treatment Works (WWTW) and the eight pump stations and associated infrastructure in the Valley and leading to the WWTW.

The total VROOM (very rough order of measurement) cost estimate for necessary work to return the achieving Green Drop status in the Nelson Mandela Metro, according to the Eastern Cape Green Drop Report is around R112 million, of which civil costs comprise approximately half (DWS, 2022b). Depending on the level of refurbishment required, refurbishment and the various upgrades and installations required at pump stations are estimated to cost between R300,000 and R5 million per station, according to figures extracted from the Department of Water and Sanitation's Green Drop Report (DWS, 2022a). Triangulating this with inflation-adjusted figures from the NMBM Sewerage Master Plan (2009), a high-level estimate of R30 million is used as the total cost of upgrading the sewage system for the Baakens Valley, for this analysis. This is in line with the estimates developed in a recent report by Mantis (Mantis, 2021), while making provision for additional costs that may be associated with the refurbishment of the WWTW, sewerage lines and pump stations within the catchment. This is assumed to include costs associated with training the relevant technical staff and management.

For the purposes of this study, it is assumed that two full time staff members would need to be recruited, one for the purposes of sewerage line inspection, and the other to perform monitoring of site-based infrastructure throughout the Valley and ensure the implementation of litter management programs. These staff members could also feasibly undertake various other activities listed in the subsequent scenarios. Initial training basic training would be required, with periodic training also being likely. Further training of all staff involved in wastewater management has also been recommended.

As the training is unlikely to require significant investment, this is aggregated into the ongoing costs associated with these staff members.

The management of litter is closely tied to the fostering of a community action and citizen science initiative. Initial launch costs of a campaign in this regard are estimated to be around R200,000, with periodic costs likely to be necessary for publicising the initiative in the local media. The initial costs would include the installation of litter traps, and the development and launching of a media campaign. The ongoing cost associated with this is estimated to be around R20,000 per annum primarily to maintain ongoing community engagement. It is assumed that the cost of daily clearing of stormwater drains of litter is absorbed by the city.

Table 5-1: Estimated costs associated with activities identified in Scenario 1.

Activity	Capex costs (R)	Opex costs (R)
Commissioning of a Sewage Situation Assessment and Master Plan for the Baakens	250,000	
Implementation of Master Plan, including refurbishment and upgrade of sewer infrastructure	30,000,000	
Community action initiatives	200,000	20,000
Staff costs		250,000
TOTAL	**30,500,000**	**350,000**

5.2.3. Benefits

The interventions in this scenario are expected to impact primarily the delivery of ecosystem services linked to pollution regulation, air quality, and broad health benefits. Current levels of pollution in the system considerably surpass its ability to filter and assimilate dangerous pollutants, and impact on the delivery of other linked ecosystem services. Although not at a level where it confers significant costs on the health of local communities, the potential for health benefits linked to a healthy environment and enhanced usage of the recreational areas are significant.

Marginal benefits, or the value of the change in benefits, associated with the increased delivery of ecosystem services linked to the interventions in this scenario are estimated to be in the range of R9 million to R12 million per annum.

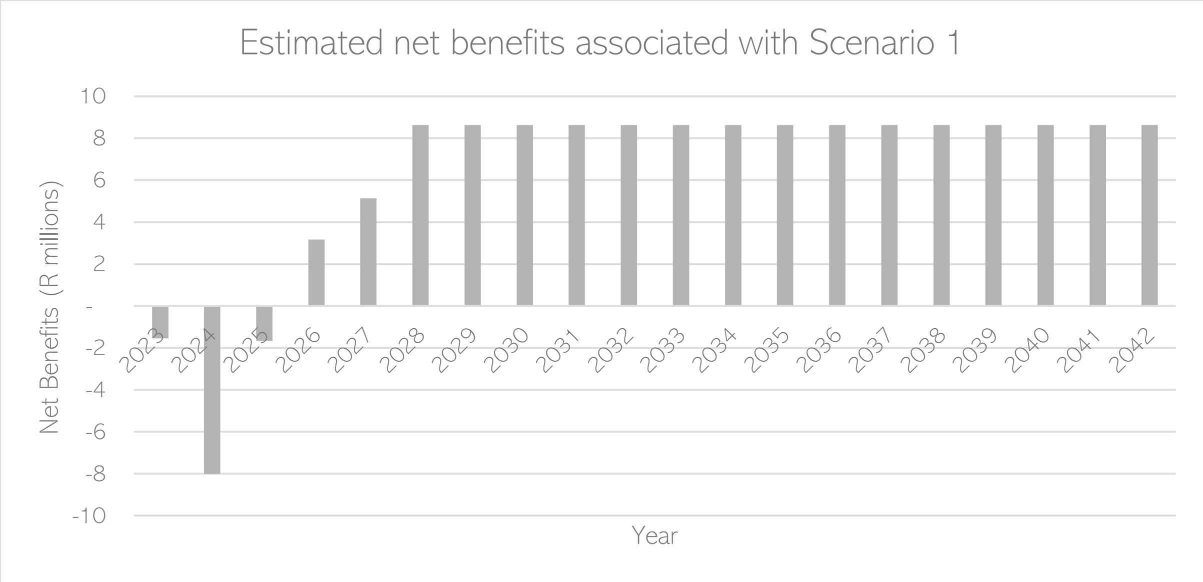

Figure 5-1: Visual representation of the estimated net benefits associated with Scenario 1 over the twenty year time horizon.

The benefit-cost ratio (BCR) calculated on the net present values estimated from the costs and benefits of this scenario is estimated to be in the range of 2.6 to 3.4, showing an exceedingly positive ratio of benefits to costs.

5.3. Scenario 2: Water quantity related

The loss of natural flood management (NFM) capability in the catchment is one of the most pressing problems associated with the current state of the river and its surrounding infrastructure, while AIV throughout the catchment and the degradation of wetlands in the upper reaches impact on its hydrological stability, which is also poorly understood. These problems are further exacerbated by the impacts and threats associated with climate change. Understanding the pre-impact and the current day hydrology, and implementing measures which would lead to a more natural flow regime with improved natural flood management capability for the river, are seen as key to maximising the benefits of improved delivery of ecosystem services, while also comprising the bulk of the costs.

5.3.1. Interventions

- Updated Stormwater Master Plan for the Baakens Catchment, with a focus on Water Sensitive Urban Design (WSUDs) and Sustainable Drainage Systems (SuDS) for the catchment.
- Augment Natural Flood Management by provision of stormwater detention facilities, improved floodplain functionality, and the introduction of various SuDS particularly in the lower river.
- Clear and manage AIV in the upper catchment.
- Rehabilitate upper catchment wetlands.

- Apply for formal protection of upper catchment area and place limits on further development.
- Clear and manage AIV in the lower catchment.
- Initiate flow gauging in the river.

5.3.2. Costing

The development of a Stormwater Master Plan for the Baakens catchment forms the basis for improving the water quantity regulation services of the catchment. Such a plan would guide any new development within the catchment, while also providing guidelines for the redevelopment or retrofitting of existing infrastructure. This process would of necessity also form a part of the metro's climate change plans.

According to the Nelson Mandela Bay (NMB) Climate Change and Green Economy Action Plan (NMB, 2015), a major revamp of the NMB Metro's (NMBM) stormwater and roads infrastructure is required to mitigate the impacts of climate change. The document notes that around R4.8 billion will be required over the next fifty years to implement the necessary infrastructure, most of which will likely be allocated to road infrastructure.

The activities associated with the restoration of the upper catchment wetlands is contingent on the findings of the Stormwater Master Plan, which would lay the basis for a detailed costing of all necessary interventions. For the purposes of this analysis, high-level cost estimates using available data are used, based on related studies and available data.

The average cost of around R2,000 per square meter derived from costing calculated by Maketha Development Consultants (2017), provides a higher end estimate for the construction of bioretention ponds. Other estimates indicate a figure closer to R1,000 (Washington DC, 2017). A mid-level estimate, assuming the construction of four relatively small bioretention ponds, with a footprint of 7`,000 m^2 each throughout the catchment provides a cost of R42 million.

Triangulation of data on the average spending by Working for Water (WfW) on alien removal and wetland restoration, as well as data from the Nelson Mandela Bay Conservation Programme (Griffiths, 2014) indicate that the AIV clearing would likely cost in the region of R400,000 to R800,000. Annual costs related to ongoing control of AIV may require either a dedicated full time position, or periodic clearing every six months. This has been included as opex of R120,000.

Flow gauging in the river may be linked to the monitoring stations discussed in Scenario 1. The cost of establishing monitoring will depend on the method selected (see Uys et al., 2022b). For instance, an existing weir could be retrofitted to provide a gauging weir (with a fishway), or real-time monitoring could be considered. Development of a rating curve will be required. There are ongoing opex costs in the form of data management and conversion, and storage and transfer of information.

Table 5-2: Estimated costs associated with activities identified in Scenario 2.

Activity	Capex (R)	Opex (R)
Clearing and management of AIV in upper and lower catchment and restoration of floodplain function	600,000	120,000
Wetland management plan and implementation, including conservation	800,000	120,000
Construction of bioretention ponds	42,000,000	
Establishment of flow gauging	1,000,000	200,000
TOTAL	**44,400,000**	**440,000**

5.3.3. Benefits

The interventions in this scenario are expected to impact positively on the delivery of ecosystem services related primarily to the regulation of water flows, while also showing strong positive effects associated with carbon sequestration over the longer term.

The value of the change in ecosystem services is estimated to be in the range of R5 million to R7.5 million per annum, which are expected to be realized in full in the sixth year after the identified interventions are initiated.

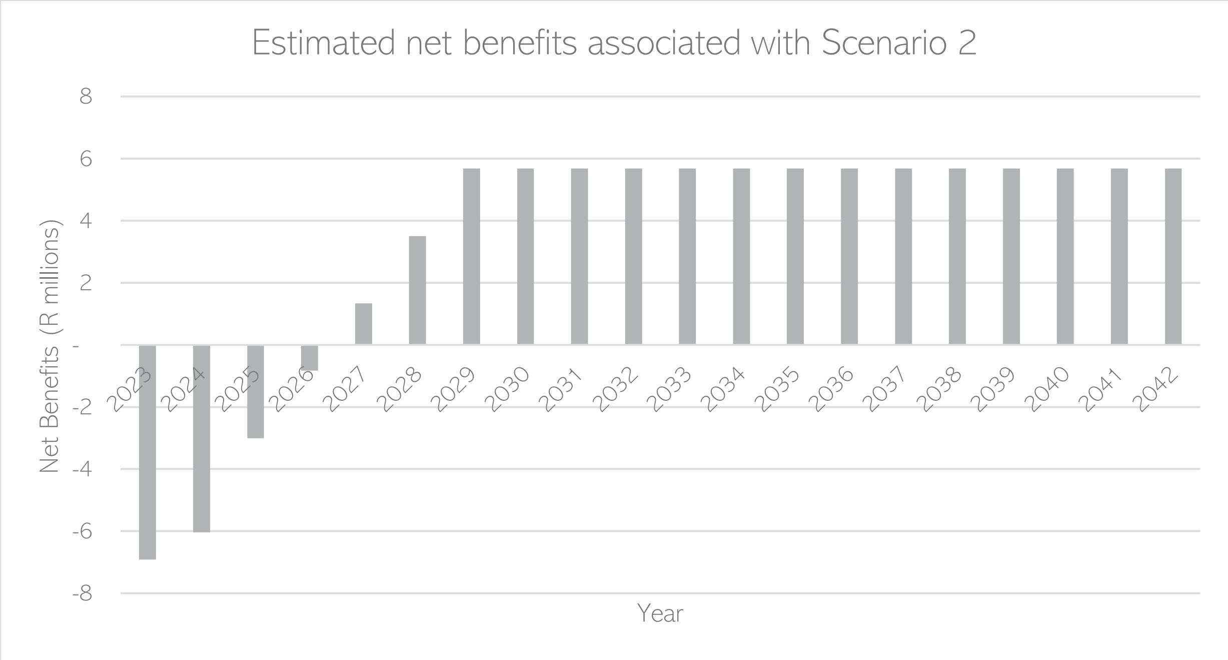

Figure 5-2: Visual representation of the estimated net benefits associated with Scenario 2 over the twenty-year time horizon.

The Benefit-Cost Ratio (BCR) associated with this scenario is estimated to be in the range of 1.1 to 1.6, showing a positive ratio of benefits to costs over the next twenty years.

5.4. Scenario 3: Improve connectivity and channel form

The problems associated with the connectivity and channel form affect the natural functioning and biodiversity of the lower river and particularly the estuary. These include the loss of natural channel form and instream and riparian habitat, and loss of system connectivity (ocean-estuary-river). This is due to engineered infrastructure in the form of barriers in the lower parts of the river, and narrowing and canalisation of the lower river and estuary (Uys et al., 2022b). The effects on the system are a loss of overall ecosystem functionality, restrictions on movement of migratory fish and eel species, reduced habitat for aquatic and terrestrial species, a significant loss of social and recreational opportunities, and increased danger of flooding in the surrounding area.

5.4.1.Interventions

These interventions are aimed at improving the ecophysical state of the lower river and are designed to interface with the NMB Development Agency plans to develop the Baakens River Parkway in the lower 1km of the river (mostly along the right bank).

- Clear AIV and thin out indigenous vegetation along the banks of the uppermost section of the reach (vicinity of Brickmakerskloof Bridge).
- Install fishways on all man-made barriers to fish migration (e.g. in Settlers Park).
- Naturalise channel morphology and reinstate habitat and hydraulic diversity in the lower 750m of the river and estuary.
- Naturalise the riparian area and floodplain where possible with plantings and the development of flood channels (wetlands).

5.4.2.Costing

The installation of fishways is estimated to cost approximately R200,000 to R500,000, or 5% to 10% of the cost of constructing a weir (Bok, pers. comm. 2022). Assuming that 16 fishways are required, and using the average of these two figures, an estimate of R5.6 million is used for this analysis.

Information on the costs involved in naturalisation of river morphology varies widely between case studies (van Zyl et al., 2004; Szalkiewics et al., 2018; Wantzen et al., 2019). The restoration costs of R15 million identified by Mantis (2021) for the Baakens River Catchment includes a range of activities from removal of alien vegetation and restoration of indigenous vegetation to restoration of the river system, including infiltration and hydrology (Mantis, 2021). Estimates based on modular costing relating to the interventions indicates that the full range of activities described in these interventions would likely require around R40 million to implement. A process of triangulation was applied, which included the data sources above, from which it was concluded that the higher estimate above is most appropriate, and thus is used for the purpose of this analysis.

Table 5-3: Estimated costs associated with activities identified in Scenario 3.

Activity	Capex (R)	Opex (R)
Installation of fishways to re-establish connectivity	5,600,000	
Vegetation management, naturalisation of river channel morphology, reinstatement of instream and riparian habitat, naturalisation of the floodplain	40,000,000	
TOTAL	**45,600,000**	

5.4.3.Benefits

The re-creation of the estuarine ecosystem and the linking of the river, estuary, and ocean, as detailed in Uys et al. (2022b) would result in significant enhancement of biodiversity and habitat creation. The improved health of the river due to the restored functioning of the ecosystem as a whole is expected to have a significant positive impact on the delivery of a broad range of ecosystem services, including regulation of water flow, recreation and amenity services, and temperature regulation.

The enhanced ability of the river to handle elevated levels of water flow and mitigate flooding, due to improvements in the river morphology and the improved connectivity to the ocean, plays a major role in climate change adaptation. This reduced vulnerability and improved resilience may significantly mitigate the financial and economic costs to the city and surrounding commercial stakeholders in the event of floods.

The value of the improvements in recreation and amenity services may be linked to the enhanced attractiveness of the area around the river and the improved connectivity of the green belt, from the estuary up into the valley. A wide range of activities, including walking, jogging, and fishing may be expected to see an uptick in the area. This intervention would also likely result in an increase in the value of commercial properties, particularly around reach 6.

The impact the re-creation of the estuarine ecosystem and the linked ecological infrastructure proposed under this scenario on the value of temperature regulation and reduced energy costs is likely to be significant in the local area. This has a linked benefit of reducing carbon emissions.

The increase in value of the improved delivery of ecosystem services is estimated to be in the range of R7 million to R10 million per annum. This assumes that the full value of these benefits is realized by the fifth year after the interventions are initiated, accounting for the time and cost of completing the proposed interventions, and allowing sufficient time for the ecosystem to re-establish successfully.

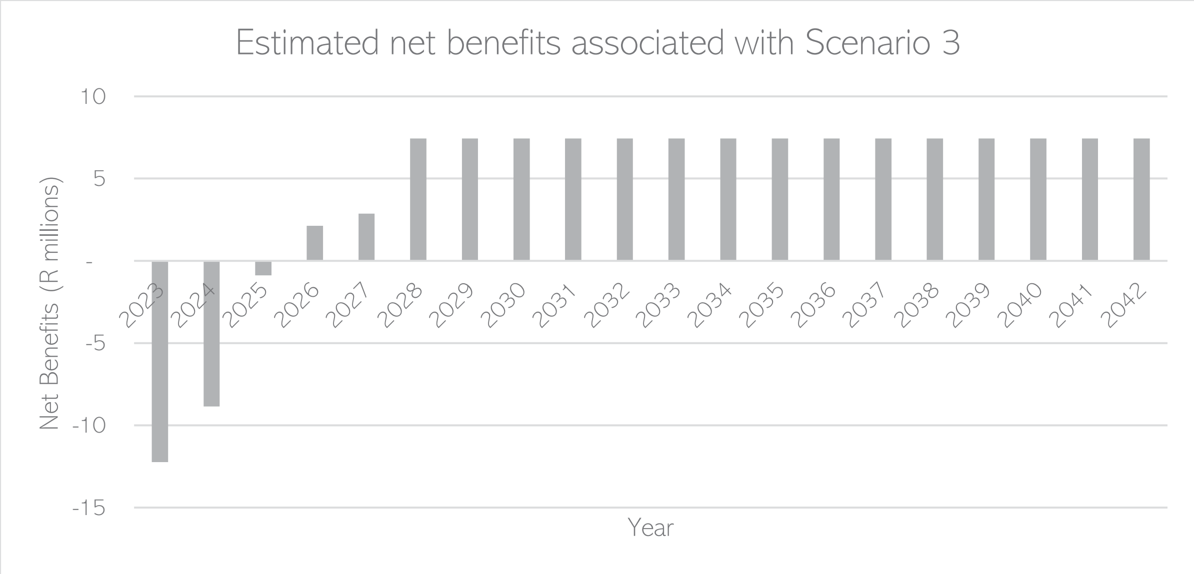

Figure 5-3: Visual representation of the estimated net benefits associated with Scenario 3 over the twenty-year time horizon.

The Benefit-Cost Ratio (BCR) associated with this scenario is estimated to be in the range of 1.5 to 2.2, showing a significantly positive ratio of benefits to costs despite the high costs involved in implementing these interventions.

5.5. Cumulative benefits

Each of these scenarios considered separately shows the positive benefits expected to arise from the implementation of interventions to restore the Baakens River Catchment to a healthier state, however the cumulative benefits of the implementation of all scenarios is expected to provide the highest level of benefits.

Cumulatively, the marginal benefits of the implementation of all listed interventions is expected to deliver additional value of over R21 million per annum to the residents of the Baakens River Catchment, with a comparative positive value to the broader community of Gqeberha and the NMB Metro area.

The flow of the cumulative net benefits associated with the implementation of all three scenarios is represented in the Figure 5-4. This represents an estimated benefit cost ratio of 1.6 to 2.3, clearly showing the value of implementing such measures.

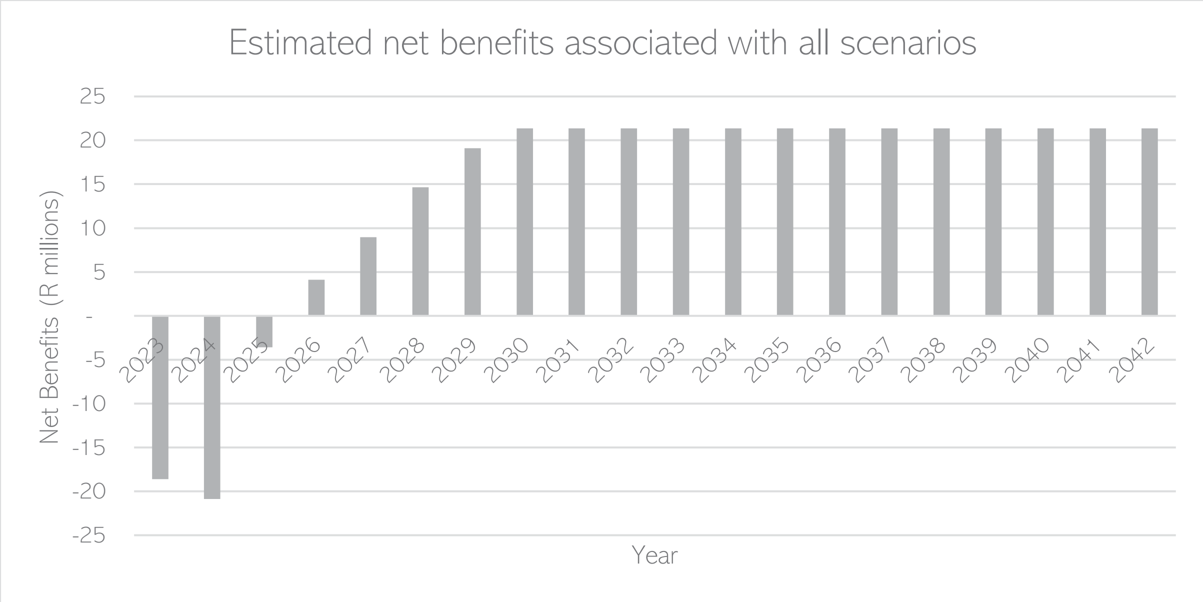

Figure 5-4: Visual representation of the estimated cumulative net benefits associated with all three scenarios over the twenty-year time horizon

6. DISCUSSION

The above analysis shows that there are significant positive benefits associated with each of the proposed scenarios. The allocation of funding towards the rehabilitation of the Baakens River Catchment should be considered in the budgeting of the NMB Metro as it is expected to contribute positive value to the residents of Gqeberha and the Metro area in general.

The value proposition linked to scenario one is the most compelling from a purely economic perspective, due largely to the significant impact improvements in water quality would have on the health of the surrounding communities and the ability of the ecosystem to better regulate pollution and air quality. This scenario is also the most cost-effective, requiring fewer financial resources to achieve the potential improvements. The improvement and effective management of the sewerage infrastructure should be a priority for the Metro.

The second scenario is expected to contribute significantly to improved flow of ecosystem service benefits, particularly through its impact on the water flow regulation benefits derived from the proposed interventions, and the likely increase in recreation and health benefits linked to enhanced habitat and aesthetic features. Due to the higher costs associated with the interventions proposed in this scenario, the benefit-cost ratio is not as pronounced as in scenario one, however the benefits are expected to outweigh the costs enough to justify its implementation.

Scenario three represents the most exciting and transformative potential options. This scenario, while being the most expensive to implement, will have far reaching benefits for the NMB Metro. The recreation and amenity services of this scenario are the most significant contributing factor to the increase in value derived from the metro's natural capital. As a drawcard for both local recreation and tourists from further afield, the knock-on impacts of re-establishing an integrated estuarine ecosystem with all the natural functioning and habitat services that accompany it would likely deliver even higher value than that which has been estimated by this study. That the interventions propose are perfectly aligned with the municipality's climate change adaptation plans makes this set of interventions an extremely attractive option. The positive benefit-cost ratios further reinforce the appeal of this scenario.

All the proposed scenarios fit with the NMB Metro's climate change adaptation and mitigation objectives, and if implemented would improve the city's resilience and reduce the vulnerability of infrastructure to potential shocks caused by extreme weather events. They also align with development objectives and biodiversity management plans.

The municipality also stands to benefit from increased property values associated with the improvement of urban green spaces within the metropolitan area. Although this was not included in calculations provided in this study, it is likely that it would have a significant positive impact on the overall benefit-cost ratios.

According to the analysis carried out for this report, scenario one represents the most viable and consequential option for improving the flow of ecosystem services associated with the Baakens River Valley. This is followed by scenario three, which links invigorating local development to healthy ecosystems functioning and enhancing the green image of the NMB Metro. Scenario two, while also representing an important improvement in the Metro's "green lung", comes in last position in terms of tangible benefits to the residents and stakeholders, but is nonetheless considered a vital requirement for the city. This is in terms of protecting upper catchment wetlands, critical biodiversity area status, and flood-attenuation functionality, and reducing future costs to life and infrastructure which are associated with the larger floods in this system.

7. REFERENCES

Brander, L.M. & Kotze, M.J. 2011. The value of urban open space: Meta-analysis of contingent valuation and hedonic pricing results. Journal of Environmental Management. 92(10): 2763 – 2773.

Carson, R.M. & Bergstrom, J.C. 2003. A Review of Ecosystem Valuation Techniques. Faculty Series 16651, University of Georgia, Department of Agricultural and Applied Economics.

Dasgupta, P. 2008. Nature in economics. Environmental and Resource Economics 39, 1–7.

Dasgupta, P. 2021. The Economics of Biodiversity: The Dasgupta Review. London: HM Treasury

Diaz et al. 2015. The IPBES Conceptual Framework — connecting nature and people. Current Opinion in Environmental Sustainability. Volume 14. Pages 1-16.

Dupuit, J. 1844. On the Measurement of the Utility of Public Works. Translated by R. H. Barback. International Economic Papers, no. 2 (1952), pp. 83- 110.

DWS. 2022a. Green Drop Report 2022. Department of Public Works. Available online: https://ws.dws.gov.za/iris/releases/Report_DPW_Rev02_29Mar22_MN%20web.pdf

DWS. 2022b. Green Drop Eastern Cape 2022. Available online: https://ws.dws.gov.za/IRIS/releases/GD22%20Report_Eastern%20Cape_Rev06_05May22_MN%20web.pdf

Elmqvist, T. et al. 2015. Benefits of restoring ecosystem services in urban areas. Current Opinion in Environmental Sustainability. 14: 101-108.

Freeman, A.M., 2003. The Measurement of Environmental and Resource Values: Theory and Methods. Resources for the Future, Washington, DC.

Griffiths, M. CEPF final project completion report. Nelson Mandela Bay Urban Conservation Programme.

Haines-Young, R. and Potschin, M. (2013): Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract No EEA/IEA/09/003

Hotelling, H. 1931. The Economics of Exhaustible Resources. Journal of Political Economy, vol. 39, p. 137-175.

IPBES. 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.

Kadykalo, A.N. et al. 2019. Disentangling 'ecosystem services' and 'nature's contributions to people', Ecosystems and People, 15:1, 269-287

Landers, D., & Nahlik, A. 2013. Final ecosystem goods and services classification system (FEGS-CS). EPA/600/R-13/ORD-004914. Washington, DC: U.S. Environmental Protection Agency.

Lee, J., Park, B.J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. 2009. Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. Scandinavian Journal of Forest Resources. 24(3): 227 – 234.

Macrotrends. 2022. South Africa Inflation Rate 1960-2023. Available online: https://www.macrotrends.net/countries/ZAF/south-africa/inflation-rate-cpi

Mäler, K, G. 1991. National Accounts and Environmental Resources. Environmental and Resource Economics 1:1-15.

Maketa Development Consultants. 2017. Bulk Service Report: Gqeberha Township Development Erf 11305. Report to NBM Metro.

Mantis. 2021. Project Green Lung. Restoration of the Baakens River Valley. Report prepared for the Nelson Mandela Bay Business Chamber.

Millennium Ecosystem Assessment (MA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

National Treasury. 2021. Guidelines on budget submissions for large strategic infrastructure proposals. Budget facility for infrastructure. 2021 budget cycle. Available online: https://www.treasury.gov.za/publications/guidelines/GUIDELINE%20ON%20BUDGET%20SUBMISSIONS%20FOR%20LARGE%20STRATEGIC%20INFRASTRUCTURE%20PROPOSALS%20final%2021%2004%2021.pdf

NMBM (Nelson Mandela Bay Municipality). 2009. Sewerage Master Plan: Phase 2 Stage 2 - Urban Areas.

Nelson Mandela Bay. 2015. Climate Change and Green Economy Action Plan.

OECD (Organisation for Economic Cooperation and Development). 2022. Purchasing Power Parities (PPP). Available online: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm

Pakati, D.E. et al. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Frontiers in Ecology and the Environment. 9(1): 29 – 36.

Pearce, D. W., Atkinson, G., Mourato, S. 2006. Cost-benefit analysis and the environment: recent developments. Organisation for Co-operation and Development (OECD), Paris

Perrings, C. 2006. Resilience and sustainable development. Environment and Development Economics, 11(4), 417-427. doi:10.1017/S1355770X06003020

SANBI. 2014. A Framework for investing in ecological infrastructure in South Africa. South African National Biodiversity Institute, Pretoria.

Szalkiewics, E., Jusik, S. & Grygoruk, M. 2018. Status of and Perspectives on River Restoration in Europe: 310,000 Euros per Hectare of Restored River. Sustainability 2019, 10, 129.

TEEB. 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

UN. 2014. System of Environmental-Economic Accounting 2012 – Central Framework. United Nations.

Uys, A.C., Bok, A., MacKenzie, J., Scherman, P., Kanise, N. 2022a. Current Ecostatus of the Baakens River, Gqeberha. Report No 1 to Water Research Commission as part of Project No. 2022-23 01221.

Uys, A.C., Bok, A., MacKenzie, J. 2022b. Baakens River Rehabilitation Feasibility. Rehabilitation Scenarios. Report 2 to the Water Research Commission as part of Project 2022-23 -1221.

Van Zyl, H., Leman, A. & Jansen, A. 2004. The costs and benefits of urban river and wetland rehabilitation projects with specific reference to their implications for municipal finance: case studies in Cape Town. Report to the Water Research Commission. WRC Report No: KV159/04

Wantzen, K.M., et al. Urban Stream and Wetland Restoration in the Global South—A DPSIR Analysis. Sustainability 2019, 11, 4975.

WAVES (Wealth Accounting and the Valuation of Ecosystem Services). 2012. Moving beyond GDP. How to factor natural capital into economic decision making. The World Bank. Washington, DC.

Waller, L.P., et al. 2020. Biotic interactions drive ecosystem response to exotic plant invaders. Science. 368(6494): 967 – 972.

Washington DC. 2017. Bioretention cost calculator. Department of Energy and Environment. Available online: https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/Bioretention%20-%20SWM%20BMP%20Green%20Infrastructure%20Construction%20Price%20Calculator_1.xlsx