An Evaluation of Sustainable Water Management Practices in Wildlife Tourism at Ngala, Limpopo, South Africa

by

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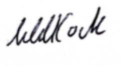

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Abstract

The sustainable management of water resources has become an increasingly prominent challenge, not only globally but also within wildlife tourism operations, particularly in water-scarce and ecologically significant regions. This study evaluates the sustainability of water management practices at Ngala Safari Lodge and Ngala Tented Camp, located within the Ngala Private Game Reserve in Limpopo Province, South Africa. Using a mixed-methods multiple case study approach, the research assessed both water quantity and water quality over 28 months (November 2022 to February 2025), supported by qualitative insights from staff interviews.

Quantitative analysis included the assessment of water consumption trends, litres per bed-night, and seasonal variation, as well as compliance of drinking and effluent water quality with relevant South African standards, benchmarks and legislation. Qualitative interviews explored staff perceptions, operational practices, and organisational commitment to sustainable water management.

The findings indicate that water use at both lodges remains relatively consistent throughout the study period and is largely driven by fixed operational demands rather than seasonal climatic variation. Water quality challenges were primarily linked to naturally hard groundwater and infrastructure limitations, with few physical, chemical, or microbial exceedances observed. While strong management commitment and technical interventions were evident, limited staff awareness and behavioural water-saving practices were identified as key gaps. The study highlights the importance of integrating technical systems with staff engagement and education to enhance long-term water sustainability in wildlife tourism operations.

Key words

sustainable water management; wildlife tourism operations; water quality; water quantity; benchmarking; water-use efficiency; sustainability awareness.

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Abbreviations and Acronyms

Abbreviation	Full Term
&Beyond	And Beyond (Ecotourism Company)
BGIS	Biodiversity Geographic Information System
CC Africa	Conservation Corporation Africa (Ecotourism Company)
CFU	Colony-Forming Units
DEA	Department of Environmental Affairs (South Africa)
DWAF	Department of Water Affairs and Forestry (South Africa)
E. coli	*Escherichia coli*
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
IWRM	Integrated Water Resources Management
Km	Kilometre
L	Litre
l/b/n	Litres per bed-night
mg/l	Milligrams per litre
Mm	Millimetre
NSL	Ngala Safari Lodge
NTC	Ngala Tented Camp
pH	Potential of Hydrogen
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SANS	South African National Standard
SDG	Sustainable Development Goal
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme

UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNISA	University of South Africa
UNWTO	United Nations World Tourism Organisation
UV	Ultraviolet
WHO	World Health Organisation
WWF	World Wide Fund for Nature
°C	Degrees Celsius

1. Chapter 1 - Introduction

1.1 Background

Water is not just a resource; it is the essence of life on Earth. American marine biologist Sylvia Earle (2009) stated in her TED Talk, "No water, no life. No blue, no green," highlighting the crucial role that water plays in sustaining life. In South Africa, a country known for its diverse cultures, languages, fauna and flora, the significance of water cannot be overstated. Like many regions worldwide, South Africa faces water scarcity due to factors such as climate change, overexploitation, population growth, and inefficient water management, causing global freshwater availability and quality to decline (Stoll, 2024). South Africans consume an average of 235 litres of water per person per day, which is 36% higher than the global average of 173 litres per day (Carelse, 2023). The South African wildlife tourism sector is also affected by this trend, underscoring the need to implement sustainable tourism practices, especially sustainable water management.

Sustainable tourism involves effectively managing all resources, including water resources, to protect cultural heritage, maintain critical ecological processes, preserve biodiversity, and sustain life support systems (Zolfani, Sedhaghat, Maknoon & Zavadskas, 2015). Sustainable tourism aims to meet economic, social, and environmental requirements without compromising these vital aspects. (Cernat & Gourdon, 2011). According to the World Travel and Tourism Council's (WTTC) 2022 Economic Impact Report, the South African Travel and Tourism sector is expected to increase at an average annual rate of 7,6% over the next decade. This growth can bring both challenges and opportunities for the sector. Both the economy and communities benefit from tourism; however, environmental and social challenges may arise (Khan, Khan, Lim, Tan & Ahmed, 2021).

Pioneers and leaders in the tourism sector frequently assert their commitment to sustainability, often incorporating these claims into their official manifestos, which emphasise their dedication to protecting the environment, wildlife, and local communities. However, this raises important questions: How genuine is their commitment to these principles? Luxury tourism establishments, especially within the wildlife tourism sector, are characterised by high-end accommodation, exclusive services, fine dining experiences, and premium pricing. These features elevate the guest experience and often lead to increased resource consumption, as luxury remains the focus of the establishment while sustainability is sometimes treated as an afterthought. While most wildlife tourism organisations are legally required to adhere to specific standards and criteria designed to promote sustainable practices, the unique challenges they face in their operating environments necessitate a closer examination. It is essential to investigate whether these organisations are truly complying with sustainability standards and if the ideals outlined in their internal manifestos are being effectively realised in practice.

As previously mentioned, water is at the core of all life, and this is particularly true for the tourism sector. Tourism industries, including wildlife tourism in South Africa, will not be able to function without water. It depends on water for essential needs such as human consumption, irrigation, food and beverage preparation, personal hygiene, and various tourist activities (Gössling, Peeters, Hall, Ceron, Dubois, Lehmann & Scot, 2012). Therefore, to ensure the future success and prosperity of the South African wildlife tourism sector, emphasis should be placed on implementing sustainable water management practices.

This study will investigate the water-related sustainability practices of &Beyond's Ngala Safari Lodge and Ngala Tented Camp by examining their water management systems. It will assess whether these practices comply with relevant laws and standards, as well as &Beyond’s internal policies. By doing a comparative case study, this research will provide a comprehensive analysis of the two tourism facilities’ water management.

For the purpose of this study, water management refers primarily to the abstraction, treatment, use, monitoring, and disposal of water associated with lodge operations and human consumption at Ngala Safari Lodge and Ngala Tented Camp. The study focuses on water used by guests, staff, accommodation facilities, kitchens, laundries, workshops, and associated infrastructure, as well as the quality of drinking water and effluent water.

Although wildlife and ecosystems depend on the same water resources and are indirectly affected by water management decisions, the study does not quantify or evaluate the direct water requirements or consumption of wildlife species.

1.2 Definition of Sustainable Water Management

Sustainable water management involves the strategic use, conservation, and safeguarding of water resources to fulfil present human needs while ensuring their availability for future generations (Ding & Ghosh, 2017). To make the most of water resources, it is essential to implement practices that significantly reduce waste, improve overall efficiency in water use, and prioritise the maintenance of water quality.

1.3 Importance

South African wildlife lodges are typically located in remote or rural areas where nature remains unspoiled. This allows guests to experience nature in its most pristine state, free from nearby transport facilities, shopping centres, and other modern conveniences. While this experience is a drawcard for tourists, it requires lodge management and staff take on responsibilities typically managed by various services in urban areas. Among these responsibilities are managing the entire water supply and disposal system within the lodge. Management faces the challenge of ensuring that both the quality and quantity of water meet required standards and regulations to sustain the lodge's operations while safeguarding the well-being of guests, staff, and the environment.

In South Africa, wildlife lodges often rely on natural water sources, such as rivers, dams, and boreholes, to fulfil their water needs. Effective water management in these lodges encompasses a thorough process that spans from water extraction to its return (disposal) to the environment. This involves monitoring water usage, maintaining water quality, implementing treatment and regular testing systems, recycling water, managing sewage treatment, and overseeing environmental discharge (Grobler, 2018).

Because these lodges rely on natural water sources, it is crucial for them to treat the water internally before it can be used for domestic purposes and consumed by staff and guests. Unlike urban settings, where water is treated at centralised facilities, lodges need to implement their own treatment processes to ensure the water meets safe quality standards. This ensures that the water utilised in the lodge is devoid of harmful substances and safe for human consumption. As part of their sustainability initiatives, these lodges also recycle greywater for irrigation, reintegrating it into the environment. This recycled water must be tested and treated to prevent the release of toxins, thereby safeguarding both the environment and human health.

Another critical aspect of these lodges is that staff members typically reside in a staff village or staff quarters near the lodge itself, utilising the same water supply for all domestic purposes. This can place additional strain on the lodge's water resources, requiring effective management to ensure sustainability.

The aspects discussed have led to the creation of various national and international standards focused on efficient water resource management, waste reduction, and maintaining high water quality standards to protect both people and the environment. However, a major challenge arises from the fact that international guidelines for sustainable water use often do not align with the specific needs of the wildlife lodge industry, especially since staff live on-site permanently (Baker & Mearns, 2015).

1.4 Gap in Research

Despite the increasing recognition of sustainable water management's importance worldwide, research gaps persist, particularly in the South African wildlife tourism sector. Current research lacks detailed analysis on the water quantity and quality specific to wildlife lodges in remote areas of South Africa, including aspects such as human consumption, irrigation and wastewater management. Existing international standards and guidelines for sustainable water use often overlook the unique circumstances of wildlife lodges in remote areas in South Africa, necessitating research to develop effective water management practices that establish internal baselines and management plans to minimise environmental impact (Baker & Mearns, 2015). Additionally, long-term impact studies on the sustainability of implemented water management strategies are lacking. Addressing these gaps, especially through case studies like Ngala Tented Camp and Safari Lodge, is essential for enhancing awareness and promoting effective, sustainable water management practices.

1.5 Motivation

The motivation for this study stems from the necessity to manage wildlife tourism operations, like those at Ngala Safari Lodge and Ngala Tented Camp, in an environmentally safe, sustainable and compliant way. By examining the water quantity and quality management practices of these lodges, the research seeks to offer insights that can guide best practices and policy recommendations. This is especially critical because of the potential environmental and human health risks linked to inadequate water management. Acquiring an understanding of current practices and pinpointing areas for improvement will contribute to enhancing the sustainability of wildlife lodges.

1.6 Aim

This study seeks to evaluate the water management practices at Ngala Safari Lodge and Ngala Tented Camp to determine their compliance with relevant South African legislation and standards, as well as their adherence to internal benchmarks. The study aims to identify areas where water management can be improved and to propose best practice strategies that support environmental, social, and economic sustainability. The key areas of focus include establishing a baseline for the lodges' water usage and comparing it to applicable benchmarks, evaluating current water quality levels to ensure they meet standards for human consumption and environmental safety, and confirming adherence to relevant South African water management regulations and standards.

1.7 Objectives

- To assess the water usage trends at Ngala Safari Lodge and Ngala Tented Camp, establish a baseline, and determine compliance with relevant benchmarks.

- To investigate the physical, chemical and microbial water quality at Ngala Safari Lodge and Ngala Tented Camp for drinking water and effluent water.
- To explore staff perceptions and experiences of water quality and usage, and to understand how these contribute to daily operations and well-being.
- To examine current water management systems and practices to determine their contribution to sustainable water use.
- To evaluate the extent to which the lodges’ water management practices align with principles of environmental stewardship and sustainable tourism.
- To identify gaps in current practices and propose best-practice recommendations that enhance environmental, social, and economic sustainability.

1.8 Research Question

The main research question guiding this study is:

How sustainable are the water management practices at Ngala Safari Lodge and Ngala Tented Camp in terms of water use, water quality, and management systems?

To address the main research question, the following sub-questions were investigated:

- To what extent do water use trends at Ngala Safari Lodge and Ngala Tented Camp comply with relevant benchmarks and sustainability targets?
- To what extent does the drinking water and effluent water quality comply with applicable South African standards and regulations?
- How do staff perceive and experience water quality, water use, and water management practices in relation to their daily operations and well-being?
- To what extent do the lodges' water management systems and practices align with principles of sustainable tourism and environmental stewardship?
- What gaps exist in the current water management practices, and what best-practice strategies can be implemented to improve environmental, social, and economic sustainability?

1.9 Overview of Research Design and Methods

This study used a mixed-methods multiple case study approach to evaluate the sustainability of water management practices at Ngala Safari Lodge and Ngala Tented Camp. Quantitative methods are used to assess water quantity and water quality through the analysis of secondary data, including monthly water consumption records and laboratory water-quality results over 28 months. These data are evaluated against relevant South African legislation, standards, and internal benchmarks to determine compliance and trends.

Qualitative methods are employed through semi-structured interviews with lodge management, maintenance personnel, and general staff to explore perceptions, experiences, and operational practices related to water use and water quality. This approach enables a comprehensive assessment of environmental, social, and economic sustainability dimensions. A detailed description of the study area, research design, data collection procedures, and analytical methods is provided in Chapter 3: Research Design and Methodology.

1.10 Chapter Outline

- Chapter 1- Introduction

This chapter introduces the context of the study by outlining the significance and challenges of sustainable water management in the international and South African wildlife tourism sector. It explains the relevance of the research, identifies existing gaps in the literature, and presents the study's aim, objectives, and research questions. The chapter also provides an overview of the structure and flow of the study.

- Chapter 2- Literature Review

This chapter reviews existing literature on sustainable water management within the context of wildlife tourism. It explores themes such as water scarcity, the water–energy nexus, and the United Nations' Sustainable Development Goals. The chapter examines the social, environmental, and economic impacts of inadequate water management, relevant standards and guidelines, and current water treatment and wastewater practices. It concludes by identifying gaps that justify the need for this research.

- Chapter 3- Research Design and Methodology

This chapter outlines the research design and methodological approach used in the study. It describes the mixed-methods case study design, the study area, sampling strategies, and data collection procedures. The chapter explains how quantitative and qualitative data were analysed and discusses ethical considerations and limitations.

- Chapter 4- Results, Discussion and Analysis

This chapter presents and analyses the findings of the study in relation to the research objectives. It reports on water quality, water usage trends, and compliance with relevant standards, supported by statistical analyses, tables, and figures. The chapter analyses staff perceptions to provide a broader understanding of water management within lodge operations. The results are discussed in relation to existing literature to highlight patterns.

Chapter 5- Synthesis, Recommendations, Limitations, and Conclusion

This chapter synthesises the main findings of the study and links them back to the research objectives. It presents practical recommendations aimed at improving the environmental, social, and economic sustainability of water management at the lodges. The chapter also discusses the limitations of the study and highlights suggestions for future research.

1.11 Flow of the Study

The overall flow and structure of the study are outlined and illustrate how the research is organised across the chapters, showing the progression from the introduction and literature review through to the methodology, results, discussion, and concluding synthesis.

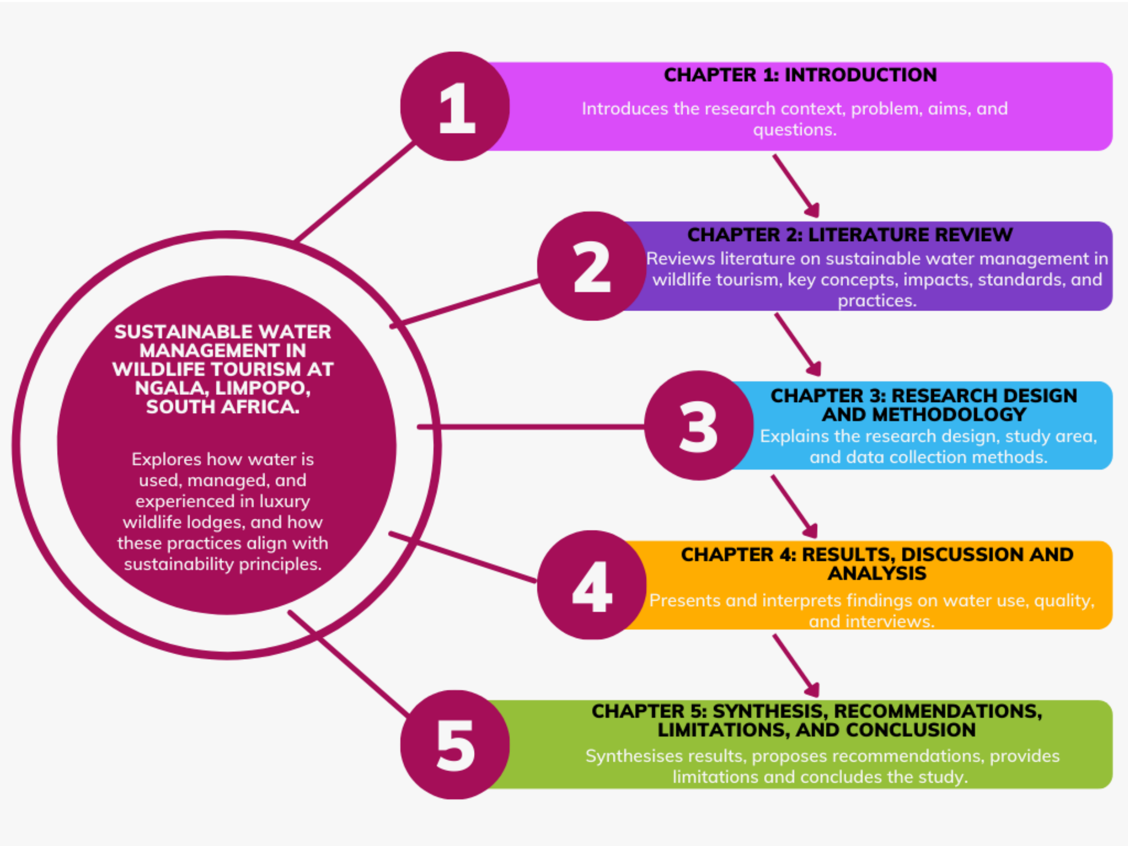

Figure 1.1 Flow of the study and chapter structure

1.12 Chapter Conclusion

This chapter has introduced the relevance and scope of the study by outlining the challenges associated with sustainable water management in the international and South African wildlife tourism sector. It presented the research gap, motivation, aim, objectives, and research questions, and provided an overview of the research design and structure of the dissertation. The following chapter provides a review of the relevant literature, examining key concepts, standards, and best-practice approaches related to sustainable water management in wildlife tourism.

2. Chapter 2 - Literature Review

2.1 Introduction

This chapter offers an in-depth review of the literature on sustainable water management in wildlife tourism, with specific reference to Ngala Safari Lodge and Ngala Tented Camp in Limpopo, South Africa. It explores the frameworks of sustainable water management, including the international challenge of water scarcity, the water–energy nexus, and the application of Sustainable Development Goal 6: Clean Water and Sanitation within tourism operations. The chapter explores research on water consumption trends, both direct and indirect, across different accommodation types and examines the implications of inadequate water management on social, environmental, and economic systems. It discusses relevant South African standards and legislation regarding source, drinking and wastewater compliance requirements for lodges. Lastly, it reviews current practices in water quality management, treatment technologies, and wastewater reuse within the tourism sector, drawing on international and regional case studies.

Figure 2.1 visually represents the core themes from the literature, demonstrating the interconnected nature of sustainable water management within wildlife tourism. It draws on relevant literature addressing water use in wildlife tourism and water quality management contexts, and the broader principles of sustainable water management. These themes are considered within the broader context of water scarcity, the water–energy nexus, and the Sustainable Development Goals, while examining the social, environmental, and economic effects of poor water management. Together, these components inform the use of benchmarks, standards, and legislation to assess performance. The framework highlights research gaps, highlighting the need for the study.

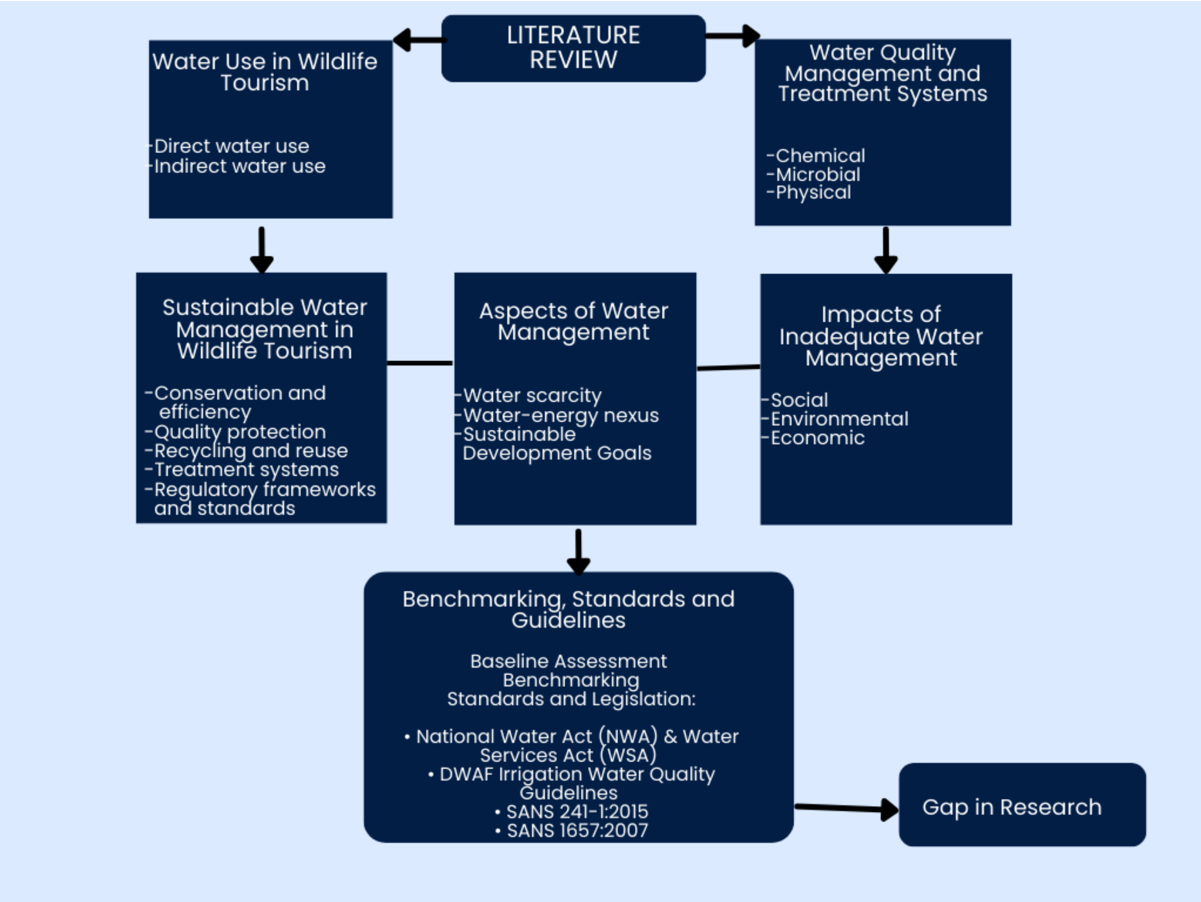

Figure 2.1 Conceptual framework for sustainable water management in wildlife tourism, Ngala Safari Lodge and Tented Camp

2.2 Sustainable Water Management in Wildlife Tourism

Sustainable water management involves the strategic use, conservation, and safeguarding of water resources to meet present and future needs (Ding & Ghosh, 2017). To effectively utilise water resources, sustainable water management practices should be implemented that reduce water wastage, improve overall efficiency in water use, and prioritise the maintenance of water quality holistically by incorporating social, environmental, and economic aspects. From an environmental management perspective, sustainable water management extends beyond using water sparingly and involves preserving the hydrological balance within ecosystems, safeguarding aquatic environments, and ensuring compliance with national and international water quality regulations (Gleick, 2018).

Wildlife tourism is a subset of ecotourism that is meant to view and/or encounter wildlife and natural habitats (Kanta, Kauravv, Allam & Srivalli, 2021). This sector has shown rapid international growth, contributing significantly to the economies of many countries, particularly in regions rich in biodiversity like Africa, including South Africa (Gupta, Zhu, Bhammar, Earley, Narain, Spencer, Whitney & Taylor, 2023). According to the WTTC (2023), South Africa’s travel and tourism sector is estimated to grow to R911.7 billion, contributing 10.3% of the country’s gross domestic product by 2035. However, the increase in tourism brings with it challenges, including sustainable natural resource management and environmental impact.

Sustainable water management within the tourism sector entails minimising the water footprint through efficient use, water recycling, minimal wastage and implementing effective treatment systems while safeguarding the natural water sources that support the environment and communities (United Nations World Tourism Organisation (UNWTO), 2020). For tourism accommodation facilities such as wildlife lodges, this includes monitoring water abstraction, implementing greywater reuse systems, and maintaining source water quality that aligns with relevant standards.

Sustainability in wildlife tourism has become a focus point as stakeholders recognise the need to balance economic benefits with environmental protection and human welfare. Sustainable tourism practices aim to minimise negative effects on the environment, conserve biodiversity, and ensure that natural resources, including water, are preserved for future generations (Liu, Tzeng, Lee & Lee, 2013).

Water is an essential resource to preserve all life and is central to operations in wildlife tourism. Wildlife lodges typically operate in remote areas where water resources are limited, highlighting the importance of sustainable water management practices in tourism to not adversely affect the local water supply, environment, or people who rely on these resources (Liu *et al*., 2013). As a result, numerous international and national laws and standards have been put in place to ensure high water quality and controlled water quantity use.

A critical component of sustainable water management in wildlife tourism is the abstraction of water from natural sources. Wildlife lodges in remote areas often rely on groundwater abstraction through boreholes or direct abstraction from rivers, dams, and other surface water resources. While these sources provide operational independence, excessive or poorly monitored abstraction can reduce groundwater reserves and negatively affect surrounding ecosystems and communities that depend on the same resources (DWAF, 2004; Gleick, 2018). Sustainable water management therefore requires the careful monitoring and regulation of abstraction volumes to ensure long-term resource sustainability.

Within wildlife tourism operations, abstraction monitoring supports water-use efficiency assessments, benchmark development, regulatory compliance, and sustainable resource management. This is relevant to Ngala Safari Lodge and Ngala Tented Camp, where groundwater abstraction from boreholes supplies most operational water requirements. As discussed later in this study, abstraction and water-use monitoring data are used to assess water-use performance and support sustainable water management decision-making.

This study evaluates the water quantity used and the water quality at Ngala Safari Lodge and Ngala Tented Camp by comparing the results and findings against relevant standards and benchmarks to determine the extent to which water resources are being managed in a sustainable and compliant manner.

2.3 Aspects of Sustainable Water Management

2.3.1 Water Scarcity

The Earth's surface is covered 71% by water, but less than 1 % is accessible for human use (Food and Agriculture Organisation (FAO), 2022). The United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Water Development Report (2024) stated that by 2030, nearly half of the world's population will face water scarcity due to factors such as population growth, urbanisation, poverty and unpredictable climatic conditions.

In sub-Saharan Africa, climate variability and uneven rainfall distribution contribute to water scarcity. Much of Southern Africa is classified as semi-arid, including Limpopo Province, South Africa, where the two case studies for this research are located. These areas frequently face drought conditions and increased competition for water among different sectors such as tourism operations, agricultural activities, and rural communities (Department of Water Affairs and Forestry (DWAF), 2004; Department of Environmental Affairs (DEA), 2013). This highlights that water resources are finite and must be shared among multiple sectors, including tourism operations, ecological systems, and local communities.

2.3.2 The Water-Energy Nexus

The water–energy nexus highlights the interconnected relationship between water availability, energy use, and overall sustainability. Water management activities such as abstraction, pumping, treatment, storage, distribution, use, and wastewater treatment all require energy inputs, while energy production often depends on water resources and can influence water quality and availability (Hoff, 2011). As a result, decisions made to improve water efficiency may have direct implications for energy consumption and vice versa.

In a study conducted by Becken and McLennan (2017), evidence was found to suggest a strong interrelationship between water, energy, and waste generation in tourist accommodation establishments, confirming that these resource flows are closely linked rather than independent. The study emphasised that resource efficiency initiatives should be approached in an integrated manner, as interventions targeting one resource can either positively or negatively influence another. For example, water-saving technologies may reduce the volume of water that requires treatment and pumping, thereby reducing energy consumption. Conversely, advanced water treatment technologies such as reverse osmosis systems can increase energy demand despite improving water quality and water-use efficiency.

The relationship between water and energy is particularly relevant within the tourism sector, where guest expectations often require high levels of resource consumption. Gössling *et al*. (2012) found that luxury accommodation facilities typically have higher water and energy footprints due to services such as laundry operations, swimming pools, landscaped gardens, air conditioning, and frequent linen changes. Similarly, Becken and Simmons (2002) reported that resource consumption within tourism establishments is often significantly higher than domestic consumption because of service standards associated with the tourism industry.

Tourism facilities located in remote wildlife areas, such as Ngala Safari Lodge and Ngala Tented Camp, are particularly dependent on the water-energy nexus. Unlike urban accommodation establishments that rely on municipal infrastructure, remote lodges often abstract groundwater, pump water over long distances, operate storage systems, and utilise on-site water treatment processes. Each of these activities requires energy and contributes to the environmental footprint of the operation. Consequently, improvements in water-use efficiency may not only reduce pressure on local water resources but may also lower energy consumption and associated greenhouse gas emissions.

Understanding the water-energy nexus is therefore important for sustainable tourism management, as it highlights the need for integrated resource planning rather than addressing water and energy management in isolation. Within the context of this study, evaluating water consumption and water quality at Ngala Safari Lodge and Ngala Tented Camp contributes to a broader understanding of how sustainable water management practices may support environmental sustainability, operational efficiency, and responsible resource use within wildlife tourism operations.

2.3.3 Sustainable Development Goals

The United Nations (2015) Sustainable Development Goal 6 (SDG 6) aims to guarantee universal access to water and sanitation through sustainable and efficient resource management. It outlines clear objectives focused on enhancing water-use efficiency, safeguarding freshwater ecosystems, and minimising water pollution by promoting effective wastewater treatment and reuse practices. Each objective has clear indicators that can measure a sector or operation’s success in compliance. SDG 6 should not only be viewed as an international guideline by wildlife lodges but should also be applied as a practical tool for assessing sustainable tourism operations and water management practices at wildlife lodges.

Table 2.1 Sustainable Development Goal 6 Description, Key Indicators and Application.

Description	Key Indicators	Application for Wildlife Lodges
6.1: Achieve universal and equitable access to safe and affordable drinking water for all.	6.1.1: Proportion of population using safely managed drinking water services.	Lodges in remote areas depend on boreholes, rivers, or groundwater systems for water abstraction. Ensuring guests and staff have safe source water that complies with SANS 241-1:2015 standards align with this indicator.
6.2: Achieve access to adequate and equitable sanitation and hygiene for all, ending open defecation.	6.2.1: Proportion of population using safely managed sanitation services, including handwashing facilities.	Lodges using septic tanks or treatment plants contribute to 6.2.1 by maintaining hygienic sanitation for staff and guests. Staff education regarding hygiene also supports 6.2.
6.3: Improve water quality by reducing pollution, eliminating dumping, and minimising hazardous releases.	6.3.1: Proportion of domestic and industrial wastewater safely treated. 6.3.2: Proportion of water bodies with good ambient water quality.	Wastewater treatment, grease traps, and responsible effluent water disposal support 6.3.1. Regular effluent monitoring of chemical, physical and microbial parameters ensures compliance with the relevant regulations and supports 6.3.2.
6.4: Increase water-use efficiency across all sectors and ensure sustainable withdrawals.	6.4.1: Change in water-use efficiency over time. 6.4.2: Level of water stress (freshwater withdrawal as a proportion of available resources).	Measuring litres per bed-night for guests and staff and complying with relevant usage standards aligns with 6.4.1. Reducing water wastage by fixing leaks and using efficient fittings reduces water stress on boreholes, contributing to 6.4.2.
6.5: Implement integrated water resources management (IWRM) at all levels, including transboundary cooperation.	6.5.1: Degree of IWRM implementation. 6.5.2: Proportion of transboundary basin area with operational arrangements for cooperation.	Lodges rely on shared catchments such as the Timbavati or Klaserie systems in Limpopo, South Africa. Cooperation with South African National Parks (SANParks) and neighbouring lodges on abstraction and monitoring supports IWRM (6.5.1) and contributes to 6.5.2 through data sharing and joint water management.

6.6: Protect and restore water-related ecosystems, including wetlands, rivers, and lakes.	6.6.1: Change in extent of water-related ecosystems over time.	Tourism depends on healthy ecosystems. Maintaining buffer zones, protecting wetlands, preventing runoff, and managing wastewater sustainably help conserve aquatic areas, supporting 6.6.1.
6. a: Expand international cooperation and capacity-building support for water- and sanitation-related activities.	6.a.1: Amount of water- and sanitation-related official development assistance that is part of a government-coordinated plan.	Lodges under international brands like &Beyond often fund community water projects or staff training programmes. These initiatives enhance compliance with 6.a.1 and contribute to broader conservation goals.
6.b: Support and strengthen the participation of local communities in improving water and sanitation management.	6.b.1: Proportion of local administrative units with established and operational policies for community participation in water and sanitation management.	Lodges engaging local communities through water education and borehole maintenance projects demonstrate participation under 6.b.1. This promotes shared stewardship of water resources and community development.

Table 2.1 shows how SDG 6 and its indicators can be translated from a global sustainability framework into practical actions within wildlife lodge operations. In this study, SDG 6 is used to assess water quality, water-use efficiency, wastewater management, and broader sustainability practices at Ngala Safari Lodge and Ngala Tented Camp.

2.4 Impacts of Inadequate Water Management.

Inadequate water management within wildlife tourism operations can reduce their sustainability with social, environmental, and economic consequences. Poor water management practices such as excessive abstraction, inefficient use, or insufficient treatment can compromise human health, degrade environmental quality, and increase operational costs for tourism establishments.

2.4.1 Social

The well-being of communities depends on water resources (Kalogiannidis, Kalfas, Giannarakis & Paschalidou, 2023). In South Africa, where wildlife is an important tourism attraction, the management of lodges has an impact on both the environment and the well-being of their staff and guests, as well as neighbouring communities. Inadequate water quantity and quality pose a human health risk, such as dehydration, improper hygiene, water-borne disease and decreased food production.

Microbial pollution, which includes bacteria, viruses, and parasites, can result from improper water management. Waterborne diseases like diarrhoea, cholera, and gastrointestinal tract infections are frequently associated with contaminated water sources, which are estimated to cause 505 000 diarrheal deaths each year (World Health Organisation (WHO), 2017).

Improper chemical treatment and inadequate water filtration can lead to the contamination of drinking water with toxic substances. Chronic and acute health concerns, such as cancers, neurological diseases, and reproductive defects, can result from exposure to chemicals such as pesticides, heavy metals, and nitrates in water (Jaishankar, Tseten, Anbalagan, Mathew, & Beeregowda, 2014).

Nearby communities are directly influenced by the water management practices of wildlife lodges, especially in semi-arid and water-scarce regions of Southern Africa. Water is a finite and shared resource, and excessive abstraction by tourism facilities can reduce its availability for local households and small-scale farmers (Gössling *et al*., 2012). Inadequate wastewater treatment and discharge pose an additional risk, if effluent containing pathogens, nutrients, or toxic substances contaminates nearby water bodies, it can degrade aquatic ecosystems and jeopardise public health, affecting not only the immediate environment but also the broader community that depends on those resources for domestic and agricultural use (DEA, 1996; United Nations Environment Programme (UNEP), 2016).

Staff residing on site in wildlife lodges rely on the water provided by the lodge for all domestic purposes. At Ngala Safari Lodge and Ngala Tented Camp, some staff live in on-site villages for six-week shifts followed by two weeks off, while others are permanent residents at the lodge. This places importance on the quality, reliability, and safety of the lodge's water supply. Access to clean and sufficient water is fundamental to staff dignity, health, and overall well-being, and inadequate provision can undermine the social sustainability of lodge operations (Baum, 2015). Inequities may arise between guests and employees at luxury tourism ventures, where tourists are provided with high-quality water and superior facilities. Staff may rely on lower-quality or less reliable sources (Scheyvens, 2014). Wildlife tourism ventures often emphasise luxury guest experiences and external environmental branding, which may result in the neglect of key internal social sustainability issues, including ensuring that staff have reliable access to safe and adequate water for their daily needs.

Water resource inequalities between wildlife lodges and neighbouring rural settlements can cause communities to feel unfairly treated and worsen social inequalities. Research by Snyman

(2017) showed that tourism lodges often have more reliable access to clean water than surrounding communities, which may face scarcity, inadequate infrastructure, or poor-quality supply. This may lead communities to perceive that tourism operations receive preferential treatment in resource allocation while residents struggle with unmet basic needs. Moswete and Thapa (2018) reported that communities living adjacent to protected areas in Botswana frequently face restricted or unreliable access to water because of conservation zoning and competition with tourism facilities. These dynamics weaken community relationships and reduce trust in protected-area management, as people question why resources like water benefit tourists and wildlife more than the residents. This can lead to social tension and conflict.

2.4.2 Environmental

Ineffective water management harms ecology, biodiversity and the environment within wildlife tourism. As wildlife lodges are located in natural, protected areas, their environmental impact is greater than that of urban lodges. Water is a shared and finite source for both humans and ecosystems, placing greater responsibility on wildlife lodges to manage water sustainably.

When water abstraction is excessive or poorly regulated, it can reduce groundwater levels and reduce flow in nearby rivers and dams. Because of the shortage of water resources, species compete more with one another, which may lead to the extinction or decline of less competitive species (Ojija & Nicholaus, 2023). Degradation of ecosystems can lead to changes in species composition and richness, which can facilitate the growth of invasive species that can adapt to new environments (Adla, Dejan, Neira, & Dragana, 2022).

Ineffective wastewater treatment poses environmental risks, as effluent containing harmful microorganisms, nutrients, or chemicals such as soaps and detergents can infiltrate the soil and migrate into nearby waterbodies when it is introduced into the environment. This impacts the soil ecology, degrades water quality, and threatens both aquatic and terrestrial ecosystems.

Nutrient-rich effluent water, especially when high nitrogen or phosphorus concentrations are present, may lead to eutrophication in water bodies. Smith, Tilman and Nekola (1999) reported that eutrophication accelerates the growth of algal blooms, many of which can be toxic or fatal to wildlife. It also reduces dissolved oxygen levels in waterbodies, which can result in the death of fish, amphibians, and other aquatic species. These ecological changes may jeopardise the conservation efforts of wildlife lodges and can reduce the quality of drinking and recreational water, thereby threatening human health.

Animal health is closely linked to environmental quality and can be regarded as an indicator of ecosystem health. In wildlife tourism environments, water quantity and quality influence the availability of suitable habitat, access to drinking water, food resources, and overall ecosystem functioning (Cosgrove & Loucks, 2015). Nishmitha, Akhilghosh, Aiswriya, Ramesh and Muthukumar (2025) state that emerging contaminants such as pharmaceuticals, personal care products, endocrine-disrupting compounds, and microplastics are increasingly detected in water and wastewater systems and may pose risks to human and animal health, aquatic ecosystems, and water quality due to their persistence and resistance to conventional treatment processes. Consequently, adverse impacts on wildlife health are often manifestations of broader environmental degradation rather than isolated biological concerns. Maintaining environmental quality through sustainable water management therefore contributes directly to the health and resilience of wildlife populations and the ecosystems on which they depend (Gleick, 2018).

Improperly treated wastewater being introduced to soil through runoff or irrigation can contaminate the soil, which can cause soil pollution. In a study by Alnaimy, Shahin, Vranayova, Zelenakova and Abdel-Hamed (2021), they found that soils irrigated with wastewater contained elevated concentrations of heavy metals, particularly lead, and noted that prolonged wastewater application can alter soil properties. This may lead to soil pollution and degradation, reducing soil fertility and overall soil quality. Heavy metals and other organic pollutants may be absorbed by vegetation or migrate through the soil profile, impacting plant health.

Water scarcity in the natural environment induced by inefficient water management at wildlife lodges can further increase pressure around the limited water sources. In a study conducted by Cosgrove and Loucks (2015), they found that water shortages brought on by poor management frequently adversely affected the local flora and fauna by diminishing the quality of their habitat and limiting their access to drinking water. Animals may alter their movement patterns in search of water, creating hotspots of herbivore impact, resulting in localised overgrazing, soil compaction, vegetation loss, and increased erosion. As vegetation cover declines, invasive species often colonise the disturbed areas, outcompeting indigenous species and reducing biodiversity (Adla *et al*., 2022).

Drought-prone, semi-arid regions are particularly vulnerable to water scarcity because their rainfall is low and variable, groundwater sources are limited, and evapotranspiration rates are high. Ait Zamzami, Tahiri, Allali, Moudane, and Boudouch (2025) emphasise that in such environments, even small increases in water demand can place disproportionate pressure on water resources. Their study in the Western High Atlas demonstrates how climatic variability and rising temperatures further exacerbate water shortages, making semi-arid tourism regions highly sensitive to any additional abstraction. They further emphasise the relationship between growing human demand for water and threatening ecological stability (Ait Zamzami *et al*., 2025).

2.4.3 Economic

South Africa's economy depends heavily on tourism. According to the South African Tourism Yearbook (2015/16), before the COVID-19 pandemic, the travel and tourism industry contributed 6.4% of the country's gross domestic product. Recent estimates from the WTTC (2025) indicate that the sector's total contribution to South African gross domestic product is around 8.8 %. It supports economic growth by generating income from a variety of industries. Apart from its financial impact, tourism plays a role in employment, supporting approximately 1.68 million jobs in South Africa across a variety of sectors, including tour guides, hotel employees, craftsmen, and service providers (WTTC, 2025). Along with providing for livelihoods, this industry boosts local economies and promotes development and infrastructural upgrades, especially in rural areas.

Water is a key operational factor for tourism establishments, especially at wildlife lodges where guests experience, food services, housekeeping, landscaping and conservation efforts take place simultaneously. As a result, water management has direct and indirect economic implications.

High water consumption contributes to operational expenditure, especially at remote wildlife lodges that rely on borehole abstraction, which requires energy-intensive pumping, treatment, and storage. Gössling and Peeters (2015) emphasise that energy is generally a more expensive resource than water itself, highlighting the water–energy nexus, where increased water use directly increases electricity costs. This is relevant for facilities that heat large volumes of water for showers, kitchens, and laundry, or treat water through ultra-violet (UV), filtration, or chemical dosing systems.

Poorly controlled or inefficient water use further increases operational costs as research on hotel water management shows that leakages, outdated plumbing fixtures, unmetered consumption, and high-flow showers can lead to 10–20% additional water losses, resulting in unnecessary spending on pumping, energy, and treatment (Gössling *et al*., 2015). Water with high turbidity, salinity, hardness, or contamination may require more frequent filter replacement, intensive chemical treatment, or investments in advanced purification technologies such as reverse osmosis. Reduced water quality may damage equipment such as washing machines, boilers, pipes, and guest amenities, increasing replacement costs.

Gössling *et al*. (2015) stated that poor water quality in tourism areas contributes to ecological degradation, which can negatively affect visitor experiences and long-term destination competitiveness. The guest perceptions of water cleanliness and safety are strong determinants of satisfaction, willingness to return, and online ratings. Studies such as Tortella and Tirado (2011) show that guests respond negatively to constraints in water supply, visible water pollution, or infrastructural failures, resulting in reputational damage and reduced revenue potential. In luxury wildlife lodges where guests pay premium rates, any negative experience associated with water creates economic risks through loss of return visitors and reduced brand trust.

Despite the economic risks associated with water scarcity and quality problems, sustainable water management presents significant financial opportunities. According to Gössling *et al.* (2015), most tourism facilities can reduce their water use by 10–50% without compromising guest comfort. These savings arise from:

- installation of low-flow fixtures
- pressure regulation through variable speed drive (VSD) pumps
- rainwater harvesting and effluent water reuse
- leak detection and smart metering
- efficient laundry systems
- behavioural interventions among staff and guests

Cost–benefit analyses compiled by Gössling *et al.* (2015) show that many water-saving technologies have payback periods of less than three years, making them financially viable options for tourism establishments. In remote lodges, such as Ngala Safari Lodge and Ngala Tented Camp, the return on investment is even faster due to high energy costs associated with pumping and heating water.

2.5 Water Use in Wildlife Tourism

2.5.1 Direct Water Use

Direct water use in tourism establishments refers to the water used directly by tourists and related operations. Globally, this accounts for only about 19% of total tourism-related water use and primarily includes water used in accommodation facilities, like drinking, bathing, and toilet flushing, and for recreational activities like pools or spas (Tervoort & Langergraber, 2024). Direct water use includes components that are straightforward to measure as they are directly linked to tourism operations (Gössling *et al.*, 2012). Ait Zamzami *et al.* (2025) highlighted in their study that tourism establishments in Morocco, especially large resorts and villas, are extremely water-intensive and collectively consume over 83% of total tourism water use in the region.

For South African wildlife lodges where staff reside on the lodge's premises, direct water consumption is considered all water used for domestic purposes.

- Accommodation

This direct use of water mostly occurs within guest rooms, where tourists use water for bathing, showering, toilet flushing, handwashing, drinking, and other general daily use. Swimming pools are another contributor, which are common features at luxury tourism establishments. These facilities increase total water consumption because of the large volumes required for filling, ongoing losses from evaporation and leaks, and, in some cases, such as at Ngala Safari Lodge and Ngala Tented Camp, additional consumption by wildlife as seen in Figure 2.2. (Gössling *et al*., 2012). Different accommodation types have different levels of water use; for example, luxury hotels and resorts with extensive facilities, including various swimming pools, spas, indoor and outdoor showers and sports activities, will have a higher direct water usage compared to camping areas with minimal facilities (Charara, Cashman, Bonnell, & Gehr, 2011).

Figure 2.2 Elephants drinking swimming pool water at &Beyond Phinda Homestead (Image Source: &Beyond Website).

- Kitchen, Scullery and Laundry

Kitchen and scullery operations contribute to direct water use at wildlife lodges, as it is used for food preparation, cleaning dishes, and equipment. At some tourism establishments, it was found that combined kitchen and laundry activities can contribute to 30% of the total water use of the facility (Antakyali, Dinçer, & Donmez, 2008). Remote wildlife lodges such as Ngala Safari Lodge and Ngala Tented Camp, where high-end catering is an important aspect of the guest experience, kitchen and scullery operations face the challenge of providing luxury service standards while managing water use efficiently. Kitchens and sculleries often contribute to higher energy use because of the heating of equipment and water for cooking and cleaning, reinforcing the water–energy nexus (Becken & McLennan, 2017).

Laundry facilities are one of the largest direct water consumers. Studies have shown that laundry alone can account for 47% of total water use in hotels and lodges (Barberán, Torregrosa, & Rueda, 2013). This high proportion is largely attributed to the frequent washing of bed linen, towels, and staff uniforms, especially in luxury lodges where guests expect daily replacements. In remote wildlife lodges such as Ngala Safari Lodge and Ngala Tented Camp, laundry demand is further amplified by high guest turnover and strict hygiene requirements. Older or household-type washing machines are typically not designed for water efficiency, often resulting in excessive water consumption and waste, especially in facilities where laundry water is not recycled or reused.

The adoption of water-efficient washers, linen-reuse policies, and load-optimisation practices has been shown to reduce laundry water consumption by up to 30–40% (Bohdanowicz & Martinac, 2007). These measures not only conserve scarce resources but also align with the sustainability objectives of operations situated within protected and water-accentuate environments such as Limpopo Province, South Africa.

- Irrigation

Landscaping and irrigation also contribute to direct water consumption in wildlife lodges, especially in semi-arid regions. Gardens, lawns, and decorative vegetation are often irrigated daily to meet guest expectations of comfort and luxury, despite the ecological sensitivity of surrounding environments. Water used for irrigation may be drawn from the same boreholes supplying source water, intensifying resource competition between tourism operations, wildlife, and nearby communities.

2.5.2 Indirect Water Use

Indirect water use refers to the water required to support the services and operations of an establishment. This includes water consumed during the construction of facilities such as lodges, hotels, or resorts, as well as in the production of energy, fuel, food, and beverages that sustain daily operations (Gössling *et al*., 2012).

2.6 Benchmarking, Standards and Guidelines

2.6.1 Baseline Assessment

In wildlife tourism, a baseline assessment involves collecting and analysing data to establish initial measurements of various environmental and operational parameters, such as water usage and quality (Gössling *et al*., 2012). This initial set of data serves as a reference point against which future changes and improvements can be measured. It provides a foundational reference for benchmarking current practices against relevant standards and guidelines, allowing for the identification of areas needing improvement. Baseline assessments vary in format depending on the situation. An effective baseline for water consumption is to assess the amount of water used per guest per day or per room per day, also stated as litres used per bed-night (l/b/n) (Grobler, 2018). To establish a baseline assessment of water quality, several key parameters should be monitored over a defined timeframe to evaluate compliance and determine the frequency of non-compliance with relevant standards. This study aimed to do a baseline assessment to understand better the current water quality and quantity trends at Ngala Safari Lodge and Ngala Tented Camp.

2.6.2 Benchmarking

Benchmarking serves as a comparative management tool utilised globally, aiming for the continuous improvement and best practices within organisations (Saagi, Kroll, Flores-Alsina & Jeppson, 2017). This process involves measuring an organisation's performance against the best in its class or similar entities. The four primary types of benchmarking include (Córcoles, de Juan, Ortega, Tarjuelo & Moreno, 2010):

- Internal Benchmarking
- Competitive Benchmarking
- Functional Benchmarking
- Generic Benchmarking

For this study, an internal benchmarking design was used to compare water quality and quantity trends of Ngala Safari Lodge with Ngala Tented Camp over the same timeframe. This method helps identify areas where water consumption improves or declines, assess compliance with water quality standards, and determine the best-performing systems and management practices. Within the tourism and hospitality sector, benchmarking is widely applied to evaluate water-use efficiency and identify opportunities for resource conservation. Water consumption varies between accommodation establishments depending on factors such as occupancy levels, climate, service standards, facility type, landscaping requirements, laundry operations, and the presence of staff accommodation (Gössling *et al.*, 2012). Research indicates that water consumption in tourism accommodation facilities typically ranges between 300 and 850 litres per guest per day, with luxury establishments often recording higher consumption levels because of additional amenities and operational requirements (Charara *et al.*, 2011; Gössling *et al.*, 2012).

In South Africa, the Water Research Commission recommends a benchmark of approximately 128 litres per guest per night for water-efficient tourism accommodation, while domestic water consumption averages approximately 235 litres per person per day (Carelse, 2023). Wildlife tourism operations frequently exceed these values because water consumption includes not only guest use but also staff accommodation, laundry facilities, kitchens, workshops, wastewater treatment systems, irrigation requirements, and other operational activities. Consequently, benchmarking within wildlife tourism requires consideration of both industry benchmarks and site-specific operational targets.

2.6.3 Standards and Legislation

To guarantee that guests and staff of wildlife lodges have access to water of acceptable quality and quantity, regulations and standards are put in place. This section investigates the relevant regulation that both the Ngala lodges need to comply with.

2.6.3.1 The National Water Act and Water Services Act

The National Water Act (Act No. 36 of 1998) offers a framework for the sustainable protection, consumption, development, conservation, and management of water resources for South Africa's water resource management. The act requires a water use license for major water abstraction or modification of water bodies, making it applicable to remote wildlife lodges that rely on abstracting for their water resources. The legislation also requires the preservation of water ecosystems and the application of water conservation measures, both of which are critical for maintaining the natural environments that draw tourists to wildlife lodges.

Regarding this study, the National Water Act's (Act No. 36 of 1998): General limits for wastewater discharge into a water source are used to assess if Ngala Safari Lodge and Ngala Tented Camp's effluent water is of an acceptable quality not to cause harm to the environment.

2.6.3.2 DWAF Irrigation Water Quality Guidelines

The DWAF developed the South African Water Quality Guidelines to assess water quality for various uses, including irrigation. These guidelines ensure that treated wastewater intended for reuse is safe for irrigating crops, lawns, or gardens, and does not pose a risk to the environment. They outline acceptable limits for key physical, chemical, and biological parameters that may have a negative environmental impact. Specifically, the upper limit for Class 4 (Marginal) Irrigation water of the guidelines was used as a benchmark for this study.

2.6.3.3 SANS 241-1:2015 Edition 2

The South African National Standard (SANS) 241-1:2015, Edition 2 specifies the minimum requirements for the quality of drinking water that is intended for human consumption. It forms the official benchmark used by water service providers, laboratories, municipalities, and private entities, including wildlife ecotourism ventures, to ensure that water supplied for drinking and food preparation is of an acceptable standard.

The standard specifies the physical, chemical, and microbiological parameters that must be monitored and tested to ensure compliance with drinking water quality requirements. It also outlines the potential impacts of each parameter when concentrations or levels exceed the acceptable limits, classifying them as acute or chronic health risks, operational risks, or aesthetic risks.

2.6.3.4 SANS 1657:2007, Edition 2

The South African National Standard (SANS) 1657:2007, Edition 2, outlines the requirements for the production, treatment, packaging, and quality of bottled or packaged water intended for human consumption to ensure safety. It applies to all forms of bottled water and sets limits for microbiological, chemical, and physical parameters. The standard addresses acute and chronic health, operational and aesthetic risks. SANS 1657:2007, Edition 2 relates to SANS 241-1:2015, Edition 2, but generally has more flexible limits for the parameters, as bottled water is consumed less often than source water.

For this study, SANS 1657:2007 is relevant as Ngala Safari Lodge and Ngala Tented Camp aim to have zero plastic bottle waste and only provide guests with water from the lodge's own bottling plant using abstracted and treated water from Ngala Tented Camp.

2.7 Water Quality Management and Treatment Systems

Wildlife lodges operating in remote conservation areas depend on a variety of water sources for daily operations. The most common sources include boreholes, surface water, and, in some cases, treated municipal or packaged drinking water transported from external suppliers. At

Ngala Safari Lodge and Ngala Tented Camp, the primary supply originates from borehole abstraction. These dual systems require monitoring to ensure compliance with South African water quality standards discussed previously to safeguard both guest and staff health and the environment.

The assessment of water quality typically includes physical, chemical, and microbiological parameters that indicate if water is acceptable for human use. Key parameters relevant to tourism operations include pH, total dissolved solids, electrical conductivity, hardness, and turbidity, which affect aesthetic and operational performance (SANS 241-1:2015). Microbiological indicators such as *Escherichia coli* and total coliforms are critical for determining the presence of faecal contamination and potential health risks (DWAF, 1996; WHO, 2017). High levels of coliform bacteria are used as an indicator of the treatment process. Chemical indicators include testing for a range of metals such as nickel and iron, and semi-metals, which are elements with both metallic and non-metallic properties, such as boron and arsenic, to ensure water safety. Elevated concentrations of these substances can pose acute or chronic health risks, making regular monitoring essential for compliance with drinking water standards.

To ensure source water quality, various treatment technologies are used depending on source water characteristics. Common methods in lodge environments include ultraviolet disinfection, ozonation, activated-carbon filtration, microfiltration, and reverse osmosis, each targeting specific contaminants or aesthetic properties (UNEP, 2016). Borehole water is often subjected to pre-filtration to remove suspended solids, followed by UV or chlorination to inactivate pathogens. In contrast, reverse-osmosis systems are used to reduce salinity and total dissolved solids. Regular monitoring of these systems is vital, as inadequate maintenance or chemical dosing can compromise water safety and equipment performance.

South African regulatory frameworks provide clear quality benchmarks for compliance. SANS 241-1:2015 Edition 2 specifies the minimum requirements for overall drinking water, while SANS 1657:2007 Edition 2 sets standards for packaged and bottled water. These standards serve as the basis for monitoring, testing, and reporting water quality in tourism facilities.

Managing water quality at Ngala Safari Lodge and Ngala Tented Camp is key to ensuring both operational sustainability and the health and safety of guests. Borehole water abstraction requires regular testing to ensure compliance with SANS 241-1:2015, while the transported bottled water from Ngala Tented Camp must meet SANS 1657:2007 standards for packaged drinking water.

2.8 Wastewater Management

Effective waste and effluent water management is key for safeguarding the environment, especially when lodges are located within protected or critical biodiversity areas. Tourism facilities generate wastewater from multiple sources, including guest bathrooms, kitchens, laundries, and staff accommodation. If not properly treated, these effluents can introduce pathogens, nutrients, and chemical pollutants into surrounding soils and waterbodies, resulting in eutrophication, groundwater contamination, and health hazards for wildlife and humans (DWAF, 1996).

Wildlife lodges commonly rely on internal wastewater-treatment systems designed to function independently of municipal infrastructure. The most frequently used systems include septic tanks, aerobic treatment units, constructed wetlands or reed-bed systems, and bio-digesters. Septic tanks remain the simplest and most widespread option, though they require maintenance and regular desludging to prevent leachate infiltration into groundwater. Aerobic treatment systems, which use oxygen to accelerate biological degradation, achieve higher pathogen removal efficiencies and are increasingly favoured in wildlife lodges. Constructed wetlands (reed-beds), as used by Ngala Safari Lodge, simulate natural filtration processes, using vegetation and microbial activity to treat waste and effluent water.

Effluent water treatment and discharge are governed by the National Water Act (No. 36 of 1998), which requires that any activity involving the discharge of waste or water containing waste into a water resource must be authorised through a Water Use Licence. Facilities such as lodges are required to ensure that discharged effluent meets applicable standards before release or reuse. Monitoring parameters include chemical, physical and microbial (Department of Water and Sanitation (DWS), 2017).

High concentrations of total coliforms and *E. coli* in effluent or irrigation water indicate inadequate treatment and pose significant risks, as they are an indication of faecal contamination. When such effluent is used for landscape irrigation, pathogens can be transmitted to humans, animals, soil, and waterbodies. Excessive nutrient loads, especially nitrates and phosphates, can lead to algal blooms, oxygen depletion, and downstream eutrophication in water bodies (DWAF, 1996). In semi-arid ecosystems, repeated irrigation with high-salinity or high-nutrient wastewater can also cause soil salinisation and long-term degradation of vegetation health (UNEP, 2016). For lodges like Ngala, these risks highlight the need for frequent monitoring of treated effluent before its reuse or discharge into the environment.

Case studies from the southern African tourism sector illustrate both challenges and innovations in wastewater management. Grobler (2018) examined multiple wildlife lodges across South Africa, Namibia, and Botswana and found that 75% of South African wildlife lodges tested wastewater before discharge, while none of the lodges from Namibia or Botswana conducted wastewater testing before discharge. The Malelane Lodge Environmental Assessment Report (SANParks, 2021) documents the use of treated effluent for onsite irrigation, demonstrating the potential for water reuse to minimise freshwater demand. Ungureanu, Vlăduț and Voicu (2020) emphasised that reusing treated wastewater for purposes such as irrigation, landscaping, and dust control is an effective approach in arid and semi-arid environments, if it is accompanied by strict monitoring and compliance with water quality regulations. This approach could help Ngala Safari Lodge and Ngala Tented Camp reduce reliance on freshwater sources during dry periods.

Sustainable wastewater management is key to balancing tourism operations with conservation objectives at Ngala Safari Lodge and Ngala Tented Camp. Both lodges rely on internal treatment systems to manage wastewater and sewage; however, maintaining consistent monitoring of effluent quality is essential to ensure compliance with the National Water Act and DWAF (1996) discharge guidelines. Treated effluent may offer potential for reuse in garden irrigation, provided parameters such as *E. coli*, total coliforms, total dissolved solids, and salinity remain within acceptable thresholds. Implementing regular sampling, record keeping, and third-party laboratory analysis will strengthen environmental accountability and demonstrate commitment to sustainable water management practices aligned with SANParks concession requirements and SDG 6 targets.

2.9 Gap in Research

Research on water use in tourism has highlighted the sector’s dependence on freshwater resources and the challenges of operating in water-scarce environments. Studies by Gössling *et al*. (2012; 2015), Tortella and Tirado (2011), and, more recently, Ait Zamzami *et al*. (2025) demonstrate that tourism establishments, particularly luxury lodges and resorts, place intensive pressure on limited water resources, especially in semi-arid regions where climatic variability and recurring droughts threaten water security. These studies emphasise challenges related to high consumption, inadequate monitoring, weak governance, and the risks associated with unsustainable water management.

However, despite growing international interest in the sustainable use of water, research gaps remain. Much of the existing literature focuses on coastal hotels, urban tourism infrastructure, or national-level water-use modelling, with comparatively little empirical research examining wildlife lodges situated within protected areas, especially in Southern Africa. There is limited evidence on how water quality, water treatment systems, and compliance with relevant local, national and international standards influence sustainability in remote African lodges. The relationship between luxury tourism demands, ecological sensitivity, and water scarcity, therefore, remains underexplored.

This study addresses these gaps by providing a comprehensive case study of water quality, water consumption patterns, and water-management practices at Ngala Safari Lodge and Ngala Tented Camp. By integrating laboratory water-quality data, 28 months of consumption records, and insights from staff interviews, the study offers an understanding of water sustainability in a South African wildlife-tourism context. This contributes new empirical evidence to an under-researched area and supports the development of more sustainable water governance strategies for lodges operating within protected areas.

2.10 Chapter Conclusion

The literature confirms that effective water management in wildlife tourism operations is critical to achieving environmental, economic and social sustainability. Studies consistently highlight the need for integrated management processes that balance water use efficiency and quality compliance. Implementing systems such as greywater reuse, advanced filtration, and effluent recycling can significantly reduce freshwater abstraction while maintaining guest comfort and operational standards. For lodges like Ngala Safari Lodge and Ngala Tented Camp, aligning operational practices with these frameworks and Sustainable Development Goal 6 not only strengthens sustainability but also supports the long-term success of wildlife tourism within protected areas. Based on the literature reviewed in this chapter, Chapter 3 outlines the study area, research design and methodology used in this research. It describes the case study area and explains how data were collected and analysed to assess water management practices at Ngala Safari Lodge and Ngala Tented Camp.

3. Chapter 3 - Study Area, Research Design and Methodology

3.1 Introduction

This chapter outlines the research design and methodology used during this study. An overview of the case study areas, the organisation and selected lodges is provided. The chapter then details the research design, describing the rationale for the chosen approach.

The water quality analysis addresses the objective of assessing compliance with SANS 241:2015 and related standards. In contrast, the assessment of water use trends supports the objective of establishing water use baselines and evaluating efficiency. The qualitative interviews contribute to understanding staff perceptions, stewardship, and operational practices. These methods form an integrated mixed-method approach that identifies management gaps and informs best-practice recommendations, aligning with the study's overall aim and objectives.

3.2 Study area

3.2.1 Background

&Beyond Ngala Safari Lodge and Ngala Tented Camp are located in the 14700-hectare Ngala Private Game Reserve in the Timbavati region of the Limpopo Province, forming part of the Greater Kruger National Park. The reserve shares open boundaries with the Kruger National Park, allowing interchange of plant and animal species, resulting in a high biodiversity area.

&Beyond was founded in 1991, operating under the name Conservation Corporation Africa (CC Africa) and was one of the first South African ecotourism companies. It was guided under the model "Care of the land, care of the wildlife, care of the people". It aimed to link luxury tourism with conservation and community upliftment. In the 1990's, CC Africa expanded across southern Africa, developing lodges in South Africa, Botswana, Zimbabwe, and Namibia, while restoring degraded land and creating local employment, notably at Phinda Private Game Reserve, its flagship conservation tourism venture.

In 2008, the company rebranded as &Beyond to reflect its international growth into India and South America. &Beyond now operates over 29 lodges across Africa, Asia, and South America. It is regarded as an international leader in sustainable ecotourism, making it an ideal case study for this project.

Ngala Private Game Reserve was established in 1992 through a partnership between &Beyond, the World Wide Fund South Africa (WWF SA), and the SANParks Trust. The reserve's creation was made possible by the donation of land by Hans Hoheisen, who transferred ownership of his property to the WWF SA. At the same time, the responsibility for tourism operations was entrusted to &Beyond (&Beyond, 2018). This collaboration led to the establishment of Ngala Private Game Reserve as the first privately managed reserve incorporated into the Kruger National Park, with Ngala Safari Lodge marking the beginning of &Beyond's tourism operations in the area. This model paved the way for future private concessions within the park, demonstrating the potential of cooperative conservation between the private sector and national authorities (&Beyond, 2018).

Ngala Safari Lodge has been operating since 1992 and features 20 cottages, including three family cottages and a family suite, each offering private bathrooms, as well as indoor and outdoor showers. Ngala Safari Lodge offers experiences which include game drives and bush walks. The lodge also includes facilities such as a dining area, lounge, bar, spa, and pool, and can accommodate approximately 40 to 44 guests. To the west of the lodge lies the staff village, which accommodates an average of 86 permanent staff members. Employees typically reside on-site for six-week work cycles, after which they take approximately two weeks of leave to return to their homes off-site.

In 2000, Ngala Tented Camp was established on the Ngala Private Game Reserve, 15 km from Ngala Safari Lodge, featuring nine luxury tents that can accommodate 19 guests, each with its own private bathroom. The camp offers the same facilities, services, and experiences as Ngala Safari Lodge. The staff village is situated southeast of the lodge and houses approximately 35 permanent staff who reside on-site in six-week work cycles.

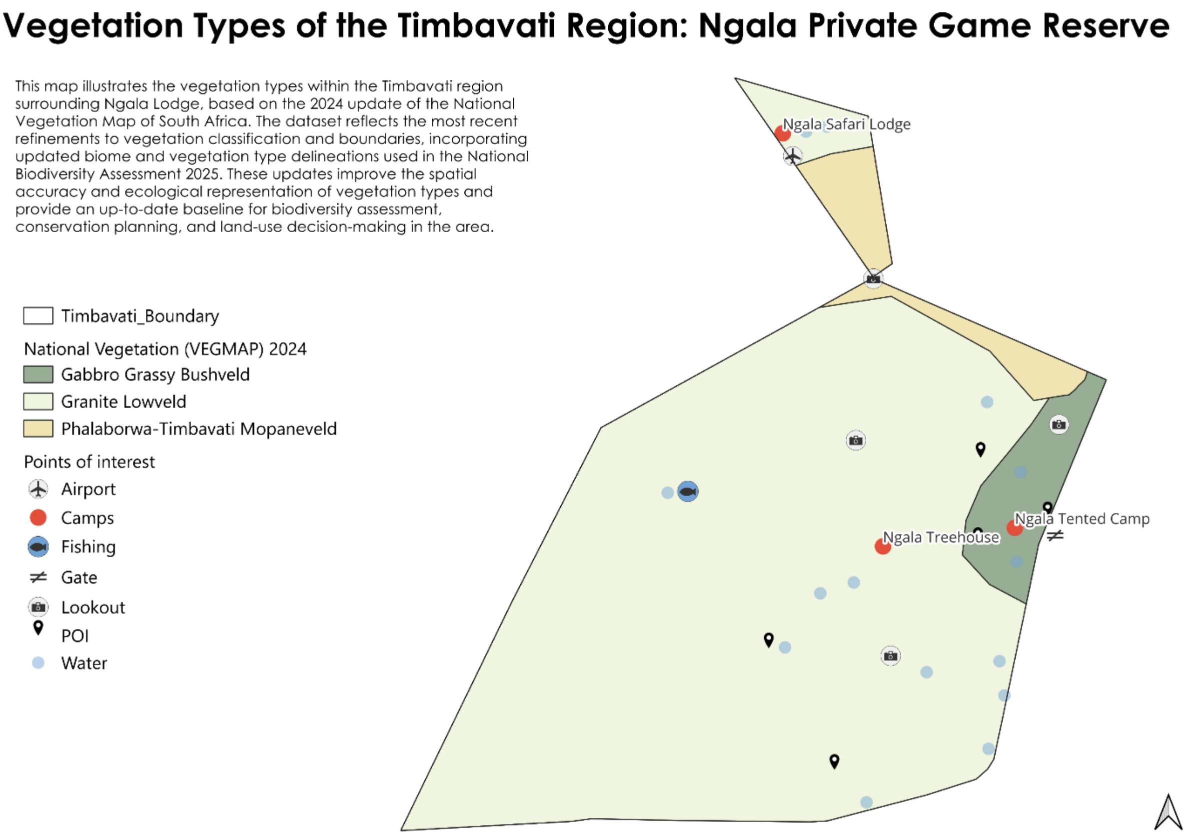

Figure 3.1 Map of Ngala Private Game Reserve (Map source: &Beyond, 2023)

3.2.2 Geography and Climate

Ngala Private Game Reserve lies at an altitude of 418 metres above sea level at coordinates 24°22.843′S; 31°19.328′ E and experiences a subtropical climate with distinct wet and dry seasons. Summers (November–March) are hot and humid, with temperatures ranging from 18 °C to 36 °C and frequent afternoon thundershowers. Winters (July–September) are dry, marked by warm days and cold nights. Rainfall typically begins in late October, peaks in mid-summer, and tapers off by April, with an annual average of 550–600 mm (Timbavati Private Nature Reserve, 2017).

This annual rainfall is low compared to the eastern and coastal regions of South Africa, such as KwaZulu-Natal and parts of the Eastern Cape, which a receive mean rainfall of more than 1000 mm annually, but higher than the arid western regions of the country, including the Northern Cape, where mean annual rainfall is below 200 mm (South African Weather Service, 2023). This highlights the semi-arid nature of the Limpopo region and emphasises the importance of sustainable water management within wildlife tourism operations that rely heavily on groundwater abstraction.

3.2.3 Vegetation

The SANBI Biodiversity GIS (BGIS) tool was used to identify the vegetation types occurring within the Ngala Private Game Reserve. The descriptions of these vegetation types were then derived from *The Vegetation of South Africa, Lesotho and Swaziland* by Mucina and Rutherford (2006), which provides the national standard classification and ecological characterisation of South Africa's vegetation.

3.2.3.1 Phalaborwa–Timbavati Mopaneveld

The Phalaborwa–Timbavati Mopaneveld is a semi-arid savanna vegetation type that occurs in the Limpopo and Mpumalanga provinces around Phalaborwa. It is characterised by open tree savanna on undulating plains, with sandy uplands dominated by *Colophospermum mopane* (mopane), *Combretum apiculatum* (red bushwillow), and *Terminalia sericea* (silver cluster-leaf). At the same time, clay-rich bottomlands support increased *Vachellia nigrescens* (knobthorn) and denser mopane stands. The geology consists mainly of Makhutswi Gneiss with granite intrusions. It is classified as Least Threatened, with about 38% conserved in the Kruger National Park and private reserves, including Ngala Private Reserve, and only 5% transformed (Mucina & Rutherford, 2006).

3.2.3.2 Gabbro Grassy Bushveld

The Gabbro Grassy Bushveld occurs in scattered patches across Limpopo and Mpumalanga Province, mainly within the Kruger National Park, at altitudes of 200–550 m. This vegetation type is characterised by open savanna with a dense grass layer dominated by species such as *Themeda triandra* (red grass). Its distribution closely aligns with the undulating intrusions of Timbavati gabbro, but also occurs on surrounding granites and gneiss, giving rise to dark vertic clay soils (20–50% clay), shallow lithosols, and mixed soil profiles where gabbro meets granite. Key species include tall trees such as *Vachellia nigrescens* (knobthorn) and *Sclerocarya birrea* (marula), as well as a variety of small trees, shrubs, and a diverse assemblage of grass species. This vegetation type is classified as Least Threatened, with 96% protected within the Kruger National Park and private reserves such as Ngala (Mucina & Rutherford, 2006).

3.2.3.3 Granite Lowveld

The Granite Lowveld vegetation type extends across the South African provinces of Limpopo, Mpumalanga, and KwaZulu-Natal, as well as Eswatini (Swaziland), occurring at elevations of 250–700 m. This vegetation type consists of tall shrubland to low woodland on deep sandy uplands dominated by *Terminalia sericea* (silver cluster-leaf), *Combretum zeyheri* (large-fruited bushwillow), and *Combretum apiculatum* (red bushwillow), with a grass layer characterised by species such as *Pogonarthria squarrosa* (herringbone grass) and *Eragrostis* *rigidior* (broom lovegrass). The underlying geology comprises Archaean granites and gneiss, including the Goudplaats and Makhutswi Gneiss and Nelspruit Suite, which weather into sandy upland soils and sodium-rich clayey lowland soils. This vegetation type is classified as Endangered, with only about 2% formally protected and a further 2% conserved in private reserves, while approximately 50% has been transformed by plantations, agriculture, and urban development. Alien invasive species such as *Lantana camara* (lantana) and *Psidium guajava* (guava) occur sporadically (Mucina & Rutherford, 2006).

3.3 Research Design and Methodology

3.3.1 Research Design

The multiple case study investigated water quality and water quantity use at Ngala Safari Lodge and Ngala Tented Camp. It employed an exploratory empirical design to gather and analyse data. A sequential mixed-method design was used, incorporating both quantitative and qualitative approaches (Creswell & Plano Clark, 2018). The quantitative component consisted of secondary data analysis, drawing on water quality laboratory reports and water consumption records provided by &Beyond, while the qualitative component involved semi-structured interviews with key informants such as lodge managers, maintenance workers and general staff. Interviews were conducted to complement the secondary data. Tables and graphs were used to present the data, depict trends and support interpretation.

Ethical clearance for the study was obtained from the University of South Africa (UNISA), and institutional permission to collect and publish the data was granted by &Beyond (Appendix B and Appendix C). Participation in interviews was voluntary, and informed consent was obtained from all participants prior to data collection. Participants were informed of the purpose of the study, confidentiality measures, and their right to withdraw at any stage without consequence. To maintain confidentiality and anonymity, no personal identifying information was disclosed in the dissertation.

The reliability and validity of the study were strengthened through the use of multiple data sources, including laboratory water-quality reports, operational water consumption records, and semi-structured interviews. Water quality analyses were conducted by accredited laboratories using standardised testing procedures, while qualitative findings were compared and cross-checked against quantitative results to improve credibility. This design was selected as it allowed for the systematic collection, measurement, and analysis of a large volume of pre-existing data and documentation within the defined time frame to meet the research objectives.

3.3.2 Methodology

The secondary data obtained from &Beyond covered 28 months between November 2022 and February 2025 and consisted of a water quality dataset and a water quantity dataset. The datasets were selected because they represented the complete set of water-related data made available by Ngala management at the time of the study. These records represented the most complete and up-to-date dataset available for both Ngala Safari Lodge and Ngala Tented Camp.

Water quality data included monthly laboratory analysis reports for both Ngala Safari Lodge and Ngala Tented Camp. These reports provided measurements of physical, chemical, and microbiological parameters such as pH, electrical conductivity, total dissolved solids, hardness, selected metals and semi-metals, and microbiological indicators. Laboratory analyses were conducted by an external accredited laboratory in Mbombela, Mpumalanga as part of the lodges' routine environmental monitoring programme to ensure compliance with relevant South African standards and legislation. Standardised laboratory procedures and calibrated analytical equipment were used by the laboratories to ensure consistency and accuracy of results. Additional internal water quality verification was conducted on-site using an iLab portable testing kit to support routine operational monitoring. All reports were clearly labelled and organised by lodge and month to ensure accurate comparison.

Water quantity data comprised monthly Environmental Compliance Officer (ECO) reports and internal monitoring records capturing total daily water abstraction and usage at each lodge. These records included meter readings as well as staff and guest occupancy rates, which allowed for the calculation of per-bed-night water use.

Key participant interviews were conducted using a semi-structured format. Interviews were held on-site at Ngala Safari Lodge and Ngala Tented Camp with staff members directly involved in water use and management, including general and maintenance staff as well as lodge management.

3.3.2.1 Water Quantity

Secondary data was obtained from &Beyond for the 28-month timeframe of the project, and the Ngala Environmental Operations Manual, previously referred to, was used as the benchmark for evaluating water consumption. Both Ngala Safari Lodge and Ngala Tented Camp have a daily usage target of 350 litres per person per day, including guests and staff. This benchmark is higher than the average domestic household water consumption in South Africa, estimated at approximately 235 litres per person per day (Carelse, 2023), as well as the global average domestic consumption of approximately 173 litres per person per day (Gleick, 2018). The higher benchmark reflects the additional operational requirements associated with luxury wildlife tourism establishments, including on-site laundry facilities, kitchens and sculleries, staff accommodation, maintenance workshops, landscaped gardens, and swimming pools.

Previous studies have reported that water consumption within the tourism and hospitality sector can range between 300 and 850 litres per guest per day, depending on the type of establishment and level of luxury provided (Gössling *et al*., 2012; Bohdanowicz & Martinac, 2007). The Ngala benchmark of 350 litres per person per day therefore falls within the lower end of the range typically associated with luxury tourism operations. Comparing water consumption at Ngala against domestic, national and tourism-sector benchmarks provides a broader context for assessing the sustainability of water use practices and the efficiency of water management systems at the two lodges.

Data was graphically presented to assess whether this target was being met and to identify consumption trends over the 28 months, contributing to the research objective of analysing water usage patterns, establishing a baseline, and determining compliance with relevant sustainability benchmarks.

An interview was conducted with the maintenance manager during a site visit to examine the complete water flow process from abstraction to discharge, to investigate the placement and accuracy of water meters, and to identify areas where water-saving measures are currently being implemented. The differences in the water system processes at Ngala Safari Lodge and Ngala Tented Camp made it possible to compare how each system supports efficient and sustainable water management. This aligns with the objectives of examining current water management systems, exploring staff knowledge and operational experiences, and assessing how these practices contribute to sustainable water use within a wildlife tourism context.

Table 3.1 Water Quality Categories and Parameters.

Category	**Parameter**
Physical	pH Total Hardness Conductivity Total Dissolved Solids
Chemical	Free Chlorine Arsenic Boron Nickel Fluoride Selenium
Microbial	*E. coli* Total Coliforms

3.3.2.2 Water Quality

Water quality data were obtained in the form of monthly laboratory reports conducted by Ngala Safari Lodge and Ngala Tented Camp as part of the requirements of the Ngala Environmental Operations Manual, which is based on the Kruger National Park's Concession Operations Manual. The manual acts as a framework outlining the environmental management requirements and operational procedures that concession holders and tourism operators must follow when conducting activities within SANParks. The water quality testing programme was not initiated specifically for this research project but formed part of the lodges' existing environmental compliance and monitoring obligations as prescribed by the Ngala Environmental Operations Manual and concession requirements. The laboratory analyses were conducted by independent SANAS-accredited external laboratories as part of routine operational monitoring undertaken by the lodges. The use of independently generated data ensured that the results were not influenced by the researcher and reduced the potential for researcher bias in the collection and analysis of water quality data.

The data were organised into two categories: effluent water and drinking water. The laboratory reports tested 32 parameters for effluent and drinking water. The laboratory results were then tabulated along with their respective measurement units. The results from the evaluation were then evaluated against applicable standards and legislation, namely SANS 241-1:2015 (Edition

2), SANS 1657:2007 (Edition 2), the National Water Act (Act No. 36 of 1998), and the DWAF Irrigation Water Quality Guidelines, as stated in Table 3.1. The analysis aimed to determine how consistently the water quality complied with these standards for both drinking and effluent water. To assess compliance, the data were graphed and compared to the specified limits outlined. These regulations were selected because they establish clear, sustainable, and environmentally compliant thresholds for water quality, specifying that when parameter limits are exceeded, it may result in acute or chronic health risks to humans, as well as operational and aesthetic impacts. The SANS 241-1:2015 (Edition 2) standard aligns with the WHO guidelines while incorporating South African-specific criteria to ensure that water remains safe for both human consumption and environmental protection.

Table 3.2 Water Standards and Their Applications.

Water Type	**Applicable Standard / Regulation**	**Description and Application**
Drinking Water	SANS 241-1:2015 (Edition 2)	Applies to treated drinking water supplied through taps for drinking, food preparation, and personal use (e.g., bathrooms and kitchens). Specifies microbiological, physical, and chemical quality to ensure water is safe for human consumption (South African Bureau of Standards (SABS), 2015).
Bottled Water	SANS 1657:2007 (Edition 2)	Regulates the quality and safety of bottled water for guests and staff, defining acceptable chemical, physical, and microbiological limits for bottled water (SABS, 2007).
Wastewater	National Water Act (Act No. 36 of 1998): General Limits for Wastewater Discharge	Applies to used or contaminated water from domestic sources such as kitchens, laundries, bathrooms, and sculleries. Establishes effluent quality limits before environmental discharge to protect water resources (National Water Act, Act No. 36 of 1998).
Irrigation Water	DWAF Irrigation Water Quality Guidelines	Applies to reused or treated water for landscape or lawn irrigation, ensuring water quality does not harm the environment (DWAF, 1996)

In addition, water samples from both Ngala Safari Lodge and Ngala Tented Camp's drinking water and effluent water were collected during the site visit on the 4th of October 2025 and subjected to chemical and microbiological testing. The iLab portable water testing kit was used to measure parameters including pH, total hardness, total chlorine, free chlorine, bromine, total alkalinity, nitrate, phosphate, and metal concentrations, as well as *E. coli* and total coliforms. The tests were performed on the 5th of October 2025. The water tests were performed in parallel with laboratory analyses to verify the accuracy of results and to determine whether field measurements reflected similar water quality trends.

3.3.2.3 Key participant interviews

Semi-structured interviews were conducted to determine the level of awareness of staff members, including management and general staff, regarding issues of sustainable water management at the lodges. These interviews provided an insight into the overall staff awareness and commitment towards water management. A snowball sampling method was conducted until the saturation point. The interview schedule was not formally piloted but was developed from the literature and aligned with the study objectives. Minor wording adjustments were made during early interviews to improve clarity without altering the intent of the questions. The interview questions are attached at the end of the document (see Appendix A)

The interview questions were designed to explore what sustainable water management practices are currently being implemented at the Ngala Private Game Reserve lodges. This highlighted their alignment with relevant environmental standards and regulations, as well as the additional measures implemented to uphold &Beyond's philosophy of "Care of the Land, Care of the Wildlife, Care of the People". The interviews explored whether staff perceived the lodges to be on par with other &Beyond operations in terms of environmental practices, or whether they believed there was potential to demonstrate an even greater commitment to sustainability.

The interview data were qualitative in nature and were analysed using thematic analysis. This involved transcribing the interviews, sorting responses, and grouping findings into key themes related to staff awareness, attitudes, and behaviours concerning water use and sustainability. The analysis explored staff understanding of water scarcity, their perceived responsibility towards water conservation, and the extent to which sustainable practices were implemented in daily operations and personal water use within staff quarters. This approach provided insight into the effectiveness of existing awareness and educational efforts. It complemented the quantitative water-use data by offering a deeper understanding of the social and behavioural aspects of water management at the lodges.

3.4 Ethics

The research was carried out in accordance with the ethical standards and procedures set by the University of South Africa (UNISA). An application for ethical clearance was submitted to UNISA. Approval was granted on 29 January 2025 with reference number 2024/CAES_HREC/5787 (see Appendix B) In line with the ethical requirements of the study, formal permission and consent were obtained from the research partner, &Beyond, to conduct the research at Ngala Safari Lodge and Ngala Tented Camp and to access relevant operational and water management data (see Appendix C). All conditions set by both institutions were observed and followed throughout the study. Prior to participation, each interviewee signed a consent form outlining the purpose of the interview and key details related to the research (see Appendix D). Information gathered from management and staff during the key participant interviews will remain confidential and anonymous and will not be directly referenced. No names will be disclosed, and any statements will be attributed to "a staff member." This approach is intended to safeguard the identities of the individuals involved.

3.5 Chapter Conclusion

This chapter presented the study area, research design, and methodologies used to investigate water quality and quantity, and sustainable water management practices at Ngala Safari Lodge and Ngala Tented Camp. A sequential mixed-method research design was described, combining quantitative analysis of secondary water quality and quantity data with qualitative insights gathered through key participant interviews. The water quality methodology outlined how laboratory and field measurements were evaluated against recognised national standards and regulatory thresholds to determine levels of compliance, responding directly to the objective of assessing physical, chemical, and microbiological water quality. The water quantity component detailed how consumption data were benchmarked against the SANParks usage target to establish trends, baselines, and levels of efficiency in alignment with the objective of analysing water use patterns. The interview process provided insight into staff perceptions, knowledge, and stewardship attitudes, supporting the objectives related to operational practices and sustainable management. Ethical procedures, permissions, and confidentiality measures were also detailed to ensure compliance with UNISA requirements. Together, these integrated methods provided a comprehensive foundation for identifying management gaps and evaluating the lodges' alignment with principles of environmental stewardship and sustainable tourism, thereby enabling the subsequent presentation and interpretation of findings in the following chapter.

4. Chapter 4 - Results, Discussion and Analysis

4.1 Introduction

This chapter presents, analyses, and discusses the results of the study in relation to the research objectives. It integrates quantitative water quality and water quantity findings with statistical analyses and interpretation to evaluate the sustainability of water management practices at Ngala Safari Lodge and Ngala Tented Camp. Graphs, tables, and trend analyses are used to illustrate trends and patterns. At the same time, statistical tools, including Pearson correlation coefficients and one-way ANOVA tests, are applied to explore relationships between water use, occupancy, and seasonal variation. The discussion compares the results with relevant standards, benchmarks, and published research. This helps to assess whether the lodges comply with requirements, how efficiently water is being managed, and where improvements are needed. Together, these analyses provide an understanding of how water is sourced, treated, used, and managed at both lodges.

4.2 Water Quantity

This section presents an analysis of water use and management at Ngala Safari Lodge and Ngala Tented Camp, focusing on system flow, consumption trends, and influencing factors. It begins by describing the physical water flow processes, including abstraction, treatment, storage, distribution, usage points, and wastewater treatment, to provide a clear understanding of how water moves through each lodge's operational system.

The section then examines water quantity trends over the 28-month study period using descriptive statistics and time-series visualisations to show variations in total daily water use, occupancy levels, and water use per bed-night. This quantitative overview establishes baseline consumption patterns and highlights periods of fluctuation.

Finally, the section investigates the primary factors influencing water consumption, particularly occupancy levels and seasonal variation, using correlation analyses and one-way ANOVA tests. These statistical approaches enable the identification of relationships between water use and operational drivers, distinguishing between variable, occupancy-related demand and fixed, baseline water requirements.

4.2.1 Flow of Water

Ngala Safari Lodge

- Abstraction

Water at Ngala Safari Lodge is abstracted from a borehole system that connects to a storage tank before being supplied to the treatment facility. Two borehole systems alternate weekly to prevent overuse and infrastructure damage. A water meter is installed at the abstraction point to measure the total volume of water entering the system. The boreholes are covered with a loose rock layer to prevent animals, such as elephants, from accessing the water or damaging the infrastructure, especially during the dry season. Water abstraction is managed through variable speed drive (VSD) pumps, which regulate pressure and flow to optimise efficiency and minimise waste.

Figure 4.1 Borehole 1 abstraction point at Ngala Safari Lodge

Figure 4.2 Borehole 2 abstraction point at Ngala Safari Lodge

- Treatment

After abstraction, water is stored in a tank before treatment, where the incoming water volume is measured. It then undergoes multi-stage purification to ensure that it meets potable standards for both guests and staff. The treatment process includes ultraviolet (UV) disinfection to remove microbial contaminants, carbon adsorption using granulated activated charcoal (GAC) to eliminate organic compounds and improve taste and odour, ozone treatment for enhanced oxidation and disinfection, and micro-filtration to remove fine particulates. This multi-barrier system ensures water quality that complies with the SANS 241:2015 standards for drinking water.

Figure 4.4 Water abstraction and pump system at Ngala Safari Lodge

Figure 4.3 Water filtration and pressure system used for lodge water supply Ngala Safari Lodge

- Storage and distribution

Once treated, the water is distributed through a pressure-controlled network that supplies both guest and staff areas. The system is divided into separate zones to ensure efficient distribution and pressure management. Usage monitoring is currently automated through LoRa (long-range) meters, which record water consumption at various points within the lodge. During the timeframe of this project, water consumption was monitored and recorded by manually taking readings from strategically placed water meters.

Due to the high lime content of the water, fittings such as push taps and water-saving showerheads are not used, as they tend to clog easily. Pressure and flow regulation, therefore, act as the main water-saving mechanisms between abstraction and end use.

Figure 4.5 On-site water storage tanks used for lodge water supply

- Usage points

Water meters are installed at key usage points across the lodge to monitor and manage consumption accurately. The primary metered usage points include the staff village, staff ablution blocks, kitchen, laundry, main treatment plant, nursery, scullery, lodge pool, guest rooms and workshop. These points represent the main areas of daily water use, covering both operational and accommodation functions. All water meters referred to in this study formed part of the existing water monitoring infrastructure at Ngala Safari Lodge and Ngala Tented Camp and were not installed specifically for this research. The meters are utilised by lodge management as part of routine operational monitoring and environmental reporting requirements. Not all individual water-use points within the lodges are separately metered; however, the primary abstraction, storage, and consumption points used for operational water management are monitored through the existing metering network.

A critical aspect of this study is that drinking water is transported daily from Ngala Tented Camp to Ngala Safari Lodge. A tractor with a mounted water tank travels the 15 km gravel road several times per day to supply potable water to the lodge. At Ngala Safari Lodge, this water is further treated through a point-of-use purification system located in the kitchen, where it is used for bottling drinking water for guests and for hot beverage preparation in kettles. Single-use plastic water bottles are not used at either of the lodges.

Figure 4.6 An on-site water meter is used to monitor lodge water consumption

- Wastewater treatment

All guest and staff units are connected to the wastewater system. Individual septic tanks collect solids, and wastewater flows to a central septic tank located away from the guest rooms. From there, it is automatically pumped to the enclosed wastewater treatment plant adjacent to the camp. The existing system is a traditional open-pond design that is currently not functioning efficiently enough to allow for effluent reuse on the lodge's front lawn. However, a new wastewater treatment plant is planned to replace the current one. Once operational, it is expected to save approximately 8 000 litres of water per day by enabling treated greywater to be reused.

Figure 4.7 Ngala Safari Lodge wastewater treatment plant

Figure 4.8 Open pond wastewater treatment using reedbeds

Ngala Tented Camp

- Abstraction

Water at Ngala Tented Camp is abstracted from a borehole system that supplies water to the camp. Although two borehole systems are available, only one is currently being used as it has superior water quality and with less staff and guests present at Tented Camp, one borehole is sufficient to provide water without damaging the equipment or risking the borehole running dry. The borehole is protected by a brick and cement structure to prevent animal interference, such as with the boreholes at Ngala Safari Lodge. A water meter is inserted to measure the amount of water being abstracted. Abstraction is controlled through variable speed drive (VSD) pumps, which help regulate pressure and flow across the camp's smaller-scale water supply network. This allows for more efficient water use and helps prevent unnecessary strain on the borehole system.

Figure 4.9 Enclosed borehole abstraction point at Ngala Tented Camp

- Treatment

After abstraction, the water is treated using a fully contained treatment system known as the Puricare system, which handles both drinking and effluent water. The treatment process ensures that water meets quality and safety standards in line with SANS 241:2015 requirements. The system includes multiple purification stages, such as carbon filtration, ultraviolet (UV) disinfection, and ozone treatment, designed to remove impurities and improve overall water quality for both staff and guests. The enclosed nature of the Puricare system helps maintain consistency in treatment efficiency and reduces the potential for contamination from external sources.

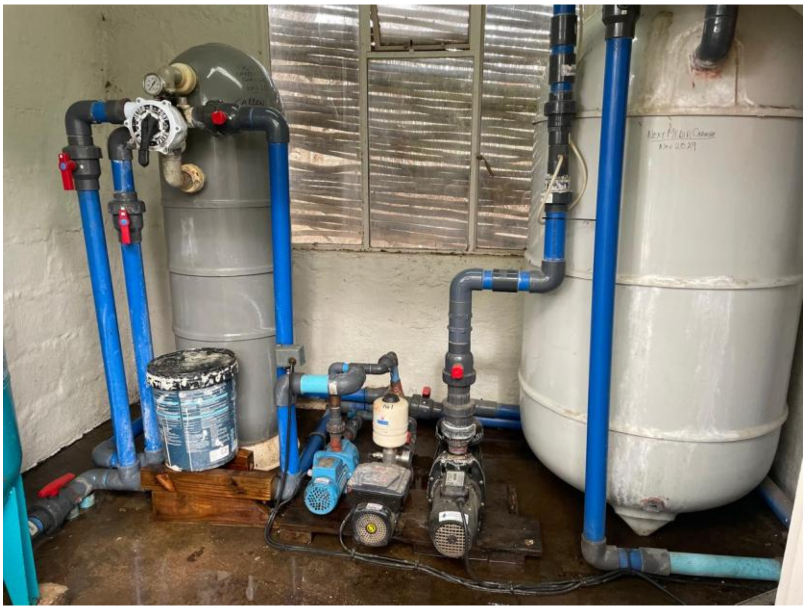

Figure 4.10 Puricare treatment facility at Ngala Tented Camp

- Storage and distribution

Once treated, the water is stored in tanks and distributed through a pressure-controlled network supplying different operational and accommodation areas within the camp. The network is divided into separate zones to ensure efficient delivery and pressure stability between guest and staff areas. Consumption is currently being monitored through an automated system, with LoRa meters recording water use at key points. For the timeframe of this study, water use was monitored by taking manual water meter readings.

Figure 4.11 Ngala Tented Camp water storage facility

- Usage points

Water use is measured at several main usage points throughout the camp, including the kitchen and scullery, laundry, swimming pool, main incoming line, staff village, guest tents one to six, and guest tents seven to nine. These points represent the primary operational and residential water users. The installation of water meters at each location allows the camp management to identify variations in consumption patterns and address inefficiencies such as leakages.

Figure 4.12 On-site Ngala Tented Camp water meter example 1

Figure 4.13 On-site Ngala Tented Camp water meter example 2

- Waste water treatment.

All guest tents and staff units are connected to the wastewater treatment system. Individual septic tanks collect solids, and wastewater is channelled to a central tank from where it is automatically pumped to the enclosed wastewater treatment plant located west of the lodge. The system has been operating successfully for over four years and ensures that treated effluent water is reused effectively for irrigation. Backwash water from the treatment plant is also collected and repurposed for staff showers.

Figure 4.14 Enclosed wastewater treatment plant

4.2.2 Water Quantity Overview

The statistics summaries presented in Table 4.1 and Table 4.2 provide an overview of the daily water use at Ngala Safari Lodge and Ngala Tented Camp across the 28-month period of the study. The data were analysed using three primary indicators: total water use per day (l/day), the total number of bed-nights (b/n) including staff and guests, and the litres per bed-night (l/b/n).

The average overall daily water use at NSL was 42 060 l, the median 43 620 l and the standard deviation 8468 l. The minimum was 31000 l, and the maximum was 72677 l. Water that was measured included the kitchen, scullery, laundry, maintenance workshops and guest and staff use points.

The average nightly occupancy was 135 bed-nights with a median of 139 b/n and a standard deviation of 29 b/n. This included regular staff, temporary construction staff, staff visitors, paying guests, complimentary guests, children, and other. The minimum was 72 b/n, and the maximum was 204 b/n.

The average daily water use per bed-*night* was calculated at 35 1/b/n, the median 325 l/b/n and standard deviation 104 l/b/n. The minimum was 221 l/b/n, and the maximum was 635 l/b/n.

Table 4.1 Ngala Safari Lodge Water Use Summary Statistics

	Water Use per Day (l/n)	Bed-nights (b/n)	Litres per bed-night (l/b/n)
Mean	42 060,64	134.94	351.36
Median	43 620.43	139.13	325.05
Standard deviation	8 467.72	29.31	103.59
Minimum	31 000.00	71.96	221.12
Maximum	72 677.42	204.25	634.74

The average daily water use at Ngala Tented Camp was 13 325 l, with a median of 13 952 l and a standard deviation of 8 835 l. A minimum of 1 065 l to a maximum of 27 968 l. The same measuring point as NSL was used; however, a single central workshop served as the measuring location.

The average nightly occupancy was 50 bed-nights with a median of 51 b/n and a standard deviation of 19 b/n. The same night-by-night breakdown was used as NSL. The minimum was 10 b/n, and the maximum was 84 b/n.

The average daily water use per bed-night was calculated at 333 l/b/n, the median 307 l/b/n and a standard deviation of 274 l/b/n. The minimum was 14 l/b/n, and the maximum was 1060 l/b/n.

The data variation can be attributed to the six-month refurbishment period during which there were no guests on-site, only temporary construction staff, and water use was primarily for construction activities. Consequently, this period does not represent normal operational conditions.

Table 4.2 Ngala Tented Camp Water Use Summary Statistics

	Water Use per Day (l)	Bed-nights (b/n)	Litres per bed-night (l/b/n)
Mean	13 324.79	50.34	332.85
Median	13 951.61	51.14	306.90
Standard deviation	8 834.62	18.96	274.52
Minimum	1 064.52	10.13	14.46
Maximum	27 967.74	84.03	1 060.68

4.2.3 Water Use Timelines

The three indicators, water use per day, bed-nights and water use per bed-night, were plotted to illustrate their trends over the study period. Graphing these parameters provides a visual representation of how values fluctuated over time, identifying periods of change or possible outliers in the data. This analysis helps to identify operational problems, inconsistencies in the data or other factors related to water use at Ngala Safari Lodge and Ngala Tented Camp.

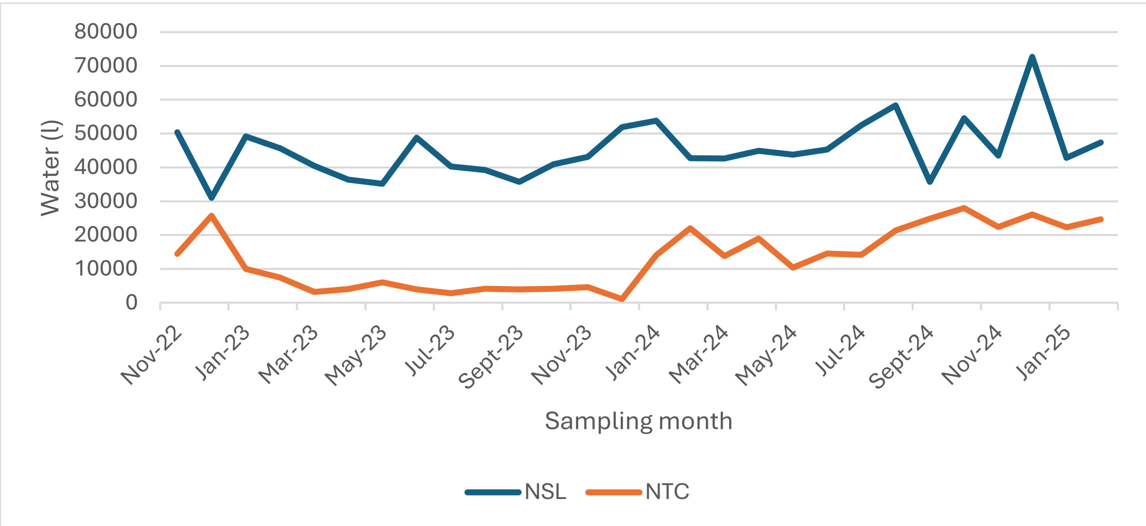

Figure 4.15 Average daily water use per month at Ngala Safari Lodge and Ngala Tented Camp

Figure 4.15 shows the average daily water use per month over the study period to illustrate the overall trend. Ngala Safari Lodge recorded a higher average daily water use than Ngala Tented Camp throughout the entire period due to its larger guest and staff capacity. At the beginning of the study period, from November 2022 to June 2023, the average fluctuated, but from July 2023 to March 2024, it became more stable, ranging between 45 000 l and 55 000 l per day. From April 2024 to February 2025, the average fluctuated but showed a steady increase, with a spike in December 2024 exceeding 70 000 l per day. This may be attributed to high guest occupancy during the festive season or increased water use due to hot summer conditions. These factors are examined in the following sections.

Although Ngala Tented Camp's average daily water use was lower than Ngala Safari Lodge's, a gradual upward trend is seen over time. From January 2023 to December 2023, the average daily water use dropped below 10 000 l per day, after which it began to rise steadily again from January 2024. This is a very low reading, which needs further investigation, as it may indicate faulty readings over this period.

NTC underwent a refurbishment between April and October 2024, during which no guests were accommodated, and only minimal staff were present. Water use during this period was primarily by temporary construction staff or for building activities. Once the lodge reopened and was fully operational again, the average daily water use showed a steady increase again, with averages between 20 000 l and 30 000 l per day. This trend is further investigated in the following sections.

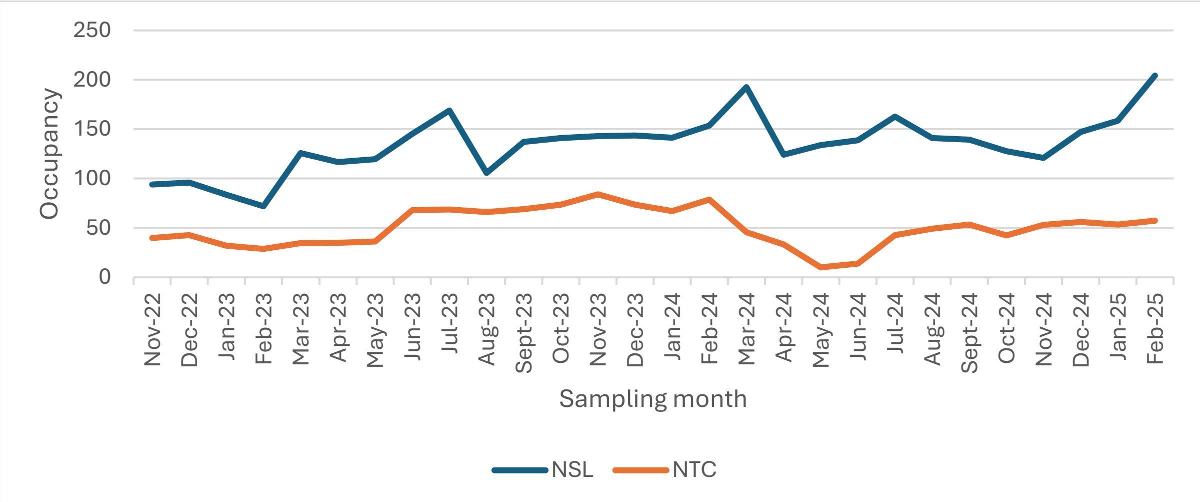

Figure 4.16 Average nightly occupancy (number of beds) per month at Ngala Safari Lodge and Ngala Tented Camp

Figure 4.16 shows the average nightly occupancy, also stated as the number of beds, including guests and staff, over the study period. Ngala Safari Lodge had a higher occupancy each month as it has more guest suites and more residing staff. From November 2022 to March 2023, occupancy fluctuated between 80 and 120 bed-nights. Between April 2023 and April 2024, occupancy levels increased, ranging between 120 and 160 bed-nights, with March 2024 reaching a peak of almost 190 people. From May 2024 to November 2024, occupancy declined slightly and rose again until February 2025, with an occupancy of more than 200 bed-nights.

From November 2022 to December 2023, occupancy at Ngala Tented Camp remained stable, showing only slight fluctuations between months. A decline is observed during the refurbishment period from April to October 2024 due to the temporary closure with no guest accommodation. After reopening Ngala Tented Camp in October 2024, occupancy rose to the same level as before the refurbishment.

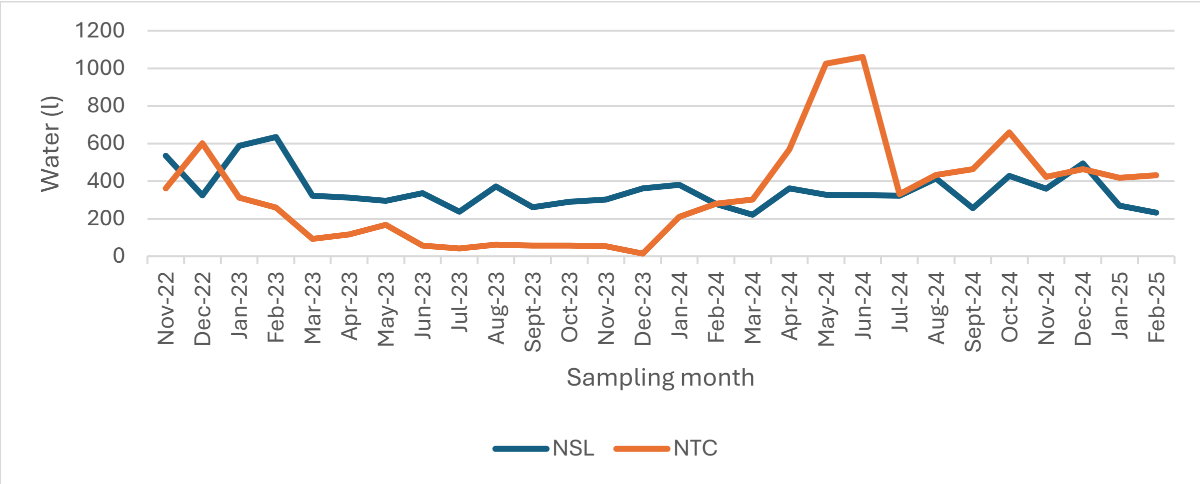

Figure 4.17 Average water use per bed-night per month at Ngala Safari Lodge and Ngala Tented Camp

Water use per bed-night at Ngala Safari Lodge remained relatively stable throughout the study period. In January and February 2023, the data showed a peak at around 600 l/b/n, after which it stabilised at around 350 to 450 l/b/n for the remainder of the period. This suggests that the lodge achieved efficient water management practices over the study period. Minor increases in late 2024 correspond with higher occupancy levels during the festive season.

Ngala Tented Camp shows greater variability and more fluctuations in water use per bed-night during the study period. Between November 2022 and March 2023, water use ranged between 300 l/b/n and 600 l/b/n, then dropped to below 300 l/b/n for much of 2023. The trend aligns with the observation in Figure 4.13, where daily water use was low. Figure 4.13 states that the average occupancy during that timeframe was on par with the rest of the study period. This observation will be discussed in the following section.

An increase occurred between April and June 2024, where the data showed values exceeding 1 000 l/b/n. This increase relates to the refurbishment period, when occupancy was low, but construction and maintenance activities continued, causing high water use relative to the number of occupied bed-nights. After reopening in October 2024, l/b/n values decreased and stabilised between 300 and 400 l/b/n.

4.2.4 Water Consumption Influencing Factors

4.2.4.1 Water use and occupancy

To better understand the relationship between water consumption and occupancy, this section uses a Pearson correlation analysis. The Pearson Correlation Coefficient (r) is a statistical measure used to determine the strength and direction of a linear relationship between two continuous variables (Field, 2013). In this study, it is used to assess how closely water use (daily water use and l/b/n) is related to occupancy levels at Ngala Safari Lodge and Ngala Tented Camp.

The coefficient values express either a strong positive or negative correlation or no correlation between variables. By analysing these relationships, this section aims to identify whether changes in occupancy significantly influence total daily water use and water use per person per bed-night, and to what extent operational factors, such as fixed water demands, contribute to overall consumption patterns.

A limitation of the occupancy analysis is that the available data recorded occupancy in terms of occupied beds rather than room occupancy or the distinction between single and double occupancy. Water consumption may vary between rooms occupied by one guest and those occupied by two guests, particularly for activities such as showering, toilet flushing, and laundry requirements.

Ngala Safari Lodge

- Occupancy and water use per bed-night

Figure 4.18 shows the relationship between average nightly occupancy and water use per bed-night (l/b/n) at Ngala Safari Lodge. The trendline equation is y = -2.5367x + 693.67, with an R^2 value of 0.515, indicating a moderate negative correlation between the two variables.

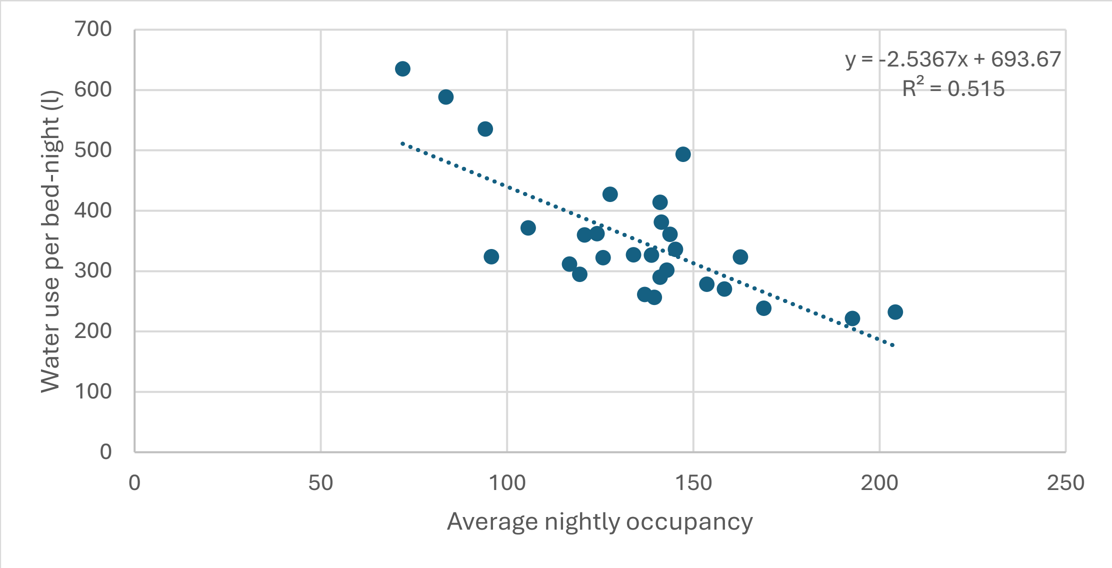

Figure 4.18 Relationship between occupancy (number of beds) and water use per bed-night at Ngala Safari Lodge

The negative slope shows that as occupancy increases, the average water use per bed-night decreases. This indicates that water use becomes more efficient as occupancy increases, because the overall water consumption is distributed among a larger number of guests and staff, thereby lowering the average water use per bed-night.

At lower occupancy levels, l/b/n values are higher. This can occur because baseline water use, such as laundry, cleaning, maintenance, and irrigation, remains relatively constant, even when fewer people are on-site. These fixed operational water usage increases the per-bed-night average during low-occupancy periods.

The R^2 value of 0,515 indicates that approximately 51,5% of the variation in water use per bed-night can be explained by changes in occupancy. This indicates a significant but not exclusive relationship, as water consumption is also affected by factors such as seasonal fluctuations, maintenance and meter reading accuracy.

- Occupancy and total daily water use

Figure 4.19 shows the relationship between average nightly occupancy and total daily water use at Ngala Safari Lodge. The trendline equation, y = 43.218x + 39 480, has an R^2 value of

0.0224, indicating a very weak positive correlation between occupancy and daily water consumption.

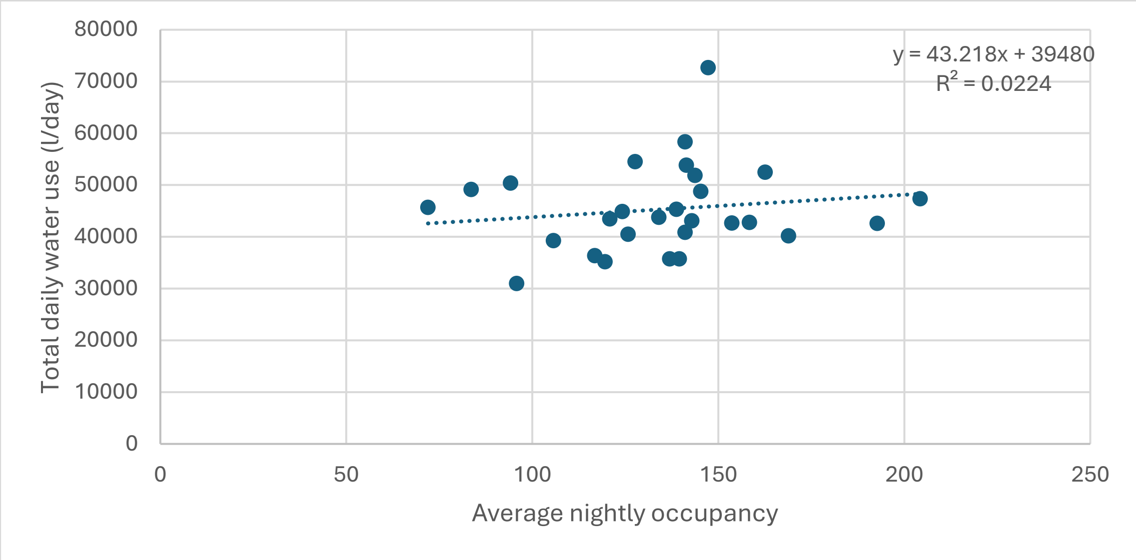

Figure 4.19 Relationship between occupancy (number of beds) and total daily water use at Ngala Safari Lodge

This suggests that changes in occupancy have minimal influence on overall water consumption. While total daily water use increases slightly with higher occupancy. The R^2 value is very low (0.0224), occupancy explains only about 2.2% of the variation in daily water use. This means that occupancy alone is not a strong contributor to total water consumption at the lodge, meaning variation may be driven by operational factors such as cleaning, laundry, irrigation, staff use, and maintenance activities. This suggests that a large part of water consumption remains constant irrespective of occupancy levels, representing fixed daily operational demands. It emphasises the importance of addressing non-occupancy-related water use to enhance overall efficiency.

Ngala Tented Camp

- Occupancy and water use per bed-night

Figure 4.20 illustrates the relationship between average nightly occupancy and water use per bed-night (l/b/n). The trendline equation $y = -9.8886x + 830.6$ and $R^2 = 0.4667$ indicate a moderate negative correlation between the two variables.

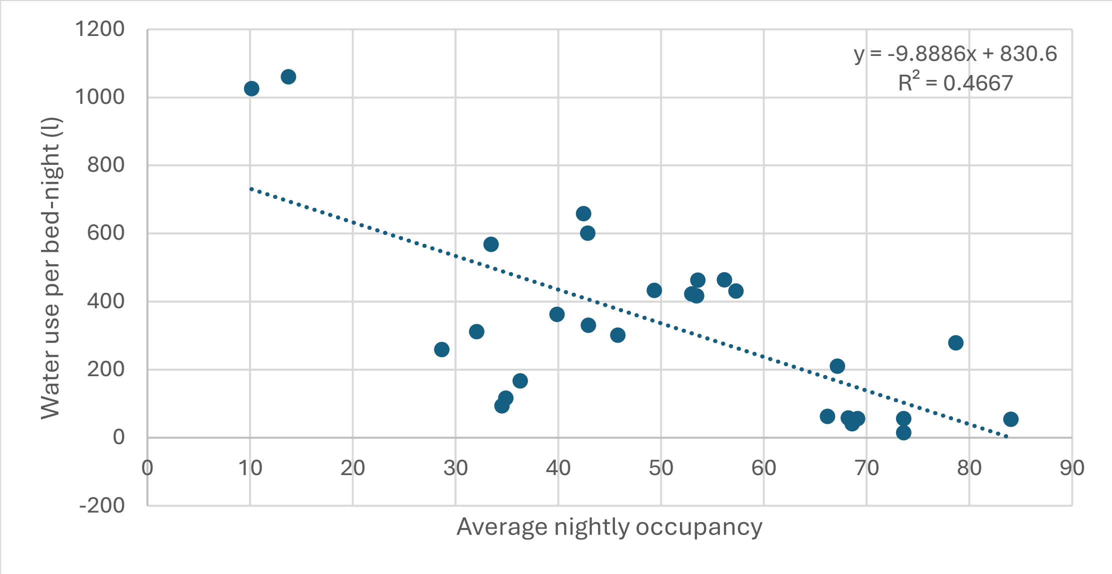

Figure 4.20 Relationship between occupancy (number of beds) and water use per bed-night at Ngala Tented Camp

The negative slope shows that as occupancy increases, the average water use per bed-night decreases, like the trend seen at Ngala Safari Lodge. The R^2 value of 0.4667 indicates that 46,7% of the variation in water use per bed-night can be explained by occupancy. The findings are in line with those of Ngala Safari Lodge.

- Occupancy and total daily water use

Figure 4.21 shows the relationship between average nightly occupancy and total daily water consumption. The trendline equation y = -66.103x + 16 652 and an R^2 value of 0.0201 indicate a very weak negative correlation between occupancy and daily water use.

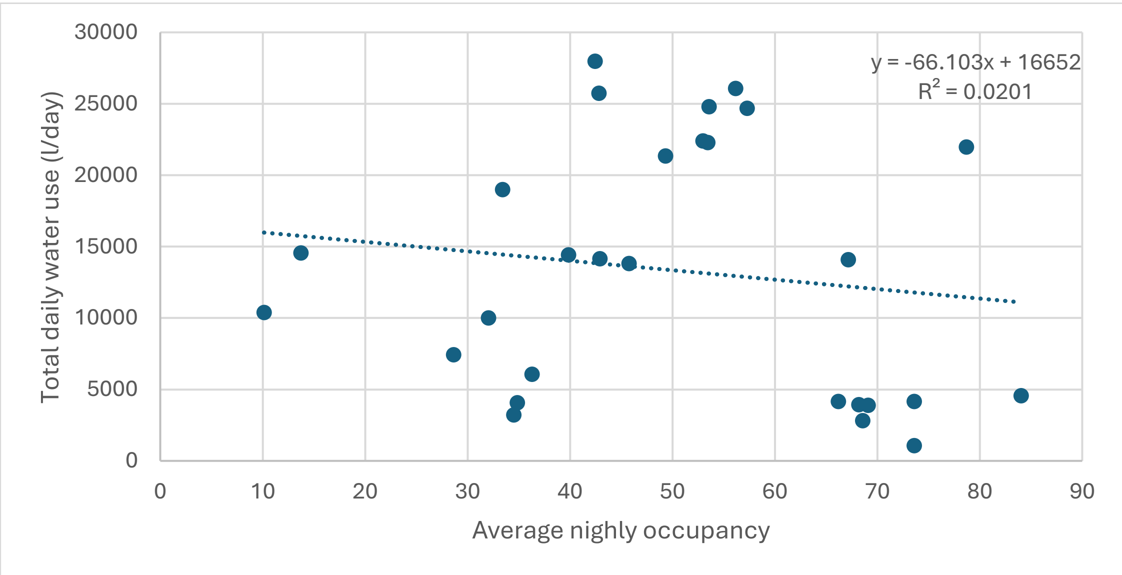

Figure 4.21 Relationship between occupancy and total daily water use at Ngala Tented Camp

The slightly negative slope suggests that water use per day tends to decrease marginally as occupancy increases. Still, the extremely low R^2 value (0.0201) means that occupancy explains only about 2% of the variation in daily water use. These findings are in line with those observed at Ngala Safari Lodge, suggesting that daily water use is influenced more by operational factors than by occupancy levels.

4.2.4.2 Water use and seasonal influence

Ngala Safari Lodge

- Total daily water use

A one-way analysis of variance (ANOVA) was used to assess whether mean daily water use differed significantly across the four seasons (spring, summer, autumn, and winter). Daily total water-use values were grouped by season, and differences between seasonal means were compared with the variation observed within each season to determine whether seasonal climatic conditions influenced overall water consumption at the lodge.

The results indicated no statistically significant difference in mean daily water use between seasons ($F(3,24) = 1.37$, $p = 0.28$), with the calculated F-value remaining below the critical value at the 95% confidence level ($F_{crit} = 3.01$). This suggests that the observed differences in average water use between seasons are small relative to normal day-to-day variability and cannot be attributed to seasonal effects.

Although summer recorded slightly higher average water use than the other seasons, this difference was not statistically significant. Overall, the findings indicate that water consumption at Ngala Safari Lodge remains relatively consistent throughout the year and is primarily driven by ongoing operational and staff-related water demand rather than by seasonal climatic variation.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Spring	7	303851,6	43407,37	49450746,7
Summer	9	437115,9	48568,44	125802604
Autumn	6	243331,2	40555,2	15953911,3
Winter	6	284421,5	47403,58	54044226,9

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	282843969,3	3	94281323	1,36877978	0,276168	3,008787
Within Groups	1653116001	24	68879833			
Total	1935959970	27				

Figure 4.22 One-way ANOVA results comparing mean total water use across seasons at Ngala Safari Lodge

- Water use per bed-night

A one-way ANOVA was conducted to assess whether differences in mean water use per bed-night across spring, summer, autumn, and winter were statistically significant or reflected normal variation. Seasonal water-use data were compared by evaluating variability between seasonal means relative to variability within each season.

The analysis indicated no statistically significant differences between seasonal means ($F(3,24) = 0.98$, $p = 0.42$), with the calculated F-value remaining below the critical value at the 95% confidence level ($F_{crit} = 3.01$). Although summer showed the highest average water use per bed night and autumn the lowest, these differences were small relative to within-season variability and were not statistically meaningful.

Overall, the results indicate that water use per bed-night at Ngala Safari Lodge is primarily influenced by operational and occupancy-related factors rather than seasonal climatic variation, resulting in relatively consistent water demand throughout the year.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Spring	7	2430,678	347,2397	10495,8011
Summer	9	3561,849	395,761	20847,0548
Autumn	6	1837,19	306,1984	2228,1113
Winter	6	2008,469	334,7448	3421,67031

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	31755,66728	3	10585,22	0,98467127	0,416572	3,008787
Within Groups	258000,1525	24	10750,01			
Total	289755,8198	27				

Figure 4.23 One-way ANOVA results comparing mean water use per bed-night across seasons at Ngala Safari Lodge.

Ngala Tented Camp

- Total daily water use

A one-way analysis of variance (ANOVA) was conducted to assess whether mean daily water use at Ngala Tented Camp differed significantly across the four seasons (spring, summer, autumn, and winter). Seasonal water-use data were compared to determine whether climatic seasonality had a measurable influence on overall water consumption.

The analysis showed no statistically significant differences between seasonal means ($F(3,24) = 1.26$, $p = 0.31$), with the calculated F-value remaining below the critical value at the 95% confidence level. Although summer recorded the highest average water use and autumn the lowest, these differences were not statistically significant.

The results indicate that mean daily water use at Ngala Tented Camp is largely independent of seasonal climatic variation and is instead driven by fixed operational requirements, resulting in consistent water demand throughout the year.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Spring	7	102229	14604,15	111288103
Summer	9	153330,7	17036,75	84144960
Autumn	6	56550,54	9425,09	38047592,4
Winter	6	60983,87	10163,98	57916784,7

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	286655278,8	3	95551760	1,25953172	0,310526	3,008787
Within Groups	1820710185	24	75862924			
Total	2107365464	27				

Figure 4.24 One-way ANOVA results comparing mean total water use across seasons at Ngala Tented Camp

- Water use per bed-night

A one-way ANOVA was conducted to assess whether average water use per bed-night (l/b/n) differed significantly across the four seasons (spring, summer, autumn, and winter). Seasonal l/b/n values were compared to determine whether climatic seasonality influenced individual water-use behaviour.

The results indicated no statistically significant differences between seasonal means ($F(3,24) = 0.09$, $p = 0.97$), with the calculated F-value remaining well below the critical value at the 95% confidence level. Although autumn recorded slightly higher average l/b/n values than the other seasons, this variation was not statistically significant.

Overall, the findings suggest that seasonal climatic variation had little influence on per-person water use at Ngala Tented Camp, with water use per bed-night remaining relatively consistent throughout the year.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Spring	7	2074,05	296,2928	58852,3635
Summer	9	2987,855	331,9839	28869,295
Autumn	6	2272,598	378,7663	131003,987
Winter	6	1985,178	330,8631	154715,65

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22035,26208	3	7345,087	0,08758633	0,966169	3,008787
Within Groups	2012666,726	24	83861,11			
Total	2034701,988	27				

Figure 4.25 One-way ANOVA results comparing mean water use per bed-night across seasons at Ngala Tented Camp

The absence of statistically significant seasonal differences in water use contrasts with findings from studies conducted in Mediterranean and coastal tourism destinations, where water consumption typically increases during warmer months because of higher irrigation requirements, swimming pool use, and increased guest demand (Gössling *et al*., 2012; Charara *et al*., 2011). In contrast, the findings of this study suggest that water consumption at Ngala Safari Lodge and Ngala Tented Camp is influenced more strongly by operational requirements than by seasonal climatic variation.

A possible explanation is that many water-intensive activities continue throughout the year regardless of season or occupancy levels. These include accommodation services, kitchen operations, laundry, staff accommodation, swimming pool maintenance, and landscape irrigation. As a result, a substantial proportion of water demand remains relatively stable, reducing the influence of seasonal changes in temperature and rainfall on overall consumption patterns.

This interpretation is supported by Gössling *et al*. (2015), who reported that accommodation facilities often maintain a consistent baseline water demand because essential operational activities continue even during periods of lower occupancy. The findings also align with those of Tortella and Tirado (2011), who found that tourism establishments benefit from economies of scale, whereby water consumption per guest decreases as occupancy increases because fixed operational demands are distributed across a larger number of guests.

The moderate negative relationship observed between occupancy and litres per bed-night supports this explanation. As occupancy increases, water-use efficiency improves because fixed operational water requirements contribute proportionally less to overall consumption. Similar relationships have been reported in hospitality studies internationally, suggesting that occupancy is often a stronger determinant of water-use efficiency than seasonal climatic conditions.

4.2.5 Water Quantity Standards and Benchmarks

According to their Environmental Operations Manual, both Ngala Safari Lodge and Ngala Tented Camp are expected to target a water consumption limit of 350 l/b/n. Analysis of the 28-month study period shows that Ngala Safari Lodge recorded an average consumption of 351,36 l/b/n, which is slightly above the limit. Even though the exceedance amounts to less than 0.5%, it still represents a slight deviation from the sustainability baseline established for the lodges.

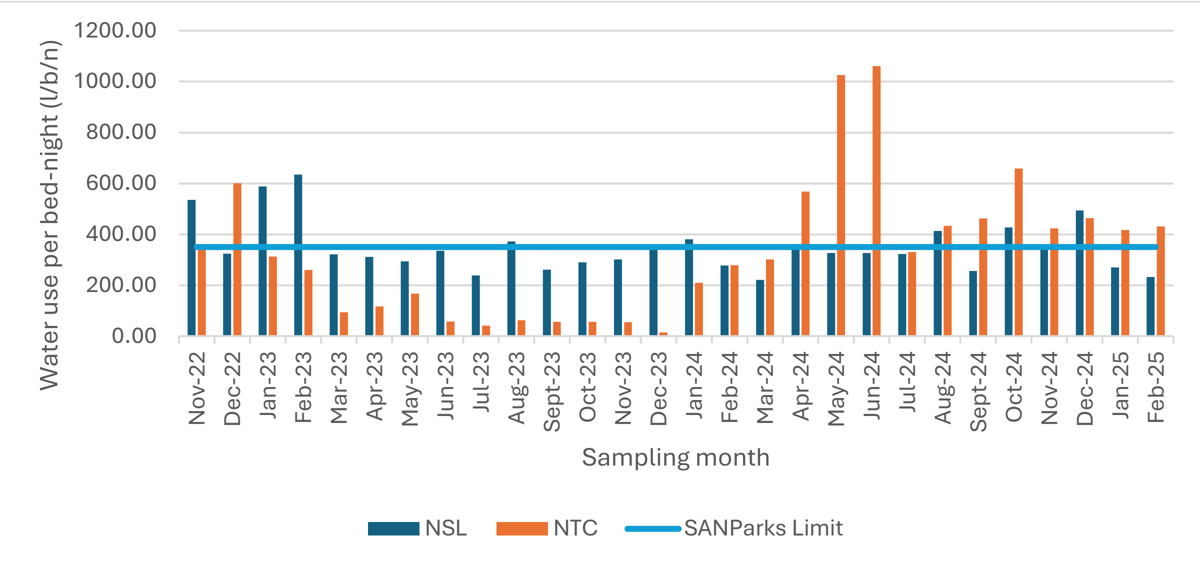

Figure 4.26 Monthly water use per bed-night at Ngala Safari Lodge and Ngala Tented Camp relative to the Ngala Environmental Operations Manual benchmark

When examining the monthly water use results, 10 out of the 28 months exceeded the 350 l/b/n limit, while the remaining 18 months remained below the target. This trend implies that the exceedances occurred intermittently rather than as a recurring issue, likely resulting from contributing factors, which are examined in the following section.

NTC had an average daily water use of 332,85 l/b/n, which is below the 350 l/b/n prescribed limit. This shows that, on average, the camp's water usages were within the sustainable water-use limit. Over the 28-month study period, 12 months exceeded the benchmark, while 16 months remained below. Of the 12 months that showed exceedances, six occurred during the refurbishment period. This indicates that water consumption fluctuated but maintained an acceptable average. The exceedances were not persistent and possibly related to other factors, which are discussed in the following section.

Table 4.3 Average occupancy per bed-night and proportional contribution by category (guests vs staff)

	Category	Average per Bed-night	Average % of Total
NSL	Guests	28.76	21.31
NSL	Staff	106.18	78.69
NTC	Guests	8.88	17.65
NTC	Staff	41.45	82.35

Table 4.3 indicates the breakdown between guests and staff residing at both lodges per night. Paying guests as well as complimentary guests and children were allocated to the guest group, and regular staff, temporary construction staff, and staff visitors were allocated to the staff group.

4.2.6 Comparison of Water Use Benchmarks

Table 4.4 Benchmark comparison of water use per bed-night

Metric	Ngala Average	SANParks Limit Guests	SANParks Limit Staff	WRC Average	WRC Target	South African Domestic Average	International Domestic
NSL	351,36	350	270	300	128	237	173
NTC	332,85	350	270	300	128	237	173

The findings demonstrate that benchmark selection influences the interpretation of water-use performance. While water consumption at Ngala Safari Lodge and Ngala Tented Camp exceeded certain international tourism benchmarks, the lodges generally performed within or close to benchmarks developed specifically for wildlife tourism operations.

A possible explanation for these higher consumption values is the unique operational context of wildlife lodges in South Africa. Unlike conventional hotels, both lodges accommodate permanent and shift-based staff on site and provide extensive support services, including laundry, kitchens, staff housing, swimming pools, and irrigation systems. These activities increase total water demand and are not always accounted for in generic tourism benchmarks. This finding supports the observations of Baker and Mearns (2015), who argued that conventional tourism water-use benchmarks may not adequately reflect the realities of South African wildlife lodges. Similarly, Gössling *et al*. (2012) noted that luxury tourism facilities generally consume substantially more water than standard accommodation establishments due to higher service expectations and operational complexity.

Water consumption by guests and staff at Ngala Safari Lodge and Ngala Tented Camp is currently not measured or reported separately. Both groups are collectively assessed against a benchmark of 350 litres per person per day, as outlined in the Ngala Environmental Operations Manual. This approach limits the ability to accurately determine which user group contributes most to overall consumption and where targeted water-saving interventions could be implemented most effectively. A possible explanation for the difficulty in interpreting water-use performance is that aggregated reporting masks differences in consumption behaviour between guests and staff.

In contrast, other lodges and concessions within the Greater Kruger region and SANParks, such as the Shingwedzi Treehouse Facility in the Kruger National Park, apply separate benchmarks to different user groups, namely 350 l/b/n for guests, 270 l/b/n for on-site staff, and 40 l/b/n for day staff (SANParks Information Memorandum, 2021). This distinction recognises that guests generally have higher water demands due to accommodation-related services such as laundry, bathing, housekeeping, and food preparation, while staff, particularly non-residential staff, typically have lower water requirements. The use of differentiated benchmarks may therefore provide a more accurate assessment of water-use efficiency and support the implementation of targeted management interventions.

According to the Water Research Commission (WRC, 2020), average domestic water consumption in South Africa is approximately 237 litres per person per day, which is considerably higher than the global average of 173 litres per person per day. This indicates that South Africa faces particular challenges relating to water availability, infrastructure, and consumption behaviour. Similar concerns have been raised by Carelse (2023), who highlighted that South African water consumption remains significantly above international averages. These findings emphasise the importance of promoting water-use efficiency and implementing sustainable water management practices across all sectors, including tourism.

Tourism-related water consumption is estimated to average approximately 300 litres per person per day (Gössling *et al*., 2012; WRC, 2020). However, studies have shown that substantial reductions can be achieved through the implementation of water-efficient technologies, behavioural interventions, leak detection programmes, and awareness campaigns. The World Health Organisation (WHO, 2020) suggests that water consumption can potentially be reduced to as low as 128 litres per person per day under efficient management conditions. Although such targets may be difficult to achieve within luxury wildlife tourism operations due to operational requirements and guest expectations, they provide a useful aspirational benchmark for continuous improvement.

In the context of this study, these benchmarks provide a valuable framework for evaluating water-use efficiency at Ngala Safari Lodge and Ngala Tented Camp. The findings suggest that the lodges perform relatively well when assessed against benchmarks developed for wildlife tourism operations, but opportunities remain to further improve water-use efficiency through enhanced monitoring, user-specific benchmarking, staff awareness programmes, and behavioural water conservation initiatives. The results further support the argument that sector-specific benchmarks are more appropriate than generic tourism standards when assessing the sustainability of water use within South African wildlife lodges.

4.3 Water Quality

This section investigates the drinking and effluent water quality of Ngala Safari Lodge and Ngala Tented Camp. Drinking water refers to water that has been abstracted, treated, and made available at various usage points, including the kitchen, scullery, laundry, maintenance workshops, and guest and staff ablution areas. These usage points represent where consumers use water for general purposes such as cleaning, cooking, and hygiene, rather than exclusively for consumption. Therefore, the term drinking water may be used interchangeably with source water.

Effluent water refers to water that has already been used at these various points. This water may contain chemicals such as soaps, detergents, and fertilisers, as well as microbial organisms. It undergoes further treatment to remove chemical, physical, and microbiological contaminants before being discharged into the environment. The term effluent water may be used interchangeably with wastewater.

Ngala Safari Lodge (NSL) and Ngala Tented Camp (NTC) conduct monthly laboratory testing of both drinking and effluent water in accordance with the requirements of the Ngala Environmental Operations Manual. This monitoring ensures that the water is safe and complies with all relevant quality standards. Drinking water was tested for 33 parameters, while effluent water was tested for 32 parameters, each contributing to the overall assessment of water safety and compliance. All results were tabulated and graphed against the relevant standards to detect any exceedances. Parameters that did not comply with the acceptable limits are discussed and analysed in detail in the following section.

4.3.1 pH

pH is the measure of how acidic or alkaline water is, expressed from zero to 14, where values below seven are acidic, seven is neutral, and above seven are alkaline (WHO, 2017). As stated by SANS 241:2015 Ed.2, the pH of water is an operational risk as it may lead to infrastructure damage and ineffective water treatment processes. The pH level plays an important role in water treatment efficiency, as disinfectants such as chlorine perform most effectively when the water has a near-neutral pH (DWS, 2017). Water with a low pH may corrode pipes and plumbing infrastructure, which may cause the pipes to leach harmful metals and contaminate the water. Water with a high pH can cause scaling and blockages due to chemical precipitation. The pH also impacts the taste of drinking water, with acidic water tasting sour or metallic and alkaline water tasting bitter or soapy.

Table 4.5 Regulatory pH limits and risk classification according to South African water quality standards.

Parameter	**pH @ 25°C**
Unit	pH units
SANS 241:2015 Ed.2 Risk Type	Operational
SANS 241:2015 Ed.2 Limits	5.0 to 9.7
SANS 1657:2007 Ed.2 Limits	5.0 to 9.5
Water Act No. 36 of 1998 Limits	5.0 to 9.5
DWAF Irrigation Water Quality Guidelines Limits	6.5 to 8.4

- Drinking water

The drinking water pH results show that all samples collected from Ngala Safari Lodge and Ngala Tented Camp over the 28-month study period complied with the applicable drinking water quality standards indicated in Figure 4.27, with some fluctuation. Five pH readings at Ngala Safari Lodge and 14 readings at Ngala Tented Camp exceeded a value of eight, deeming it slightly alkaline. Although these values are still within the acceptable range, elevated pH levels can have a negative operational and aesthetic impact, as discussed and should be prioritised for future monitoring and corrective action.

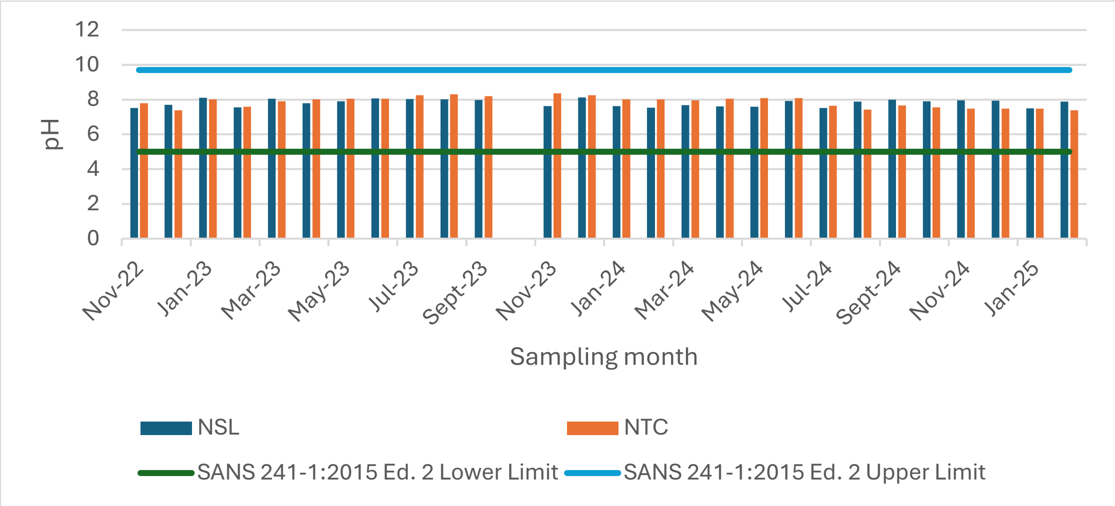

Figure 4.27 Monthly pH levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

The slight variance in results is most likely due to the characteristics of the groundwater source, which is influenced by the surrounding geology. Additional contributing factors may include extended storage times in holding tanks, which can further alter pH levels due to stagnation, temperature changes, and chemical interactions within the system. A study by Mpenyana-Monyatsi, Onyango and Momba (2012) investigated groundwater quality across 100 boreholes in rural Mpumalanga and found that pH values commonly ranged between neutral and slightly alkaline, with mean values of 8,0 ± 0,28 in Nkomazi, 7,6 ± 0,27 in Mbombela, and 7,1 ± 0,40 in eMalahleni. All readings were within national drinking water guidelines, but an alkaline tendency was evident in groundwater across the province due to regional hydrogeochemistry. These findings relate to the results from Ngala Safari Lodge and Ngala Tented Camp, where several samples exceeded pH 8,0 while remaining compliant with SANS 241, indicating that slightly alkaline groundwater pH values are typical of areas located near Ngala reflect natural geological properties rather than operational failures.

- Effluent water

Based on the effluent water quality results in Figure 4.28, all pH readings complied with the Water Act No. 36 of 1998 regulations for wastewater to be discharged into the environment, except for February 2025, when a highly acidic value of 4,8 was recorded. This outlier is considered an isolated incident rather than a recurring trend but should be monitored closely. The results were also compliant with DWAF Irrigation Water Quality Guidelines, as seen in Figure 4.28, specifically for Ngala Tented Camp, where effluent water is used for lawn irrigation.

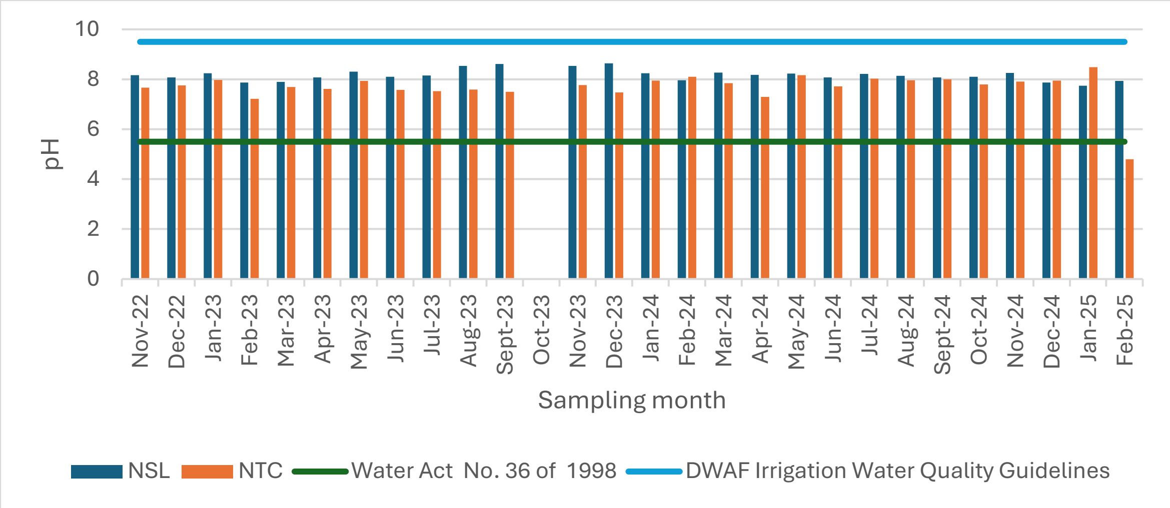

Figure 4.28 Monthly pH levels of effluent water at NSL and NTC compared with Water Act No. 36 of 1998 regulations and DWAF Irrigation Water Quality Guidelines

Effluent water generally has a higher pH than the source water. Oteng-Peprah, de Vries, and Acheampong (2018) stated that wastewater generated in hospitality facilities commonly has elevated pH levels, usually between 8,0 and 9,5. This increase was attributed primarily to the use of alkaline cleaning agents in kitchens, laundries, and ablution areas, as well as the production of ammonia during microbial decomposition of organic matter in decentralised treatment systems. This relates to the observed results, where at Ngala Safari Lodge the average pH of the source water was 7,81 before use, while the effluent water had an average pH of 8,17. Even though the results are still within acceptable limits, further monitoring and improvement should be implemented to effectively manage the physical properties of wastewater before it is released back into the environment.

- iLab Results

The iLab chemical parameter results showed that both the drinking and effluent water samples from Ngala Safari Lodge and Ngala Tented Camp recorded a pH value of 9, as seen in Appendix E. This indicates a slightly higher pH compared to the readings obtained from the laboratory tests, suggesting minor variation between field and laboratory recordings, but shows consistent alkaline water conditions at both sites.

4.3.2 Total Hardness

Water hardness measures the calcium and magnesium concentrations in water, which are naturally occurring minerals and are commonly found in water, and is attributed to geological influences such as dolomitic and calcareous rock formations (DWAF, 2017; Ochieng, Seanego & Nkwonta, 2010). Water hardness is regarded as an operational and aesthetic risk according to SANS 241:2015 Ed.2. The presence of calcium and magnesium bicarbonates causes temporary hardness. It can easily be removed by boiling the water. In contrast, permanent hardness is caused by sulphate and chloride salts and can only be reduced through more advanced methods like ion exchange, demineralisation or chemical water softening (DWAF, 1996).

Table 4.6 Regulatory total hardness limits and risk classification according to South African water quality standards

Parameter	**Total Hardness as $CaCO_3$**
Unit	mg/l
Risk Type	Operational, Aesthetic
SANS 241:2015 Ed.2	200
SANS 1657:2007 Ed.2	n/a
Water Act No. 36 of 1998	n/a
DWAF Irrigation Water Quality Guidelines	n/a

Excessively hard water causes scaling and build-up in pipes, geysers, and kitchen appliances, reducing energy efficiency and increasing maintenance and costs. Hard water reduces soap efficiency, requiring more soap to create a lather and causing the formation of insoluble scum. Over time, this buildup can leave inaesthetic marks and dull the surfaces of baths and basins (DWAF, 1996).

- Drinking water

SANS 241:2015 does not specify a limit for total hardness in drinking water but suggests that concentrations above 200 mg/l cause operational and aesthetic problems. As shown in Figure 4.29, the water at both Ngala Safari Lodge and Ngala Tented Camp exceeds this suggestion for total hardness. Ngala Safari Lodge shows very high hardness levels, causing the water to be unsuitable for operational use at the lodge. Although Ngala Tented Camp's water also exceeds the standard, its hardness is comparatively lower and has a lesser impact on infrastructure and appliances.

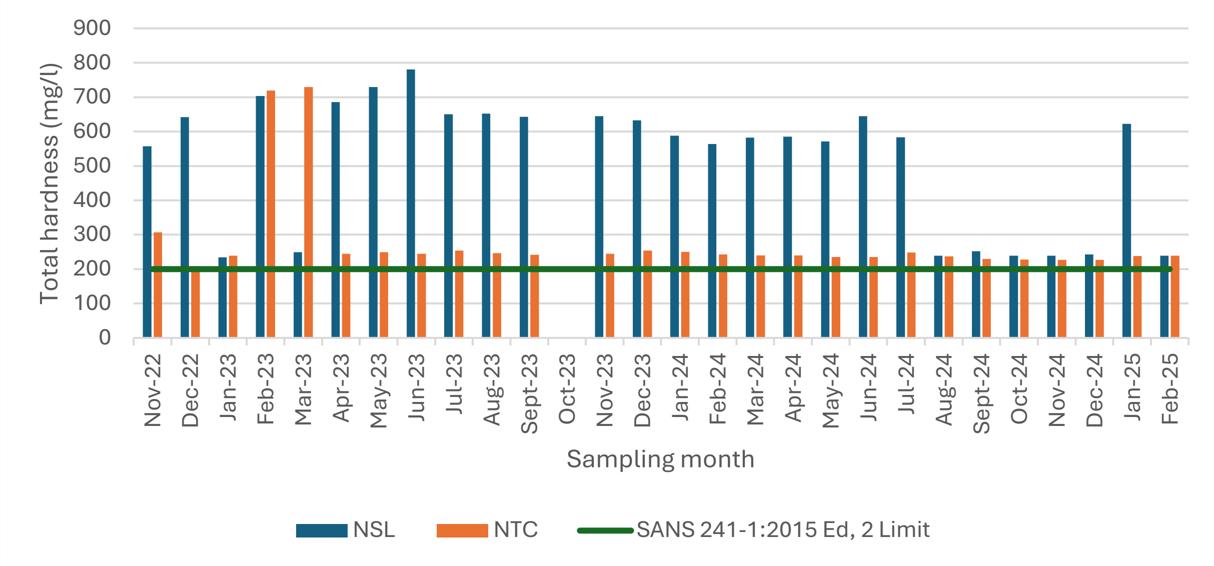

Figure 4.29 Monthly total hardness levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

The extremely hard water is being used for staff consumption as well as for guest and staff general use at both lodges. According to the WHO (2017), hard water is not considered a direct health risk; water with a hardness of more than 500 mg/l may cause digestive discomfort, including diarrhoea or constipation in sensitive individuals. Recordings of more than 500 mg/l were observed 19 times at Ngala Safari Lodge, and twice at Ngala Tented Camp.

In addition to these potential health effects, hard water contributes to significant operational challenges as previously mentioned. Key participant interviews revealed that prolonged use of hard water for domestic purposes has caused staff to experience dry skin, hair breakage and loss, and damage to clothing during laundry, highlighting the impact of excessively hard water on long term daily use.

- Effluent water

Ngala Safari Lodge and Ngala Tented Camp did not test for total hardness in their effluent water throughout the study period, resulting in an incomplete dataset. According to the National Water Act and the DWAF Irrigation Water Quality Guidelines, there is no prescribed limit for total hardness in wastewater intended for discharge into the environment or for irrigation use. It was observed that Ngala Safari Lodge exhibited higher overall total hardness levels compared to Ngala Tented Camp, which is consistent with the trends identified in the drinking water results.

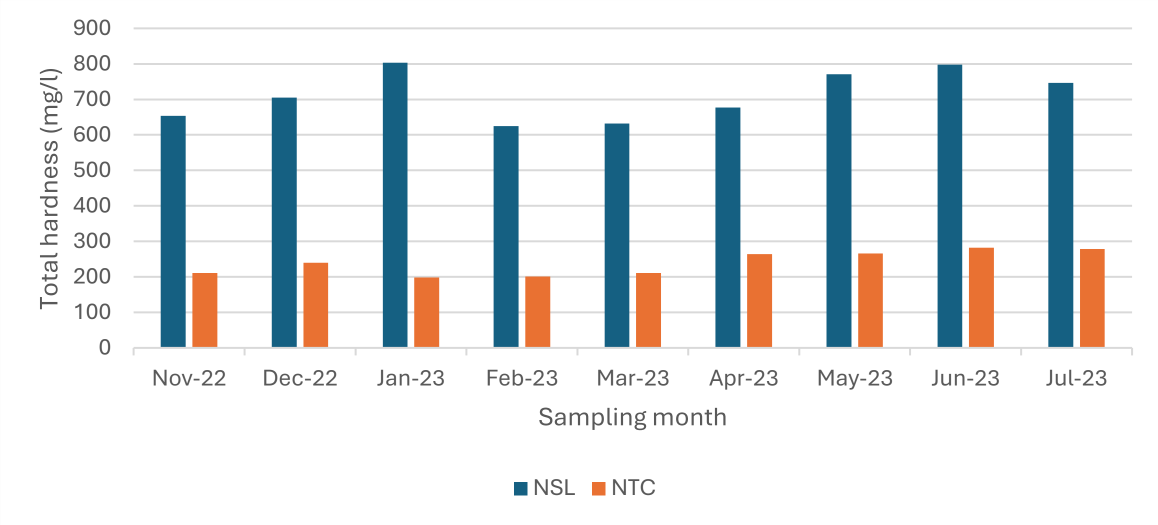

Figure 4.30 Monthly total hardness levels of effluent water at NSL and NTC

- iLab Results

The iLab chemical parameter tests showed that water from all four sources recorded the highest measurable hardness value of 425 parts per million, as seen in Appendix E. This aligns with the laboratory test results, confirming consistently high hardness levels across all samples.

4.3.3 Conductivity

Conductivity in water refers to its capacity to transmit an electrical current, and is influenced by the number of dissolved salts, minerals, and ions present in the water, with higher concentrations of elements like sodium, chloride, and calcium leading to greater electrical conductivity (DWAF, 1996). Electrical conductivity has a direct correlation to total dissolved solids concentration of water, and since electrical conductivity is simpler to measure, it is commonly used as an indicator or estimate of TDS levels (DWAF, 1996). Associated risks and treatment are discussed in the TDS chapter.

Table 4.7 Regulatory conductivity limits and risk classification according to South African water quality standards.

Parameter	**Conductivity @ 25°C**
Unit	mS/m
Risk Type	Operational
SANS 241:2015 Ed.2	≤ 170
SANS 1657:2007 Ed.2	n/a
Water Act No. 36 of 1998	70 – 150
DWAF Irrigation Water Quality Guidelines	<540

- Drinking water

The conductivity results show that Ngala Tented Camp complies with the SANS 241:2015 Ed.2 standard, except for February and March 2023. Ngala Safari Lodge, however, is over the acceptable limit, 19 out of the 28 months, making it unsuitable for human and operational use. As stated in Figure 4.31, there is no conductivity limit for drinking water under SANS 1657:2007 Ed.2.

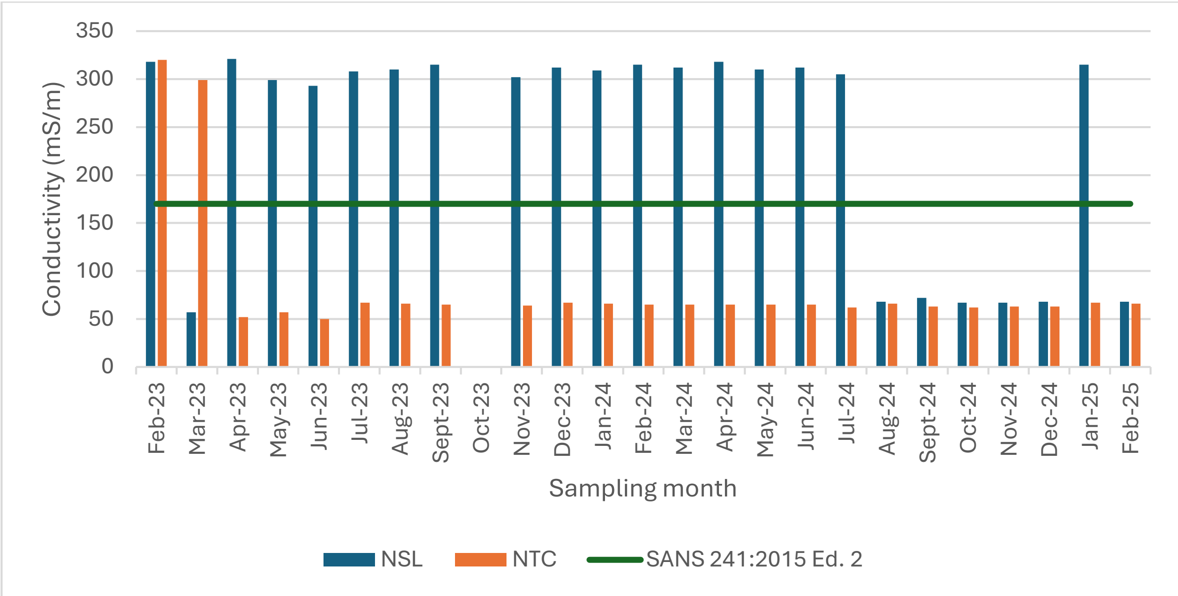

Figure 4.31 Monthly conductivity levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

- Effluent Water

As seen in Figure 4.32, the conductivity results for Ngala Safari Lodge and Ngala Tented Camp's effluent water are not in compliance with the relevant standard. Ngala Safari Lodge exceeded the limit every month over the timeframe of the study, making it unsuitable to be discharged into a water source. Ngala Tented Camp was within the limit for 25 months, but experienced very high levels in January and February 2025, which requires investigation, monitoring and corrective action.

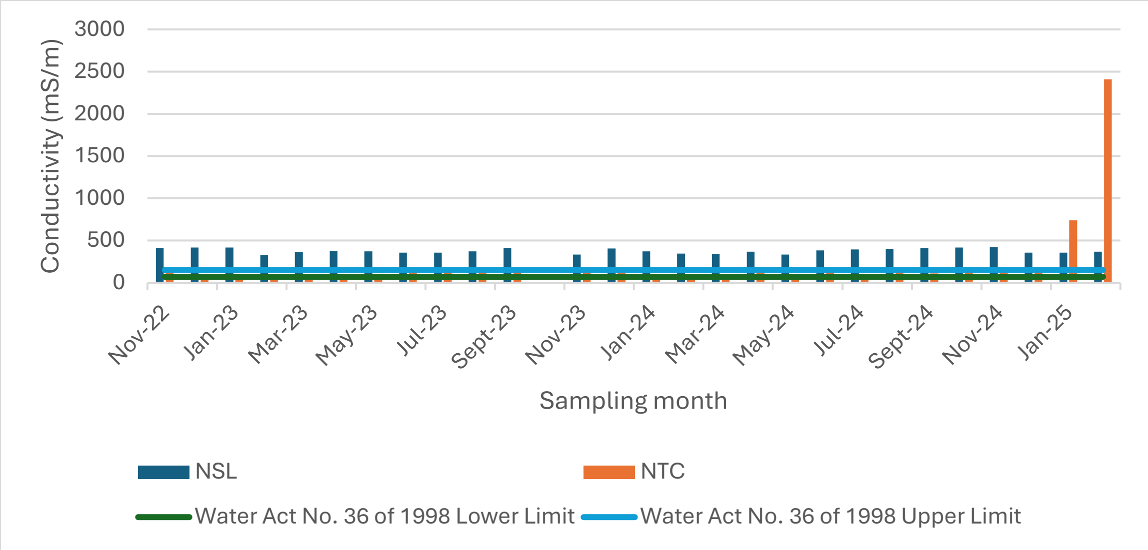

Figure 4.32 Monthly conductivity levels of effluent water at NSL and NTC compared with the Water Act No. 36 of 1998 regulations

4.3.4 Total Dissolved Solids

Total Dissolved Solids (TDS) refer to the overall concentration of inorganic salts and small amounts of organic matter dissolved in water. Elevated TDS levels are associated with operation, aesthetic and health risks. and may also pose potential health risks due to high concentrations of salts such as sodium, which can contribute to cardiac and kidney problems. High TDS levels can present operational challenges such as corrosion or scaling within pipes and treatment systems, damaging appliances and creating increased maintenance pressure. High TDS and sodium concentrations in water may have direct health implications, including increased risk of cardiac and kidney problems, potential laxative effects, and adverse impacts on pregnant women diagnosed with preeclampsia if used long-term. Moderate concentrations of dissolved salts such as magnesium and calcium can enhance the nutritional value and taste of water. Low TDS concentrations may cause the water to taste flat and unpleasant (DWAF, 1996).

Table 4.8 Regulatory total dissolved solids limits and risk classification according to South African water quality standards

Parameter	**Total Dissolved Solids**
Unit	mg/l
Risk Type	Operational
SANS 241:2015 Ed.2	≤ 1200
SANS 1657:2007 Ed.2	n/a
Water Act No. 36 of 1998	n/a
DWAF Irrigation Water Quality Guidelines	n/a

- Drinking Water

The TDS results indicate that Ngala Safari Lodge generally complies with the relevant standard, except during February and March 2023, which aligns with the elevated conductivity values previously discussed. Ngala Tented Camp exceeded the acceptable limit in 19 of the 28 monitored months. This prolonged exceedance of TDS in the drinking water relates to the same long-term high levels of conductivity and total hardness. The problem arises from the elevated levels of dissolved salts and ions in the water, which influence all three parameters and highlight the need for a sustainable, long-term solution to address the problem.

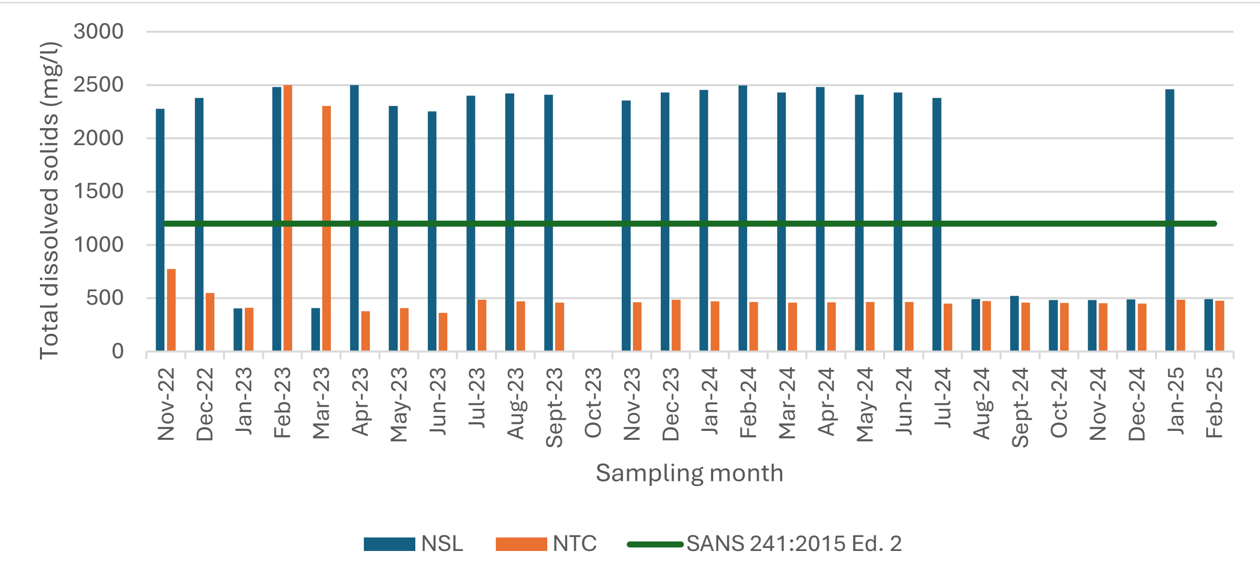

Figure 4.33 Monthly TDS levels of effluent water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

- Effluent Water

Although the Water Act No. 36 of 1998 and DWAF Irrigation Water Quality Guidelines do not specify a limit for TDS in effluent water, there is a limit for conductivity, which is directly related to TDS. The trends and implications are discussed in the above section.

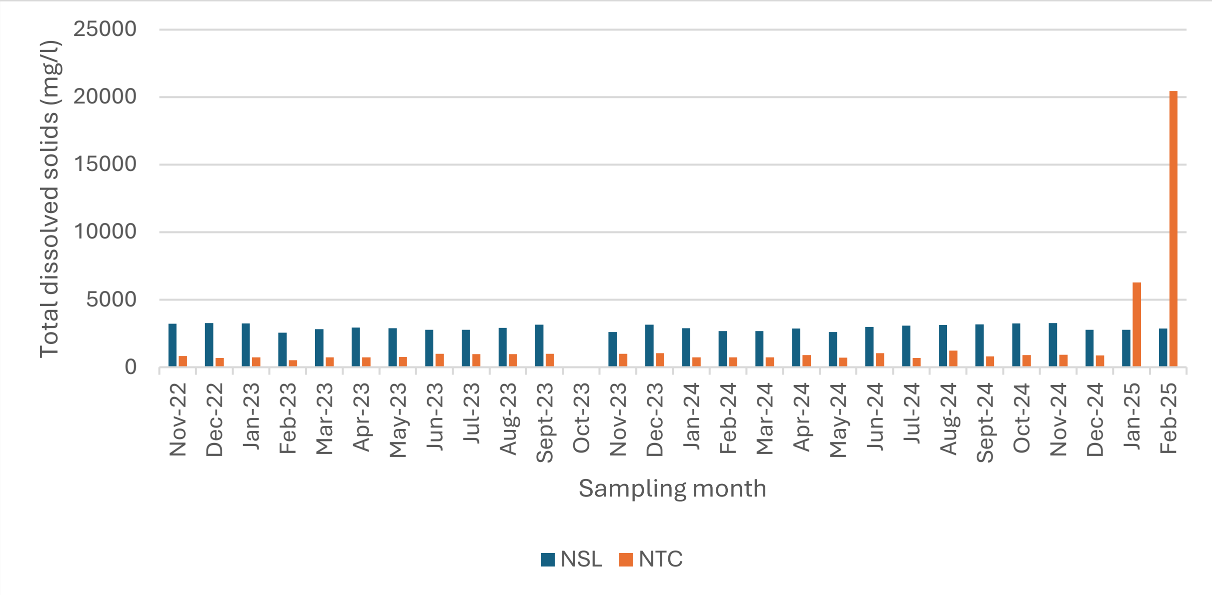

Figure 4.34 Monthly TDS levels of effluent water at NSL and NTC

4.3.5 *E. coli*

Escherichia coli (*E. coli*) is a bacterium commonly found in the intestines of humans and animals and is the definitive indicator of faecal contamination in water. *E. coli* contaminates water when faecal matter from humans or animals enters a water source through sewage leaks, runoff, or seepage from septic tanks. The presence of *E. coli* indicates faecal pollution and potential contamination by other harmful microorganisms, making the water unsafe for consumption and considered an immediate health risk. Drinking water contaminated with *E. coli* can cause gastrointestinal problems such as diarrhoea, stomach cramps, nausea, and vomiting. At the same time, more severe pathogenic strains like *E. coli* O157:H7 may lead to haemorrhagic colitis and, in some cases, haemolytic uraemic syndrome, which can result in kidney failure. Therefore, DWAF (1996), SANS 241-1:2015, and the WHO (2017) specify that no trace of *E. coli* should be present in drinking water.

Table 4.9 Regulatory E. coli limits and risk classification according to South African water quality standards.

Parameter	***E. coli***
Unit	count/100ml
Risk Type	Acute health
SANS 241:2015 Ed.2	None detected
SANS 1657:2007 Ed.2	None detected
Water Act No. 36 of 1998	1000
DWAF Irrigation Water Quality Guidelines	< 1000

- Drinking Water

According to the results, three recordings from Ngala Safari Lodge detected *E. coli* in January and April 2023, as well as May 2024. Four recordings for Ngala Tented Camp detected *E. coli* in January, June, July and September 2023. The presence of *E. coli* in both Ngala Safari Lodge and Ngala Tented Camp during January 2023 can possibly be explained by seasonal rainfall, as heavy rain can increase surface runoff and groundwater infiltration, possibly introducing faecal material into boreholes or storage systems. The presence of *E. coli* in both camps in one particular month appears to have been an isolated incident rather than a trend, highlighting the importance of intensified monitoring and maintenance during wet months.

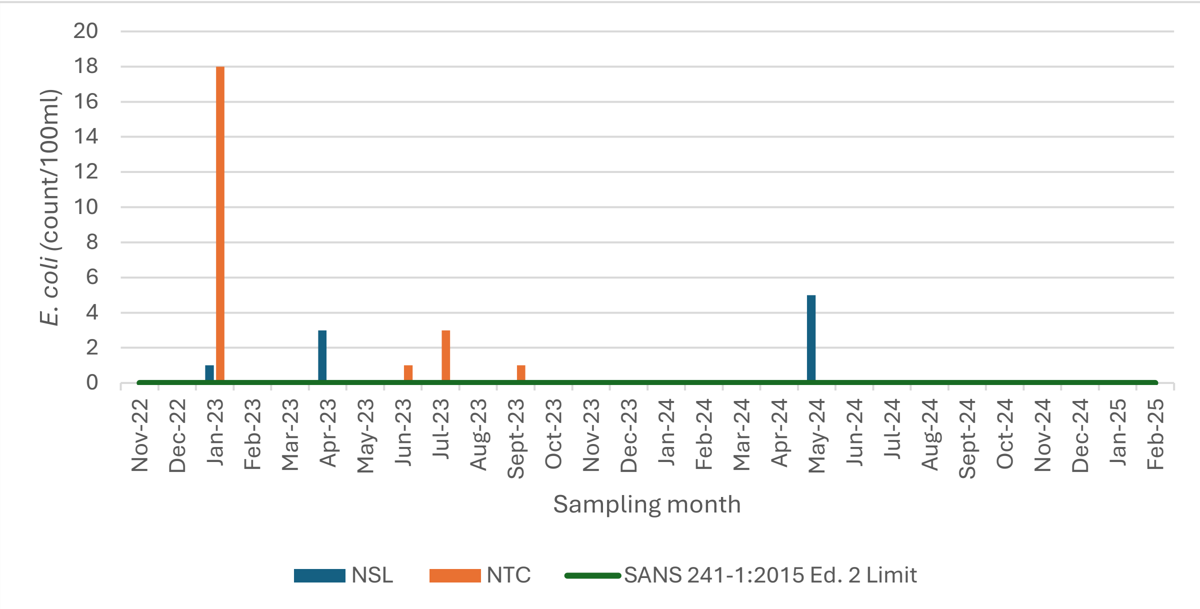

Figure 4.35 Monthly *E. coli* levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

- Effluent Water

The results show that the effluent water at Ngala Safari Lodge was compliant with the relevant standard. Ngala Tented Camp, however were non-compliant 13 out of the 28 months, with 11 readings being over the limit that the test is capable of detecting. This is a serious problem as Ngala Tented Camp uses its effluent water to irrigate the lawn and garden, releasing the faecal contaminated water directly into the environment. Since this occurrence happened 46% of the timeframe of the study, this is not a situational occurrence, and drastic intervention is needed to confirm the source of the *E. coli* and eliminate the problem.

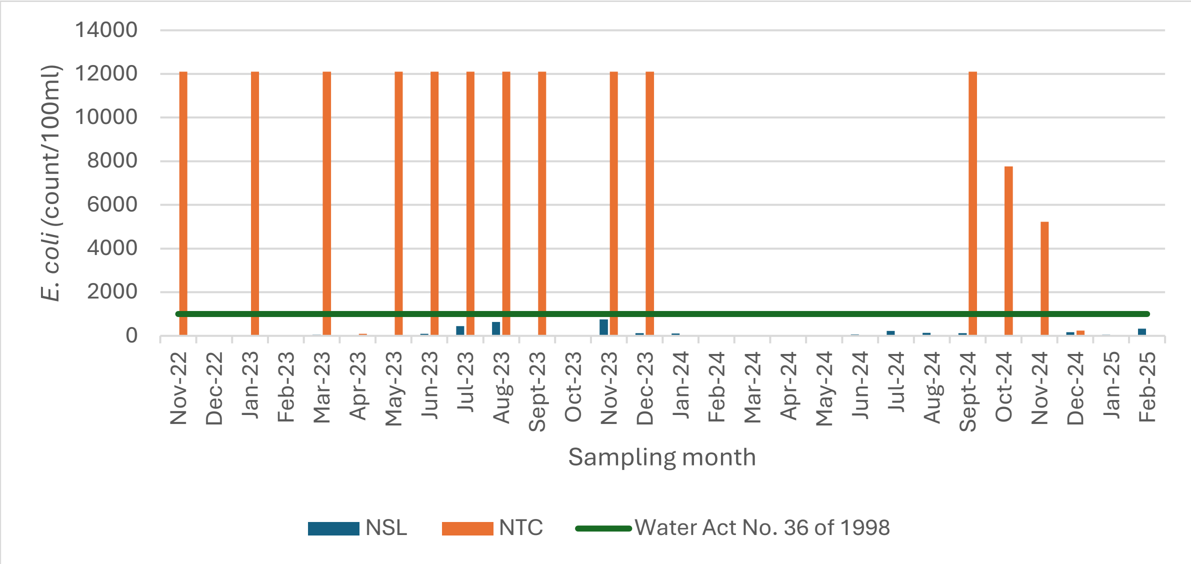

Figure 4.36 Monthly *E. coli* levels of effluent water at NSL and NTC compared with the Water Act No. 36 of 1998 regulations

- iLab Results

The iLab microbial tests detected no *E. coli* colonies that grew on the petrifilm on any of the four samples, indicating that no *E. coli* was present in Ngala Safari Lodge and Ngala Tented Camp's drinking or effluent at the time the test was performed (see Appendix F).

4.3.6 Total coliforms

Coliforms are a broad group of bacteria that occur naturally in the environment, including in soil, vegetation, and the intestines of humans and other animals. Total coliforms are indicators of the hygiene of water and the effectiveness of the treatment and distribution system. Their presence in treated drinking water indicates ineffective treatment or contamination after treatment, creating potential pathways for pathogenic organisms such as *E. coli*, *Salmonella*, *Shigella*, and *Giardia* to enter the water supply.

Table 4.10 Regulatory total coliform limits and risk classification according to South African water quality standards

Parameter	Total Coliforms
Unit	count/100ml
Risk Type	Acute health
SANS 241:2015 Ed.2	≤ 10
SANS 1657:2007 Ed.2	None detected
Water Act No. 36 of 1998	n/a
DWAF Irrigation Water Quality Guidelines	<n/a

- Drinking water

Figure 4.37 shows that total coliform levels exceeded the acceptable limit for drinking water in 10 out of 28 months at Ngala Tented Camp and in two out of 28 months at Ngala Safari Lodge, indicating inadequate treatment processes and contamination. This poses significant health risks, including the potential for diseases like gastroenteritis, salmonellosis, dysentery, cholera, and typhoid fever. This presents a serious health concern that requires immediate investigation to identify the source of contamination and implement corrective measures.

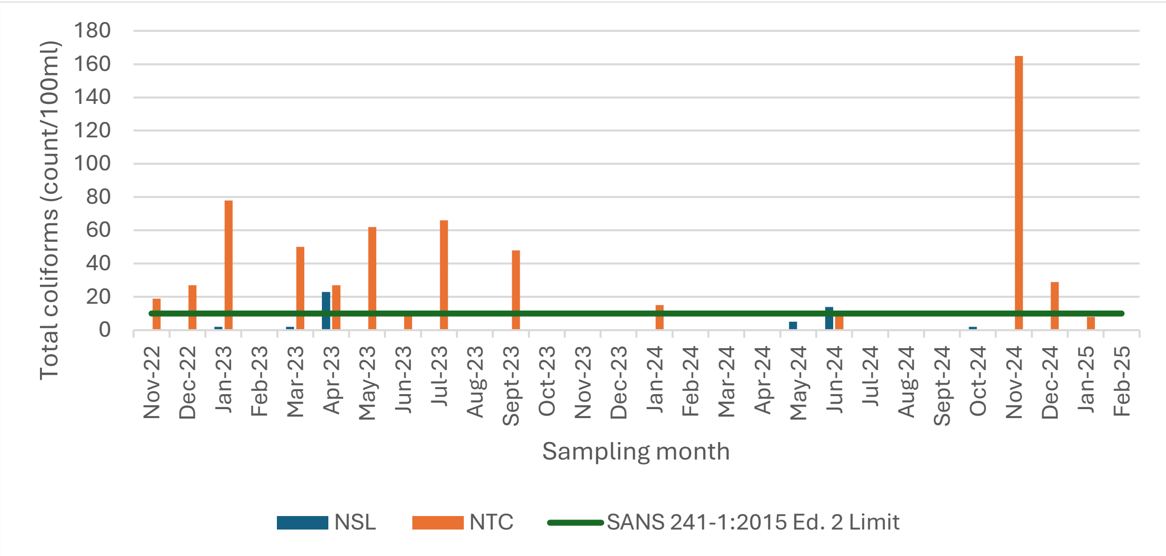

Figure 4.37 Monthly total coliform levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits.

- Effluent

Although no specific limit for total coliforms is applicable to wastewater discharge or irrigation use, both Ngala Safari Lodge and Ngala Tented Camp recorded exceptionally high total coliform counts. This indicates inadequate wastewater treatment processes and poses a significant risk to surrounding water bodies by promoting eutrophication, which may lead to other forms of environmental degradation.

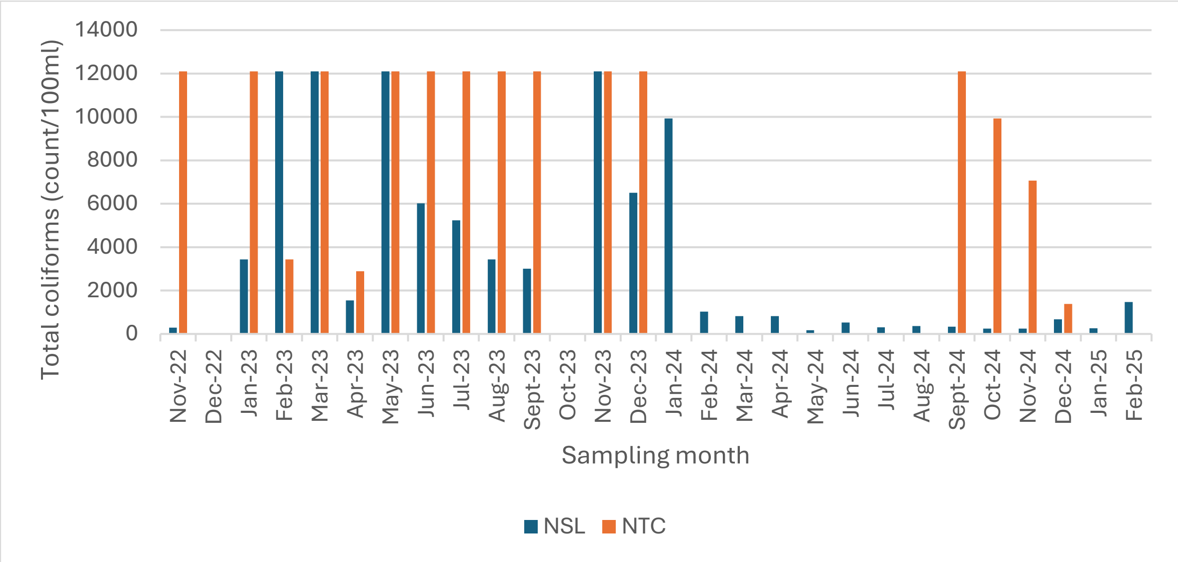

Figure 4.38 Monthly total coliform levels of effluent water at NSL and NTC

- iLab Results

The iLab microbial analysis confirmed the presence of coliform colonies in Ngala Safari Lodge's drinking water, indicating that the borehole water is not being properly treated and that the treatment system may be faulty or ineffective, as seen in Figure 4.37. This contamination causes the water to be unsafe for human consumption and poses a high risk of acute health effects. No coliform colonies were detected in Ngala Safari Lodge effluent water, or Ngala Tented Camping drinking and effluent water (see Appendix F).

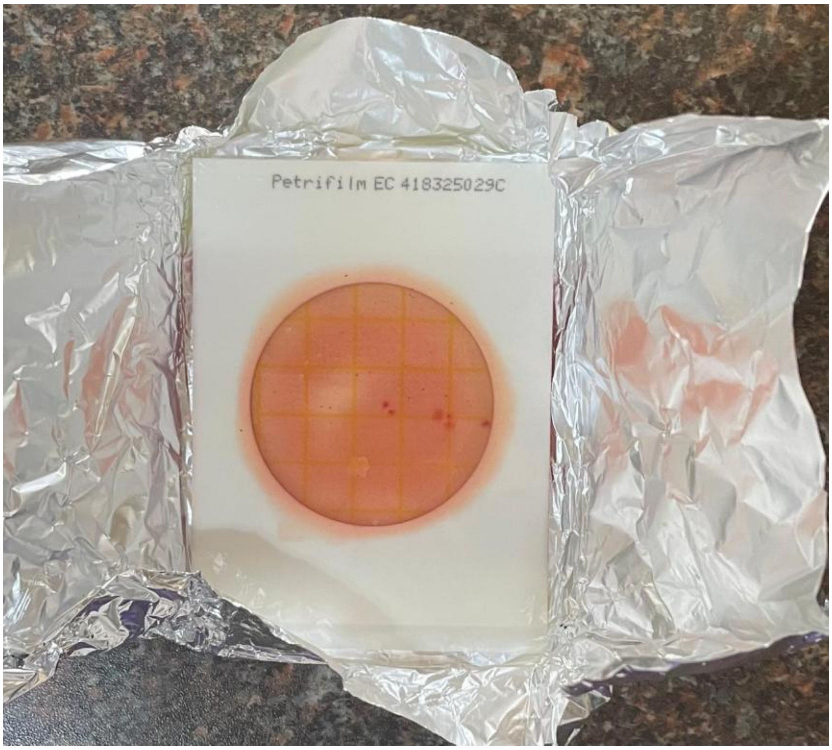

Figure 4.39 Coliform colony detection in Ngala Safari Lodge drinking water

4.3.7 Free chlorine

Free chlorine is added to water during the disinfection process to treat the water abstracted from the borehole to eliminate harmful microorganisms and pathogens. It is typically introduced as chlorine gas, which dissolves to form hypochlorous acid, HOCl. For disinfection to be effective, a free chlorine residual of at least 0,5 mg/l should be maintained after a 30-minute contact period at a pH below 8 (WHO, 2017). A residual chlorine concentration of 0.2 mg/l should remain in the distribution network to the usage points to prevent recontamination. If free chlorine levels are higher than specified by SANS 241-1:2015, it is considered a chronic health determinant as it can cause effects such as nausea and vomiting when consumed over a long period (WHO, 2017).

Table 4.11 Regulatory free chlorine limits and risk classification according to South African water quality standards

Parameter	**Free Chlorine**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	Chronic health
SANS 241:2015 Ed.2 Limits	≤ 5.0
SANS 1657:2007 Ed.2 Limits	n/a
Water Act No. 36 of 1998 Limits	2.5
DWAF Irrigation Water Quality Guidelines Limits	n/a

- Drinking water

Ngala Safari Lodge and Ngala Tented Camp did not include free chlorine testing in their laboratory analyses for drinking water. It is strongly recommended that this parameter be incorporated in future, as the absence of free chlorine may be linked to the occurrence of *E. coli* or coliform colonies (DWAF, 1996).

- Effluent

Figure 4.40 shows that Ngala Safari Lodge complied with the relevant limit for free chlorine throughout the study period. In contrast, Ngala Tented Camp recorded concentrations exceeding 50 mg/l in four of the 28 months. Such elevated levels represent an exceptionally high release of disinfectant into the environment through the irrigation of lawns and gardens. If discharged into natural water bodies, these concentrations could have negative ecological effects, including harm to aquaculture.

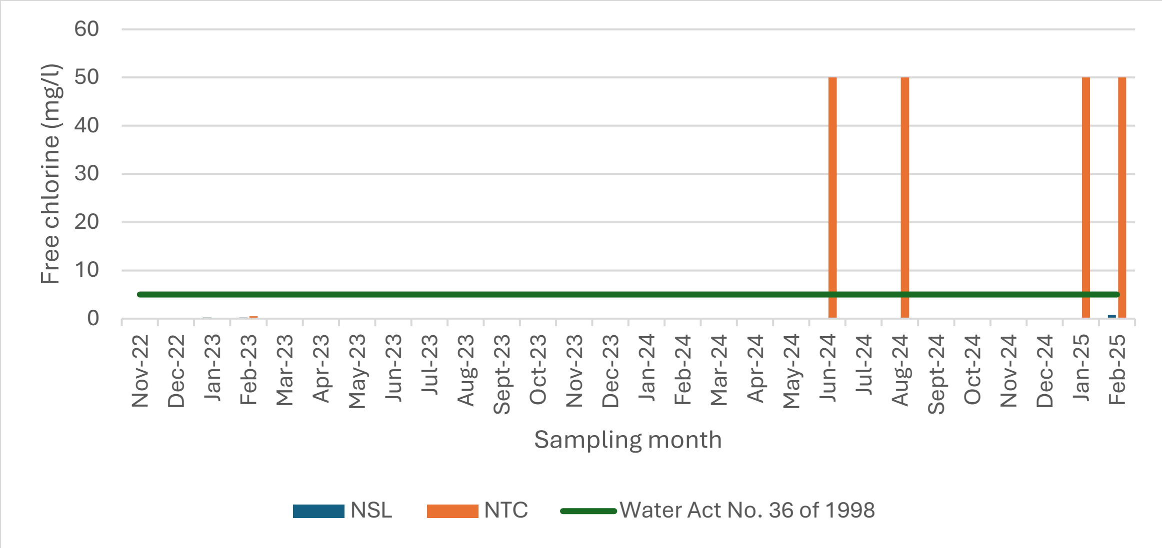

Figure 4.40 Monthly free chlorine levels of effluent water at NSL and NTC compared with the Water Act No. 36 of 1998 regulations

- iLab Results

The iLab water test showed that no free chlorine was detected in Ngala Safari Lodge and Ngala Tented Camp's drinking water, or Ngala Safari Lodge effluent water. A reading of three parts per million was detected in Ngala Tented Camp's effluent water, which aligns with the laboratory results showing increased concentrations of free chlorine (see Appendix E). This emphasises the importance of corrective action and monitoring for Ngala Tented Camp's effluent water again.

4.3.8 Arsenic

Arsenic is a semi-metal that occurs naturally in the earth's crust and in certain groundwater sources. In its soluble form, arsenic is readily absorbed by the human body but is excreted slowly, leading to gradual accumulation over time (DWAF, 1996). Therefore, even a single high-level exposure can have serious and long-lasting health effects, posing both acute and chronic health risks. Chronic exposure may result in skin hyperpigmentation and increase the risk of cancer, while acute exposure can be fatal, affecting the respiratory, gastrointestinal, and cardiovascular systems. Continuous monitoring and strict compliance with arsenic limits in water are therefore essential to protect human health.

Table 4.12 Regulatory arsenic limits and risk classification according to South African water quality standards

Parameter	**Arsenic**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	Chronic and acute health
SANS 241:2015 Ed.2 Limits	≤ 0.01
SANS 1657:2007 Ed.2 Limits	0.01
Water Act No. 36 of 1998 Limits	0.02
DWAF Irrigation Water Quality Guidelines Limits	2.0

- Drinking water

As shown in Figure 4.41, all arsenic results complied with the acceptable limit and comply with SANS 241:2015 Ed. 2 and SANS 1657:2007 Ed. 2 except for July 2024, when a concentration of 0,01 mg/l was detected. Although this was an isolated occurrence, it is essential to investigate the potential pathway through which arsenic entered the drinking water, as even a single exceedance can pose serious and potentially fatal health risks.

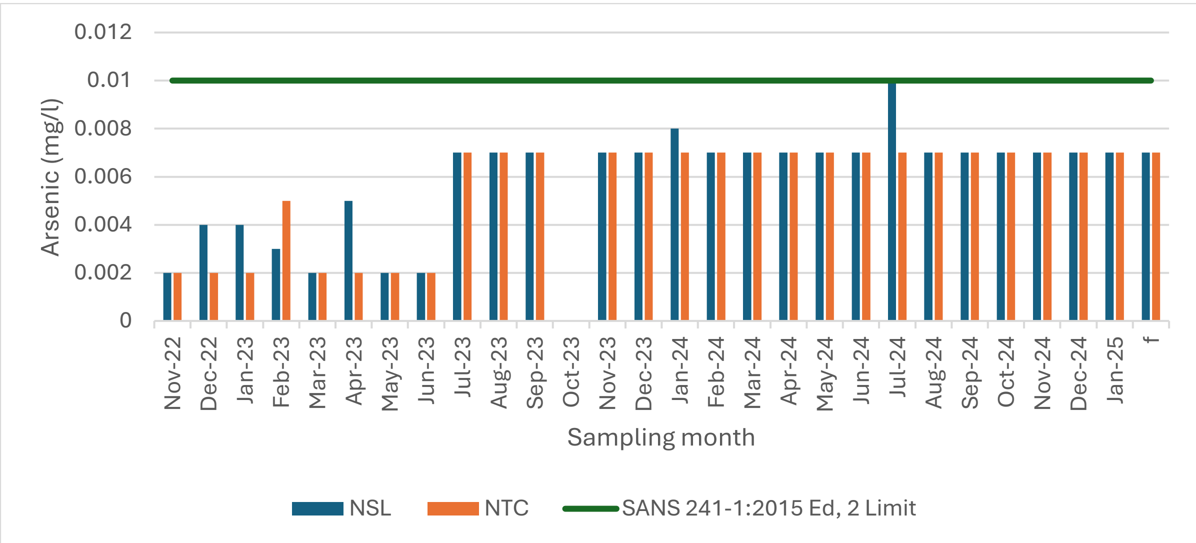

Figure 4.41 Monthly arsenic levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

4.3.9 Boron

Boron occurs naturally in groundwater mainly through the leaching of rocks and soils containing borates and borosilicates (WHO,2017). Elevated levels in surface water can also result from wastewater discharge containing traces of detergents or fertilisers. While low concentrations are not considered harmful, higher levels can cause reproductive and developmental effects, particularly with long-term exposure. Testing for boron is important for both drinking water safety and irrigation suitability, as it can be toxic to crops at elevated concentrations.

Table 4.13 Regulatory boron limits and risk classification according to South African water quality standards

Parameter	**Boron**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	None
SANS 241:2015 Ed.2 Limits	≤ 0.30
SANS 1657:2007 Ed.2 Limits	5.0
Water Act No. 36 of 1998 Limits	1.0
DWAF Irrigation Water Quality Guidelines Limits	<15

- Drinking water

Figure 4.42 shows that for most of the study period, Ngala Safari Lodge recorded boron levels above the SANS 241:2015 limit, whereas Ngala Tented Camp consistently remained well below the threshold. NSL's boron concentrations typically ranged between 0,35 and 0,5 mg/l, with slight fluctuations over time. These elevated readings indicate periods of non-compliance with the drinking water standard, suggesting potential problems related to the water source or treatment process. The underlying cause should be investigated and mitigated.

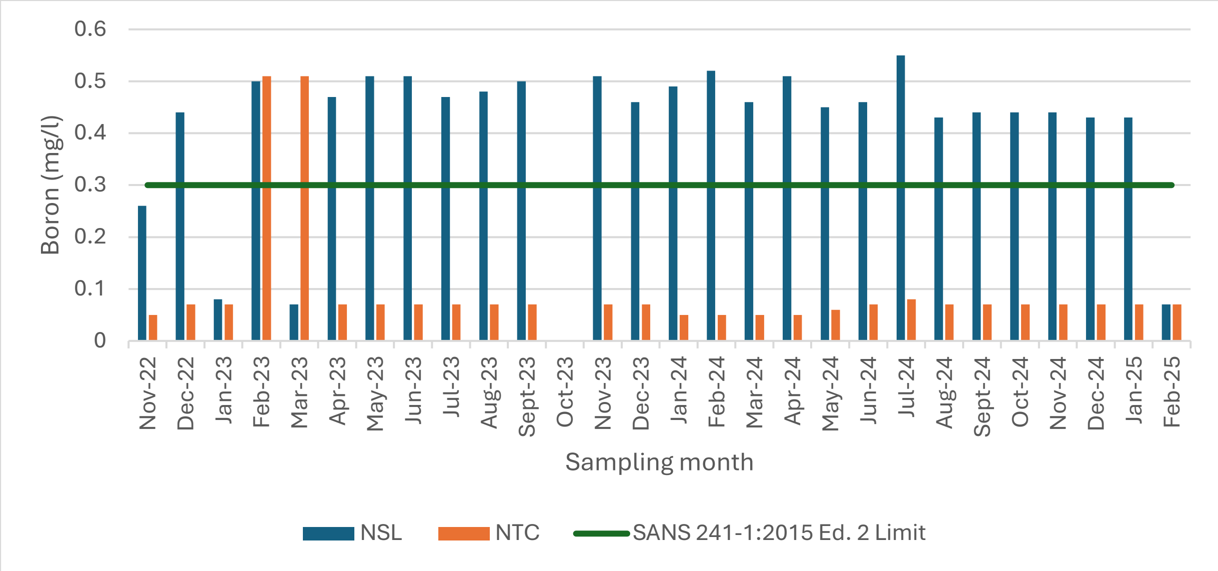

Figure 4.42 Monthly boron levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

- Effluent water

Both Ngala Safari Lodge and Ngala Tented Camp maintained boron concentrations well below the 1,0 mg/l limit throughout the study period, indicating full compliance with the National Water Act standard for effluent water to be discharged into a water source.

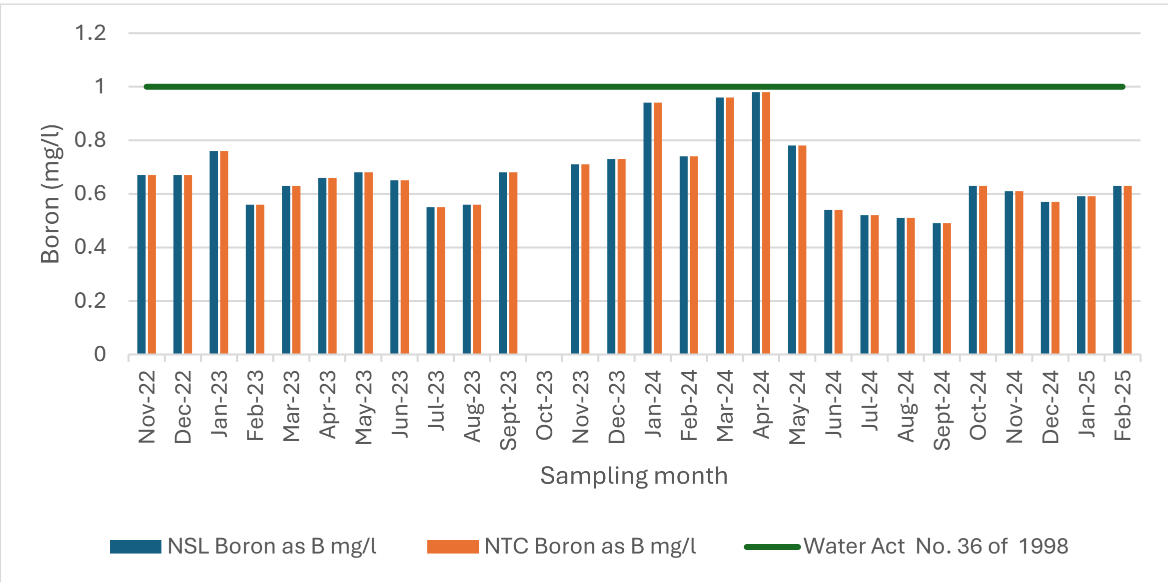

Figure 4.43 Monthly boron levels of effluent water at NSL and NTC compared with the Water Act No. 36 of 1998 regulations

4.3.10 Nickel

Nickel levels in drinking water can become elevated in areas with heavy pollution, where naturally occurring nickel in groundwater is mobilised, or when water comes into contact with nickel or chromium-plated materials such as kettles, taps, or well components made from non-resistant metals (WHO,2017). SANS 241:2015 Ed.2 classifies nickel as a chronic health risk if concentrations are above the specified limit, as nickel exposure may cause dermatitis and skin allergies. The WHO (2017) classified nickel as a possible human carcinogen, stating that exposure should be kept to a minimum.

Table 4.14 Regulatory boron limits and risk classification according to South African water quality standards

Parameter	**Nickel**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	Chronic health
SANS 241:2015 Ed.2 Limits	≤ 0.07
SANS 1657:2007 Ed.2 Limits	0.02
Water Act No. 36 of 1998 Limits	n/a
DWAF Irrigation Water Quality Guidelines Limits	< 2.0

- Drinking water

Figure 4.44 shows that throughout the study period, both Ngala Safari Lodge and Ngala Tented Camp consistently recorded nickel concentrations below the SANS 241 limit, indicating compliance with national drinking water standards. However, when compared with the SANS 1657 bottled water guideline, which has a lower acceptable limit, January and February 2023, and August to 2024 to December 2024 showed readings that were equal to or slightly above the limit. These fluctuations suggest occasional increases in nickel levels, but still within safe limits for general drinking water quality. An investigation should be done to determine the source of nickel and how to mitigate it.

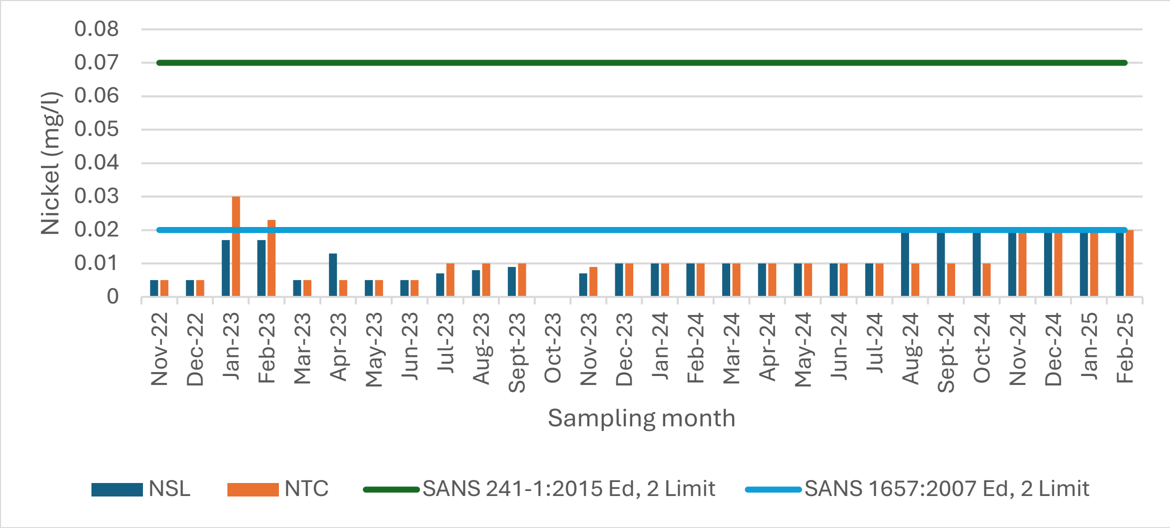

Figure 4.44 Monthly nickel levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 and SANS 1657:2007 Ed. 2 limits

- Effluent water

Ngala Safari Lodge and Ngala Tented Camp did not include nickel testing in their effluent water laboratory analyses during the study period, resulting in an incomplete dataset for this parameter. It is recommended that nickel be added to the list of monthly laboratory tests, as the DWAF Irrigation Water Quality Guidelines specify a limit of 2 mg/l for irrigation water. This is important as Ngala Tented Camp reuses its treated effluent water for lawn irrigation.

4.3.11 Fluoride

Fluoride in water is a naturally occurring ion that originates from the weathering and dissolution of fluoride-bearing minerals in rocks and soils. It can also enter water sources through industrial discharges or fertiliser runoff. At low concentrations, fluoride provides human health benefits by strengthening tooth enamel and preventing dental decay (WHO, 2017). At elevated levels, it may cause dental or skeletal fluorosis, which causes damage to teeth and bones (DWAF, 1996). Under SANS 241-1:2015, fluoride is identified as a chronic health risk.

Table 4.15 Regulatory fluoride limits and risk classification according to South African water quality standards

Parameter	**Fluoride**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	Chronic health
SANS 241:2015 Ed.2 Limits	≤ 1.5
SANS 1657:2007 Ed.2 Limits	n/a
Water Act No. 36 of 1998 Limits	1.0
DWAF Irrigation Water Quality Guidelines Limits	15

- Drinking water

During the study period, both Ngala Safari Lodge and Ngala Tented Camp maintained fluoride concentrations within the SANS 241-1:2015 Ed. 2 limit. NSL displayed slightly higher and more variable fluoride levels. Both lodges' results confirm that the water supplied to guests and staff remains safe for consumption and in compliance with national standards.

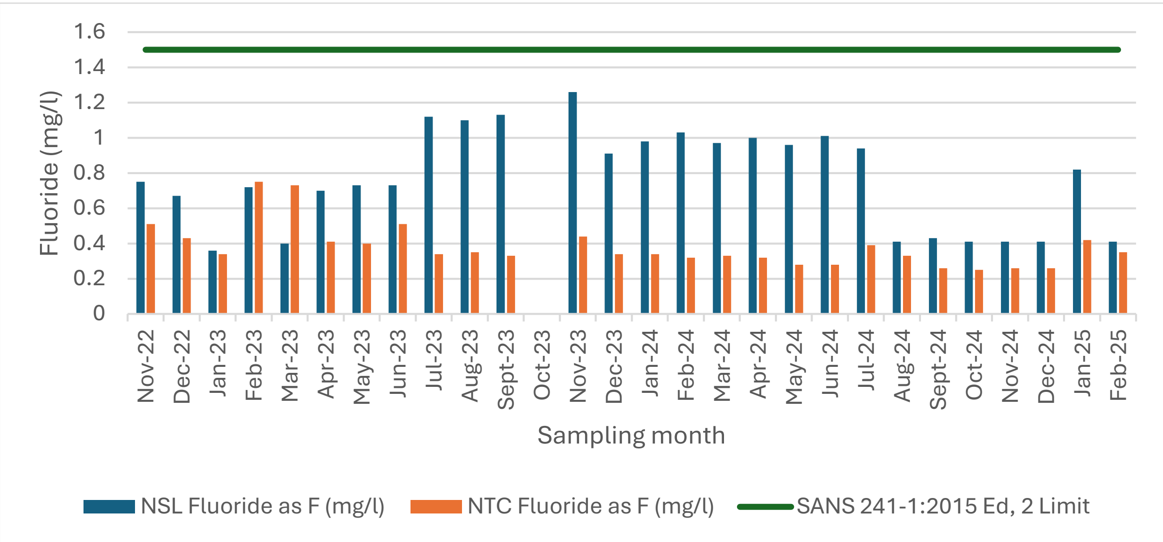

Figure 4.45 Monthly fluoride levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

- Effluent water

Fluoride concentrations at Ngala Safari Lodge were over the acceptable limit in August and December 2023, as well as February 2024, but remained within the regulatory limit the rest of the study period. Ngala Tented Camp showed greater variability, with exceeded fluoride levels between January and April 2024. Overall, both lodges complied, with variations reflecting short-term operational or treatment inefficiencies.

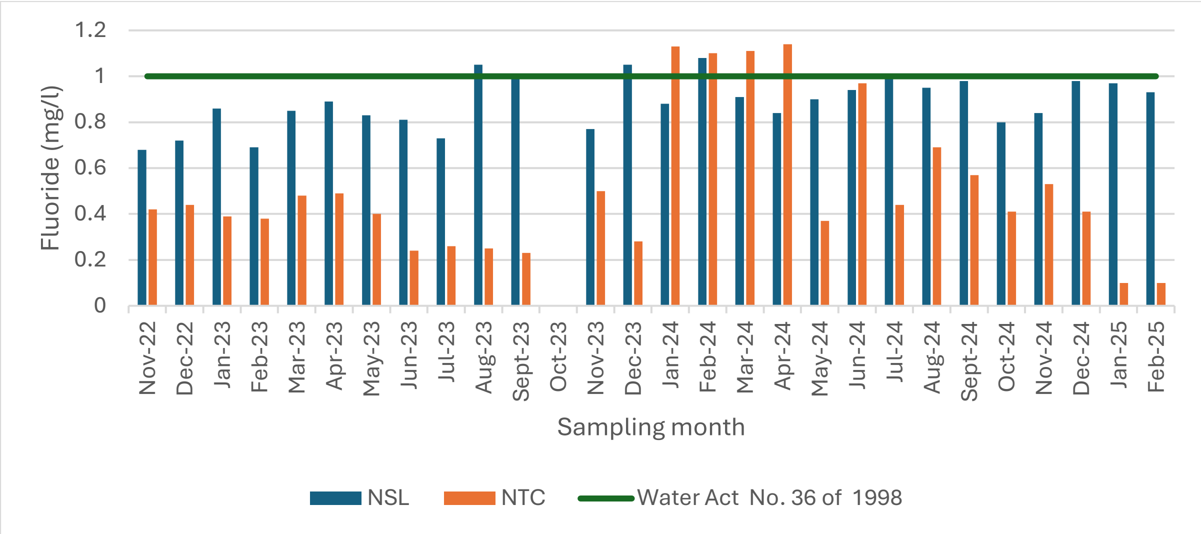

Figure 4.46 Monthly boron levels of effluent water at NSL and NTC compared with the Water Act No. 36 of 1998 regulations

4.3.12 Selenium

Selenium is a semi-metal that naturally occurs in trace amounts in rocks and soils, and small quantities are essential for human health. In small quantities, selenium is essential for human health, playing a role in antioxidant defence systems and thyroid hormone metabolism. However, excessive selenium intake through drinking water can pose a chronic health risk (DWAF, 1996; WHO, 2017).

Under SANS 241:2015 Ed.2, selenium is classified as a chronic health determinant, with a maximum allowable concentration of ≤ 0,04 mg/l. Prolonged exposure to selenium concentrations above this limit may lead to selenosis, a condition characterised by hair and nail loss, skin lesions, garlic-like breath odour, neurological disturbances, and gastrointestinal symptoms (WHO, 2017). More severe exposure can result in liver and kidney dysfunction.

Table 4.16 Regulatory selenium limits and risk classification according to South African water quality standards

Parameter	**Selenium**
Unit	mg/l
SANS 241:2015 Ed.2 Risk Type	Chronic health
SANS 241:2015 Ed.2 Limits	≤ 0.04
SANS 1657:2007 Ed.2 Limits	0.01
Water Act No. 36 of 1998 Limits	0.02
DWAF Irrigation Water Quality Guidelines Limits	< 0.05

- Drinking water

Figure 4.47 shows selenium concentrations at Ngala Safari Lodge and Ngala Tented Camp complied with the SANS 241:2015 Ed.2 limits throughout the study period. However, Ngala Safari Lodge showed Minor fluctuations were observed at NSL, with slightly elevated readings in April and May 2023, while NTC recorded a single higher value in February 2023. These temporary increases were minor and did not approach the regulatory limit. Overall, selenium levels at both lodges were stable, safe, and compliant, indicating effective water management and no significant contamination risk.

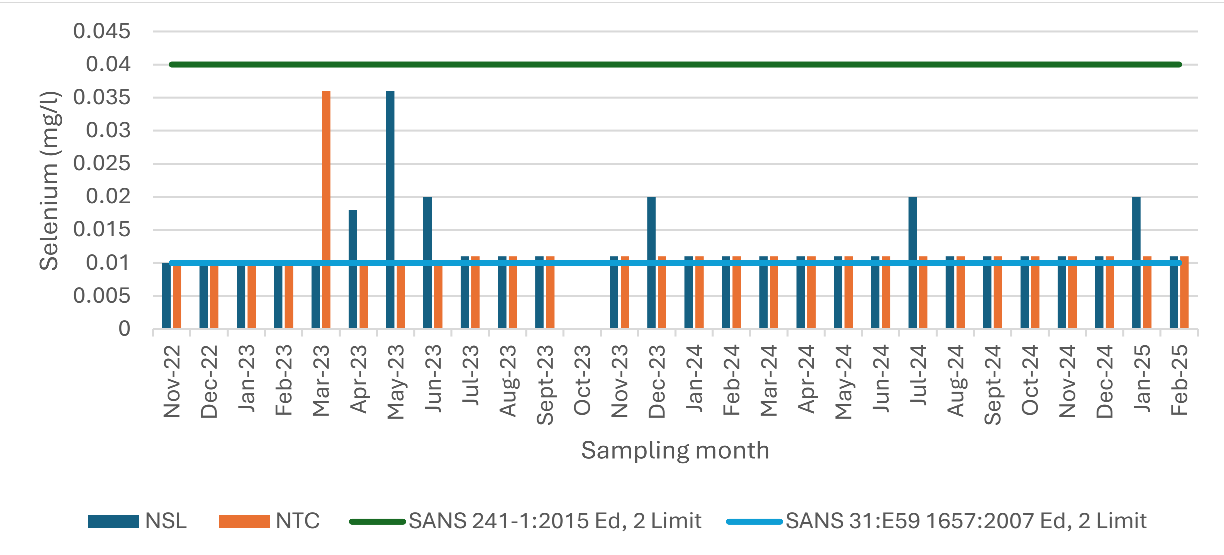

Figure 4.47 Monthly selenium levels of drinking water at NSL and NTC compared with SANS 241:2015 Ed. 2 limits

4.4 Key Participant Interviews

This section presents the qualitative findings from the semi-structured interviews with management, maintenance personnel, and general staff at Ngala Safari Lodge and Ngala Tented Camp. This section aims to explore how sustainable water management is understood, implemented, and experienced by different functional groups within the lodges. The analysis focuses on thematic areas aimed at addressing the objectives of the study.

These insights provide context to the quantitative water-use and water-quality results presented earlier in this chapter, allowing for a more comprehensive understanding of how technical systems, organisational culture, and human behaviour interact to shape water sustainability outcomes.

4.4.1 Interview Questions and Responses

1. What sustainable water management practices, such as water saving interventions, are currently implemented at Ngala Safari Lodge and Ngala Tented Camp to minimise water consumption and maintain water quality?

Across the interviews, sustainable water management at Ngala Safari Lodge and Ngala Tented Camp was described as technical and infrastructure-based interventions, with few operational or behavioural measures implemented. Maintenance staff described engineering upgrades that improved the lodge's water system, including the installation of a second variable speed drive pump to support pressure-based water reduction, the recent installation of LoRa water meters for automated and accurate water use monitoring, and the addition of a borehole meter to record total abstraction. Treated wastewater is reused for irrigation at Ngala Tented Camp. Participant 5 explained that "*the second variable speed drive pump allows the system to lower pressure without changing flow, with consumption now being captured by a meter on the main borehole line"* (P5).

However, the lodge faces operational constraints due to its hard groundwater. Participants explained that shower restrictors, push taps and efficient showerheads often become blocked with lime, making standard water-saving devices ineffective. Maintenance staff also noted that technologies such as reverse osmosis or salt-based softeners are not viable because of the high sodium content and associated costs. As a result, Ngala cannot rely on typical physical water-saving solutions used at other lodges.

At the departmental level, sustainability practices were described as minimal and mainly informal. Staff noted that the kitchen does not reuse water or follow structured conservation procedures. Greywater is occasionally reused for gardens, and Participant 2 stated *"they take* *showers instead of baths, while general staff perform personal habits such as washing dishes in small basins and reporting leaks promptly"*. The findings indicate that Ngala's current water management strengths lie in technical interventions, while operational water-saving behaviour remains limited.

2. How would you describe the level of commitment from &Beyond's top management towards implementing and sustaining water management practices at Ngala Safari Lodge and Ngala Tented Camp?

All participants rated top management's commitment to water sustainability as high, with scores between 9/10 and 10/10. Management was recognised for obtaining a Water Use Licence, driving engineering upgrades, participating in SANParks Concession compliance audits and investing in improved monitoring systems. Participant 5 summarised this view by stating, *"Management is very committed, they just needed someone practical to connect the issues with the solutions"*.

3. In your opinion, how committed are the general staff members at Ngala Safari Lodge and Ngala Tented Camp towards sustainable water management? Are there any initiatives in place to enhance their engagement?

In contrast to management, the general staff were described as having low commitment to water-saving practices. Ratings ranged from 0/10 to 6/10, highlighting the variability of the general staff's perception of sustainable water use. The most common reasons included limited awareness of Ngala's water-use requirements, no formal education or training, and a perception that water conservation does not affect them personally. Participant 2 noted: *"Some people are here because they are passionate about conservation, but a lot are here because it's a job. They won't be motivated unless it affects them"*.

Despite this, several staff indicated that they are willing to follow instructions when expectations are clearly communicated. Participant 3 stated: *"If they tell us what to do, we listen and we follow."* These responses indicate an opportunity to educate staff and implement more sustainable practices.

4. What measures are currently in place to ensure that the water provided to guests and staff meets all relevant laws, regulations, and standards for water quality?

Water quality was a strong and frequent theme during interviews. Staff described personal and operational challenges linked to the hard water, including hair loss, dry skin, damaged clothing and frequent appliance failures. Participants also described the water as salty or unpleasant to taste. Participant 6 stated: *"My kettle was ruined after using tap water twice"*.

5. How does Ngala Safari Lodge and Ngala Tented Camp ensure that water usage by both guests and staff is compliant with local water regulations and standards concerning sustainable quantities?

Interviews revealed gaps in awareness regarding Ngala Safari Lodge and Ngala Tented Camp's water use targets. Only management and maintenance staff were aware of the lodge's 350 l/b/n limits. At the time of the interviews, there were no behaviour-based practices in place to conserve water for guests and staff. Existing measures consisted mainly of leak reporting, metering, and the use of the VSD pump to reduce pressure and consumption. Participant 5 explained: *"They would be more committed if they understood what 350 litres actually means,"* highlighting the need for training and education.

6. What measures or initiatives have been implemented to raise awareness among guests and staff regarding the importance of sustainable water use? How effective have these measures been?

Awareness initiatives were described as fragmented and inconsistent. For guests, communication is largely passive and includes sustainability cards placed in rooms, as well as occasional discussions during game drives, which mostly relate to the ecological role of water. For staff, participants reported no structured training, no dedicated sessions on water use, and language barriers that make communication difficult. Even so, staff expressed willingness to learn and participate if provided with proper guidance.

7. Under &Beyond's Impact Model (Care of the Land; Care of the People; Care of the Wildlife), what specific practices are promoted at Ngala Safari Lodge and Ngala Tented Camp to ensure sustainable water management in line with these principles?

Participants showed varied understanding of how water management fits into &Beyond's Impact Model. Some staff linked responsible water use to ecological protection. Participant 4 stated: *"If I waste water, the animals also need that water. We must think of tomorrow, for children's children."* This indicated an understanding of sustainable water management and a willingness to participate if training and education are provided.

8. In terms of sustainable water management, where do you think Ngala Safari Lodge and Ngala Tented Camp rank compared to other &Beyond lodges? What factors contribute to this ranking?

Participants described &Beyond's Phinda as having greywater reuse systems and stronger staff engagement in sustainability based on what they saw on their social media pages and visits. In comparison, Ngala faces unique challenges due to extremely hard groundwater and has fewer staff dedicated to sustainability. Participant 6 stated: *"At Phinda, everyone understands the* *system. Here it is still developing."* This highlights the need for Ngala to strengthen both its technical systems and its behavioural components of water management.

4.4.2 Interview Findings

The interview findings provide important context for understanding the quantitative water-use and water-quality results at Ngala Safari Lodge and Ngala Tented Camp. Overall, sustainable water management is largely driven by technical and infrastructure-based interventions, with limited operational or behavioural water-saving practices in place. This finding aligns with Gössling *et al*. (2015), who emphasise that tourism establishments frequently prioritise technological solutions such as metering, pressure regulation systems, and water-treatment technologies to improve water efficiency. Similarly, Becken and McLennan (2017) found that resource management within tourism operations is often focused on technical interventions rather than behavioural change initiatives.

The strong emphasis on engineering controls at Ngala Safari Lodge and Tented Camp, including the installation of LoRa water meters, VSD pumps, and improved monitoring systems, demonstrates a proactive management approach towards sustainable water management. These findings support the principles of SDG Goal 6 (United Nations, 2015), particularly regarding improved water-use efficiency, monitoring, and responsible resource management. Furthermore, the implementation of monitoring systems and abstraction controls reflects aspects of IWRM, which promotes informed decision-making and sustainable use of water resources.

The interviews revealed a high level of commitment from top management towards sustainable water management. Participants consistently rated management commitment highly and highlighted investments in infrastructure upgrades, compliance monitoring, and regulatory requirements. This finding is consistent with Liu *et al*. (2013), who found that management commitment is a key driver of sustainability performance in tourism establishments. Sustainable tourism literature further suggests that leadership support is essential for the successful implementation of environmental initiatives and long-term sustainability outcomes.

In contrast, the interviews revealed relatively low levels of awareness and engagement among general staff regarding sustainable water use. Participants indicated that limited training, insufficient communication, and a lack of understanding of water-use targets contribute to low levels of participation in water conservation initiatives. This finding supports previous studies which suggest that staff awareness and behavioural engagement are critical components of successful water management programmes (Gössling *et al*., 2015). While technical interventions can improve efficiency, sustainable water management requires active participation from employees at all organisational levels. The willingness of staff to follow guidance when expectations are clearly communicated suggests that targeted education and awareness programmes could significantly improve water-saving behaviour at Ngala.

Water quality emerged as another important theme during the interviews. Participants frequently described challenges associated with hard groundwater, including impacts on household appliances, infrastructure, personal comfort, and operational efficiency. These perceptions correspond with the quantitative findings, which identified elevated hardness, conductivity, and total dissolved solids in the water supply. Similar challenges have been documented in remote tourism operations that rely on groundwater sources, where natural hydrochemical conditions often present management difficulties despite compliance with water quality regulations (Gleick, 2018). The findings therefore suggest that some water-quality concerns experienced at Ngala are linked to natural environmental conditions rather than inadequate management practices.

The interviews further highlighted limited awareness of water-use benchmarks and water-consumption targets among staff members. Most participants were unaware of the lodge's internal benchmark of 350 litres per bed-night. This finding supports the argument that sustainability initiatives are more effective when performance targets are communicated clearly throughout an organisation. According to SDG 6 principles and sustainable tourism best practice, awareness and participation are necessary to complement technical measures and promote responsible resource use.

Participants recognised the relationship between water management, biodiversity conservation, and environmental stewardship, as several participants acknowledged that water is a shared resource required by both humans and wildlife, reflecting an understanding of the broader sustainability objectives promoted under &Beyond's Impact Model. These views align with sustainable tourism principles, which emphasise balancing environmental conservation, social responsibility, and operational requirements to ensure long-term sustainability (Liu *et al.*, 2013).

The findings suggest several practical actions that could strengthen sustainable water management at Ngala Safari Lodge and Ngala Tented Camp. These include the implementation of regular staff training and awareness programmes, the communication of water-use targets and performance indicators, the incorporation of water conservation responsibilities into staff induction processes, and the provision of ongoing feedback regarding water-use performance. In addition, behavioural interventions such as awareness campaigns, visual reminders, and departmental water-saving initiatives could complement existing technical measures and further improve water-use efficiency. These actions would support the objectives of SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land), while strengthening long-term environmental stewardship within the lodges. The finding from the study should also be considered within the broader South African context, which may influence how water is perceived and valued by both staff and management. South Africa is classified as a water-scarce country and has experienced recurring droughts, water restrictions, and infrastructure challenges over recent decades. Despite these challenges, access to municipal water services in many communities often creates a perception that water is readily available and that responsibility for water management rests primarily with authorities rather than individual users. This may partly explain the limited awareness of water-use targets and the low levels of behavioural engagement observed among some staff members at Ngala Safari Lodge and Ngala Tented Camp.

Furthermore, South Africa's socio-economic inequalities and diverse cultural backgrounds influence how environmental issues are prioritised. For many individuals, employment security, income generation, housing, and basic service delivery may be viewed as more immediate concerns than environmental sustainability initiatives. Similar findings have been reported by studies in developing countries, where environmental stewardship is often secondary to socio-economic priorities. This differs from many developed countries, where sustainability awareness programmes are more deeply embedded within organisational culture and environmental education systems. Consequently, the limited staff engagement observed in this study may not solely reflect organisational shortcomings but may also be influenced by broader societal and developmental factors.

Overall, the interview findings confirm that Ngala's water management systems are technically well developed and supported by strong management commitment. However, the findings also indicate that future improvements should focus on strengthening staff awareness, behavioural interventions, and organisational engagement with water conservation practices.

4.5 Chapter Conclusion

This chapter analysed water use and water quality data from Ngala Safari Lodge and Ngala Tented Camp, supported by qualitative insights from staff interviews. The results show that water consumption at both lodges remains relatively consistent throughout the year and is largely driven by fixed operational demands rather than seasonal climatic variation or changes in occupancy. Periodic exceedances in water use per bed-night were observed, particularly during low-occupancy and refurbishment periods.

Water quality results indicated general compliance with applicable standards; however, challenges related to hard groundwater, elevated salinity, and intermittent microbial exceedances were identified. These issues are primarily linked to natural hydrogeological conditions and infrastructure limitations. Interview findings confirmed strong management commitment and technical water-saving interventions but highlighted limited staff awareness and behavioural water-saving practices. Overall, the findings indicate that while Ngala's technical water management systems are well established, further improvements in staff engagement and education, as well as operational practices, are needed to enhance long-term sustainability.

The following chapter presents the overall conclusions of the study in relation to the research objectives and integrates the key quantitative and qualitative findings. It outlines practical recommendations to improve water-use efficiency, water quality management, and staff engagement at Ngala Safari Lodge and Ngala Tented Camp, and identifies areas for future research.

5. Chapter 5 - Synthesis, Recommendations, Limitations of the Study and Conclusion

5.1 Introduction

In this final chapter, the results were integrated and discussed in relation to the study's objectives and suggested recommendations derived from the results and analysis. The chapter concludes with a summary that brings together the insights of the research and outlines the overall contribution of the study.

5.2 Synthesis

5.2.1 Objective 1 - To assess the water usage trends at Ngala Safari Lodge and Ngala Tented Camp, establish a baseline, and determine compliance with relevant benchmarks.

The analysis of the 28-month dataset revealed the water use patterns at Ngala Safari Lodge and Ngala Tented Camp, which served as the baseline assessment. This dataset showed an average water use per bed-night of 351,36 l/b/n at Ngala Safari Lodge, which slightly exceeded the Ngala Environmental Operations Manual benchmark of 350 l/b/n. Ngala Tented Camp averaged 332,85 l/b/n, remaining below the benchmark. Although both lodges achieved acceptable average values, monthly variability was high, with Ngala Safari Lodge exceeding the limit in 10 of the 28 months and Ngala Tented Camp in 12 of the 28 months, six of which occurred during the refurbishment period. This indicates that exceedances were intermittent and likely driven by operational factors rather than systemic overuse. The variability in water use suggests that the lodges' water use targets may not be effectively communicated or incorporated into general operational activities. The lack of awareness among staff and guests means that water-saving objectives are not influencing decision-making or daily activities, contributing to benchmark exceedances.

Both lodges demonstrated a weak positive correlation between occupancy and total water use, indicating that fixed operational demands drive most daily water use, for example, the kitchen, laundry, irrigation and maintenance, rather than the number of guests. Pearson correlations showed that occupancy explained only 2 to 2,2% of variation in total daily consumption at both lodges, confirming that water use remains mostly constant independent of guest volumes.

A stronger negative correlation was observed between occupancy and litres per bed-night, with higher occupancy associated with lower average water use per bed-night. Pearson correlation results indicated that occupancy explained approximately 46.7% to 51.5% of the variation in water use per bed-night. During periods of low occupancy, average bed-night consumption increased due to fixed operational water use. Ngala Tented Camp's refurbishment period from April 2024 to October 2024 highlighted this trend, with extremely high l/b/n values when construction activities continued despite low bed-nights.

Seasonal analysis using ANOVA confirmed that water use is not significantly influenced by season at either lodge ($p > 0,28$ for total daily use, $p > 0,42$ for l/b/n at NSL; $p > 0,31$ for total daily use, $p > 0,97$ for l/b/n at NTC). This indicates constant operational water demand throughout the year.

The findings of this study challenge the conventional assumption that guest occupancy is the primary driver of water consumption in tourism accommodation facilities. While occupancy influenced water use efficiency, as reflected by litres per bed-night, it had little influence on total daily water consumption. Instead, the results suggest that fixed operational activities such as laundry, kitchen operations, staff accommodation, irrigation, swimming pool maintenance, and infrastructure-related water use contribute substantially to total water demand.

The findings contribute to the growing body of literature recognising the importance of baseline operational water requirements within tourism facilities. For remote wildlife lodges, where accommodation, hospitality, staff housing, and environmental management functions operate continuously, water demand may be less responsive to occupancy fluctuations than is often assumed. This has important implications for water management planning, as reductions in occupancy may not necessarily translate into proportional reductions in water consumption.

5.2.2 Objective 2 - To investigate the physical, chemical and microbial water quality at Ngala Safari Lodge and Ngala Tented Camp for drinking and effluent water.

The water quality analysis over 28-months mostly complied with SANS 241:2015 for drinking water and with the National Water Act and DWAF Guidelines for effluent water, with some parameters exceeding acceptable limits at both lodges. pH levels remained within the acceptable limits throughout the study period. However, various readings exceeded a pH of 8, indicating a tendency toward slight alkalinity that aligns with the regional hydrogeochemical characteristics of groundwater in the area (Mpenyana-Monyatsi *et al.*, 2012). The hardness levels were of concern, particularly at Ngala Safari Lodge, where readings frequently exceeded 500 mg/l, which is well above the acceptable limit and is associated with many risks. The implications of this extreme hardness were reinforced by key participant interviews, which highlighted increased maintenance requirements, appliance breakages and discomfort experienced by staff. Conductivity and total dissolved solids (TDS) levels reinforced these findings, as Ngala Safari Lodge and Ngala Tented Camp exceeded the conductivity and TDS limit in 19 of the 28 monitored months, highlighting the long-term elevated dissolved salt concentration. These results indicate that the groundwater supplying both lodges is highly mineralised, which contributes to the below-par physical water quality parameters observed.

Chemical parameters were also investigated, where a gap in water quality monitoring was identified in the absence of free chlorine testing in the drinking water supply, despite its role in verifying the effectiveness of disinfection processes and ensuring microbiological safety in water distribution systems. Free chlorine levels in the effluent water at Ngala Tented Camp were excessively high, with concentrations exceeding 50 mg/l during several months, which poses a risk of environmental pollution when discharged into waterbodies and soils. Trace metal analysis showed acceptable results in general, although some exceedances were observed. Arsenic levels remained within acceptable limits throughout the study period except for a single month in which the concentration reached 0,01 mg/l, warranting further investigation into potential pathways of contamination. Boron concentrations at Ngala Safari Lodge frequently exceeded the SANS 241:2015 limit, suggesting the need for an assessment of geological or operational sources. Other trace elements, including nickel, fluoride, and selenium, remained compliant with relevant standards, exhibiting only minor fluctuations that did not exceed health-related benchmarks. Collectively, these findings highlight both strengths and gaps in chemical water quality management across the two lodges.

The analysis of microbial determinants revealed some critical water quality concerns. Multiple exceedances of *Escherichia coli* were detected in the drinking water at Ngala Safari Lodge and Ngala Tented Camp, which may be attributed to rainfall infiltration and/or contamination of the borehole or storage systems. The effluent water results at Ngala Tented Camp were non-compliant in 46% of the monitored months after treatment and frequently exceeded the maximum detectable concentration of *E. coli*. This treated effluent water is used to irrigate lawns and garden areas, which pose an environmental and human-health risk. Total coliform levels further highlighted the shortcomings in the treatment system, as Ngala Tented Camp exceeded the drinking water limit in 10 months, while Ngala Safari Lodge recorded exceedances twice. Effluent samples from both lodges showed high total coliform counts, indicating ineffective wastewater treatment processes and suggesting possible recontamination within the distribution or storage systems.

Permission to conduct this research and to utilise the operational water quality data was formally granted by &Beyond through a Memorandum of Agreement with UNISA (Appendix C). The study was undertaken with the knowledge and support of the participating organisation, and the findings are presented for academic and sustainability management purposes. The intention is not to highlight organisational shortcomings, but rather to identify opportunities for continuous improvement in water management practices and to contribute to the broader body of knowledge relating to sustainable water management in the wildlife tourism sector.

Overall, the water quality results indicate general compliance with relevant standards and regulations, pardon a few readings. This may suggest periods of non-optimal treatment performance, as well as gaps in monitoring and system maintenance. Although these occurrences are minimal, they may pose a risk to human health, lodge infrastructure, and the surrounding environment.

5.2.3 Objective 3 - To explore staff perceptions and experiences of water quality and usage, and to understand how these contribute to daily operations and well-being.

The qualitative insights obtained from staff interviews supported the quantitative findings and provided additional context regarding the water quality and water-use challenges experienced at Ngala Safari Lodge and Ngala Tented Camp. Although staff generally expressed positive perceptions of the lodges' water management systems, many reported experiencing the practical effects of extremely hard water, including impacts on personal well-being, household appliances, and operational activities. These findings support the quantitative water quality results, which identified elevated hardness levels throughout the study period, and demonstrate how water quality influences not only environmental compliance but also daily operational efficiency and employee well-being.

The interviews further highlighted gaps in awareness regarding the lodges' water-use objectives. While management and maintenance personnel demonstrated an understanding of water-use limits and internal benchmarks, general staff had limited knowledge of the targeted consumption rate of 350 litres per person per day. Participants indicated that greater communication and education regarding water-use expectations would encourage more responsible water-use behaviour. This finding is consistent with Gössling *et al*. (2015), who emphasised that effective sustainable water management requires both technical interventions and behavioural engagement. Similarly, Liu *et al*. (2013) found that sustainability initiatives are often management-driven, with limited employee participation unless awareness and training programmes are actively implemented.

The findings suggest that water quantity and water quality management cannot be viewed solely as technical or compliance-related issues. Instead, they are closely linked to social sustainability through their influence on staff well-being, workplace experiences, and operational effectiveness. The absence of structured water conservation training and education highlights a gap between management commitment and employee engagement. However, the willingness expressed by staff to participate in sustainability initiatives demonstrates an opportunity to strengthen behavioural water conservation measures and improve overall water-use efficiency.

This study contributes to the broader sustainable tourism and water management literature by demonstrating that successful water stewardship within wildlife tourism operations depends not only on infrastructure, monitoring systems, and regulatory compliance but also on employee awareness and participation. The findings therefore reinforce the importance of integrating technical, social, and behavioural dimensions of sustainable water management, particularly within the South African wildlife tourism context where water scarcity, environmental stewardship, and operational sustainability are closely interconnected.

The findings of this objective also demonstrate the relevance of sustainable water management within the context of the United Nations Sustainable Development Goals (SDGs). The identified opportunities to improve water-use awareness and conservation practices among staff support SDG 12 (Responsible Consumption and Production), which promotes the sustainable use of natural resources and encourages resource-efficient operational practices. Furthermore, the management of drinking water quality and treated effluent quality contributes to SDG 6 (Clean Water and Sanitation) by supporting safe water use and reducing potential risks to human health. Effective wastewater management and the prevention of contamination of surrounding ecosystems are also aligned with SDG 15 (Life on Land), which aims to protect terrestrial ecosystems and minimise environmental degradation. Consequently, the findings demonstrate that employee awareness and participation are not only important for operational sustainability but also contribute to broader global sustainability objectives.

5.2.4 Objective 4 - To examine current water management systems and practices to determine their contribution to sustainable water use.

The findings indicate that both lodges have well-developed water management infrastructure, including boreholes, variable-speed drive pumps, purification systems, storage networks, and wastewater treatment facilities. The operational performance of these systems is generally effective. However, certain areas require attention to improve their sustainability and safety. Areas of the treatment process requiring further investigation include the elevated conductivity and TDS levels, as well as the recurring microbial detections, as mentioned under the synthesis of Objective 2.

Ngala Tented Camp's wastewater treatment plant enables effluent water to be reused for irrigation. In contrast, the outdated system at Ngala Safari Lodge does not support reuse, resulting in continued high reliance on groundwater abstraction. The high fixed operational water demand further contributes to overall consumption, aligning with the findings that occupancy has little influence on total daily water use. These points demonstrate that although the physical systems are in place, greater emphasis on water-use management, monitoring, and awareness is required to ensure the system contributes to sustainability more holistically.

5.2.5 Objective 5 - To evaluate the extent to which the lodges' water management practices align with principles of environmental stewardship and sustainable tourism.

The sustainable management of water at both lodges shows a general alignment with sustainable tourism best practices, with some areas to be targeted for improvement. When evaluated against sustainable tourism best practice, the Ngala Environmental Operations Manual water-use targets, and the broader aims of Sustainable Development Goal 6 - Clean Water and Sanitation, the lodges demonstrate a general alignment with recognised principles of environmental stewardship.

Several positive aspects are evident, as both lodges conducted routine laboratory testing, obtained water use licenses, maintained monitoring records, and invested in advanced treatment technologies. Ngala Tented Camp has further implemented sustainable practices by reusing treated effluent for irrigation, and both lodges have adopted variable-speed drive pumps to improve operational efficiency. Regular environmental reporting through ECO reports and environmental audits also reflects a commitment to regulatory compliance.

Areas for improvement include maintaining consistent compliance with the physical, chemical, and microbial parameters of water quality, as well as strengthening efforts to meet water consumption targets. The outdated wastewater treatment plant at Ngala Safari Lodge hinders the lodge's commitment to environmental stewardship and sustainable tourism, as treated water cannot currently be reused, and the system poses a risk of exposing the environment, fauna, and flora to contaminated effluent water. Regular educational and awareness workshops should be implemented across all staff levels to provide clear updates on the lodge's performance regarding water quantity and quality, and to create a platform for collectively identifying challenges and discussing actions to address them.

Overall, while the lodges demonstrate a clear commitment to sustainable practices in principle, greater effort is required to achieve full implementation. The current gaps indicate that environmental stewardship and sustainable tourism goals are recognised, but not yet fully operationalised.

5.2.6 Objective 6 - To identify gaps in current practices and propose best-practice recommendations that enhance environmental, social, and economic sustainability.

The synthesis across all research objectives revealed gaps and opportunities that collectively limit the sustainability of water management at both lodges.

Environmentally, the non-compliances of the relevant standards and regulations highlighted challenges in maintaining sustainable water quality. These non-compliances may pose risks to the surrounding environment, as untreated or inadequately treated water can infiltrate soils, contaminate nearby waterbodies, and introduce substances that may be toxic to plant and animal life. The limitations of the wastewater treatment system at Ngala Safari Lodge have been discussed in Objective 5's synthesis. Improving the treatment processes would not only enhance compliance but also support ecosystems and biodiversity and reduce long-term environmental impacts.

Socially, the findings highlighted implications for staff well-being, as staff reported adverse effects linked to poor water quality, including skin irritation, hair loss, and discomfort during daily use. A lack of staff awareness regarding water-use targets and sustainable practices was evident, with many staff unaware of benchmark limits or the necessity for water conservation. Currently, no open communication or educational initiatives are in place to discuss the importance of water conservation at the lodges, creating an opportunity to better educate staff and guests about water's role in all aspects of life and how it can be managed sustainably.

Economically, the lodges face increased operational costs associated with poor source water quality and system inefficiencies. High electricity consumption is required to operate pumps and treatment systems continuously, particularly given the mineralised nature of the groundwater. The extreme hardness of the water contributes to recurring damage to appliances and plumbing infrastructure, resulting in elevated maintenance and replacement costs. By optimising the lodges' water management systems, long-term economic stability can be strengthened, as improved efficiency and more reliable infrastructure reduce maintenance and operational costs.

These environmental, social, and economic gaps highlight the need for coordinated intervention performance but also grant opportunities for cost efficiency, staff well-being, and environmental safety.

5.3 Recommendations

5.3.1 Water Quality and Quantity Monitoring

Water quality testing can be strengthened by incorporating additional operational parameters, such as residual free chlorine for drinking water, and total hardness and chlorine in effluent water. Where exceedances are identified, an investigation should be implemented to trace the source and pathway of contamination and implement corrective actions.

Operational water demand should be evaluated in greater detail, with specific focus on high-use areas. The recent installation of LoRa smart meters offers an opportunity for real-time monitoring of water use patterns. Management should utilise this data to identify inefficiencies, detect usage exceedances and regulate water use through targeted interventions.

Further water-efficient practices can be implemented by installing additional water-saving technologies. These include rainwater harvesting systems, dual-flush or water-efficient toilets, automatic leak-detection systems, and optimised irrigation schedules that prioritise the reuse of treated effluent.

The author recommends that the wastewater treatment infrastructure at Ngala Safari Lodge be replaced with a modern system like that used at Ngala Tented Camp. The existing system is maintained following breakdowns, but its outdated design, operational complexity, and declining reliability make it unsustainable in the long term. An upgraded system would be better equipped to treat the lodge's highly mineralised water and would offer economic benefits by reducing frequent maintenance and breakdown costs.

5.3.2 Stakeholder Engagement

Improving water-use awareness and staff engagement is essential for strengthening sustainable water management at the lodges. Educational workshops should be implemented across all staff levels to explain water quality issues, benchmark limits, and the importance of water conservation. Ideas and suggestions from these workshops should be implemented on the operational level across all departments, and collective goals should be set and worked towards together.

5.3.3 Baseline

The baseline established through this study can be used by management at Ngala Safari Lodge and Ngala Tented Camp to assess future performance and identify areas requiring intervention. Additionally, other &Beyond lodges can use this baseline as a comparative benchmark to evaluate their own water management practices and identify opportunities for improvement.

5.4 Limitations of the Study

The study was conducted at only two lodges within a single organisation, managed largely by the same leadership team, within the same environment. This scope limits the extent to which the findings can be generalised to other wildlife tourism establishments that operate under different environmental conditions, resource constraints, or management structures. The quantitative component relied on a 28-month dataset, which provided a snapshot of water quality and consumption trends but did not depict long-term variability. Additionally, the study took place during a refurbishment period at Ngala Tented Camp, during which operations were not typical lodge operating practices, which influenced water use trends.

The qualitative findings were based on a small sample of participants, calculated at nearly 5% of the population, meaning that only limited staff experiences and perspectives could be explored. While the interviews provided insight, the depth of some responses was constrained by language barriers, as several participants could not communicate in their home language.

5.5 Contribution of the Study

This study contributes to the field of sustainable water management in wildlife tourism, particularly within semi-arid regions of Southern Africa. It offers a detailed long-term assessment of water quality and quantity at remote wildlife lodges and establishes baselines and benchmarks that apply to &Beyond and similar tourism organisations. These findings provide a foundation for future monitoring and benchmarking to contribute to sustainable water management within the sector.

The study provides insights into the interconnectedness of technical water systems, staff perceptions, and daily operational behaviour, and how these elements collectively influence water sustainability. It identifies risks associated with treatment processes and offers practical recommendations relevant to both Ngala's lodges and the wider ecotourism sector. Finally, the research explores the concept of a water-scarce future, showing that the long-term competitiveness and resilience of wildlife lodges will depend increasingly on their ability to secure and sustainably manage water resources.

5.6 Conclusion

This study aimed to evaluate the sustainability of water management practices at &Beyond's Ngala Safari Lodge and Ngala Tented Camp. Water quantity and quality were analysed using a mixed-methods design consisting of 28-months of quantitative data and qualitative interviews to determine the extent to which the lodges comply with relevant standards and legislation.

Overall, the findings show that both lodges have a strong foundation to implement sustainable water management with dedication from management, as well as the necessary infrastructure to abstract and treat water resources effectively. The study revealed gaps and opportunities to further their environmental stewardship that will enable all aspects of the lodge to apply sustainable tourism practices regarding their water use.

Water quantity analysis showed that although both lodges achieve acceptable mean water use levels relative to internal and South African National Park Concession benchmarks, variability and frequent exceedances indicate that water use targets are not effectively integrated into all aspects of their operations. Fixed daily operational demands influence consumption, while staff demonstrated limited awareness of water-use expectations. The weak relationship between occupancy and total water use highlights the need for improved operational efficiency, continuous monitoring, and behavioural interventions to reduce baseline consumption.

The water quality results highlighted several areas for improvement, as many parameters complied with applicable standards, while others did not align with the relevant requirements. Recurring microbial detections, especially *E. coli* exceedances in Ngala Tented Camp's effluent water, present an acute health and environmental risk, as this water is used for irrigation and directly re-enters the environment. These findings emphasise the need for stronger monitoring and corrective action.

Qualitative insights reinforced the quantitative findings by revealing gaps in sustainable water management related education, awareness and communication. Staff indicated that they would adopt more responsible water-use practices if expectations and the reasoning behind them were communicated more clearly.

This study highlights a shift in the future, not only for wildlife tourism but for everyday life: luxury will no longer be defined by fine dining or lavish décor, but by the security of clean, sufficient, and responsibly managed water. In a world where water scarcity is an increasing threat, the true value of safe and sufficient water resources cannot be overstated due to direct social, environmental, and economic impacts.

Ngala Safari Lodge and Ngala Tented Camp have already taken important steps toward sustainable water management, positioning themselves as leaders in the ecotourism sector. With increased focus on monitoring, preventative action, and fostering a culture of responsible resource use, they can further strengthen their commitment to sustainability. The opportunity arises for Ngala Safari Lodge and Ngala Tented Camp to become pioneers in a new era of luxury within the Southern African wildlife tourism sector—an era defined by sustainable water management.

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Appendixes

Appendix A – Key participant interview questions

1. What sustainable water management practices, such as water saving interventions, are currently implemented at Ngala Safari Lodge and Tented Camp to minimize water consumption and maintain water quality?

2. How would you describe the level of commitment from &Beyond's top management towards implementing and sustaining water management practices at Ngala Safari Lodge and Tented Camp?

3. In your opinion, how committed are the general staff members at Ngala Safari Lodge and Tented Camp towards sustainable water management? Are there any initiatives in place to enhance their engagement?

4. What measures are currently in place to ensure that the water provided to guests and staff meets all relevant laws, regulations, and standards for water quality?

5. How does Ngala Safari Lodge and Tented Camp ensure that water usage by both guests and staff is compliant with local water regulations and standards concerning sustainable quantities?

6. What measures or initiatives have been implemented to raise awareness among guests and staff regarding the importance of sustainable water use? How effective have these measures been?

7. Under &Beyond's Impact Model (Care of the Land; Care of the People; Care of the Wildlife), what specific practices are promoted at Ngala Safari Lodge and Tented Camp to ensure sustainable water management in line with these principles?

8. In terms of sustainable water management, where do you think Ngala Safari Lodge and Tented Camp rank compared to other &Beyond lodges? What factors contribute to this ranking?

Appendix B – UNISA Ethical Clearance Approval Letter

NHREC Registration # : REC-170616-051
Ref #: 2024/CAES_HREC/5787
Name: Ms Cornelia Christina de Kock
Student #: 21148198

Date: 29/01/2025

Dear: Ms Cornelia Christina de Kock

Decision: Ethics Approval from 27/01/2025 to 31/01/2028

Researcher: Ms Cornelia Christina de Kock
21148198@mylife.unisa.ac.za 0827947091

Supervisor: Prof Kevin Mearns Mearnkf@unisa.ac.za

Sustainable Water Management in Wildlife Tourism at Ngala, Limpopo, South Africa

Qualification: MSc Environmental Management

Thank you for the application for research ethics clearance by the College of Agriculture and Environmental Sciences_Health REC for the above mentioned research study. Ethics approval is granted for three years, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report is submitted.**

Due date for progress report: 31 January 2026

The **low risk application** was **reviewed** by College of Agriculture and Environmental Sciences_Health REC on 27 January 2025 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the College of Agriculture and Environmental Sciences_Health REC.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.

7. No field work activities may continue after the expiry date (31 January 2026). Submission of a completed research ethics progress report will constitute an application for renewal, for Ethics Research Committee approval.

Additional Conditions

1. Disclosure of data to third parties is prohibited without explicit consent from Unisa.
2. De-identified data must be safely stored on password protected PCs.
3. Care should be taken by the researcher when publishing the results to protect the confidentiality and privacy of the university.
4. Adherence to the National Statement on Ethical Research and Publication practices, principle 7 referring to Social awareness, must be ensured: "Researchers and institutions must be sensitive to the potential impact of their research on society, marginal groups or individuals, and must consider these when weighing the benefits of the research against any harmful effects, with a view to minimising or avoiding the latter where possible." Unisa will not be liable for any failure to comply with this principle.

Note

The reference number 2024/CAES_HREC/5787 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,

Dr MD Matlala
Chair of College of Agriculture and Environmental Sciences_Health REC
E-mail: matlamd1@unisa.ac.za

Prof NO Mapholi
Executive Dean / By delegation from the Executive Dean of College of Agriculture and Environmental Sciences_Health REC
E-mail: maphon@unisa.ac.za

Appendix C - Letter of Institutional Consent from &Beyond

&BEYOND

07th November 2024

To: Cornelia De Kock

In my capacity as &Beyond's Group Sustainability Manager, we accept your request and proposal to have &Beyond as your research partner for the Masters study in Sustainable Water Management (supervised by Prof. K Mearns). We hereby give you full permission and consent to use our data, analyse data and publish the results.

The motivation for our decision is due to certain points you highlighted in your consent request letter and the following conditions will be adhered at all times:

- The UNISA's Ethical Code of Conduct
- All the conditions in the Memorandum of Agreement (MOA) already established between &Beyond and UNISA
- Protecting the organisation, its members, executives and personnel that will be involved
- All documentation would need to be proofed by andBeyond before publication

Failure to comply with any of the conditions in the documents as stated above can result in &Beyond withdrawing from the project / research.

We are also confident that the project will be a major success and will have mutual benefits for all parties involved. It is a great privilege to be involved in this study and we would like to wish you all the best for the project.

Kind Regards

Mr. Jonathan Braack
(Group Sustainability Manager, &Beyond)

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DIRECTORS HJA Kent, SP du Preez, AD Enthoven, MH Getty, PRV Maxwell

COMPANY SECRETARY JP De Villiers

Appendix D – Interview Participant Information and Consent Form

PARTICIPANT INFORMATION SHEET

Ethics clearance reference number: 2024/CAES_HREC/5787

Sustainable Water Management in Wildlife Tourism at Ngala, Limpopo, South Africa.

Dear Prospective Participant

My Name is Christina de Kock and I am doing research with Kevin Mearns, a professor in the Department of Environmental Sciences towards a Master's degree at the University of South Africa. We are inviting you to participate in a study entitled "Sustainable Water Management in Wildlife Tourism at Ngala, Limpopo, South Africa."

WHAT IS THE PURPOSE OF THE STUDY?

This study is expected to collect important information that could contribute to sustainable water management practices in wildlife tourism, specifically for &Beyond's Ngala Safari Lodge and Tented Camp. By analysing the water quantity and quality at these sites, the study can provide insights into the effectiveness of current practices, helping to identify areas where water usage can be optimized and environmental impact minimized.

WHY AM I BEING INVITED TO PARTICIPATE?

You are being invited to participate in this study because of your involvement in water management practices at &Beyond's Ngala Safari Lodge and Tented Camp. The aim is to gather insights from those with practical experience and knowledge about water usage, water quality and sustainability practices within the lodge's operations. Your perspectives will be invaluable in understanding current water management practices, levels of awareness, and compliance with environmental standards.

Your contact details are obtained through official channels with the permission of the lodge management, specifically the lodge's general manager and/or maintenance manager. The study involves approximately 10 participants, and we take steps to protect the confidentiality of all responses. This information is used solely for the purposes of this study, and your privacy is respected throughout. This invitation allows you to make an informed choice about participating, with a clear understanding of confidentiality measures in place.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

As a participant in this study, your role will involve sharing your knowledge and experiences related to water management practices at &Beyond's Ngala Safari Lodge and Tented Camp. The study will use semi-structured interviews as a way of obtaining data, allowing for an understanding of your perspectives on sustainable water management, water usage reduction, compliance with environmental standards, and awareness-raising efforts within the lodge.

The interview is expected to take approximately 10-20 minutes and will be scheduled at a time that is convenient for you. With your consent, the interview will be voice-recorded to ensure accuracy. Your participation will remain completely anonymous, and the recordings will only be accessible to myself, and my academic supervisors involved in this study. Participation is entirely voluntary, and all responses will be treated with the utmost confidentiality.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Participation in this study may not provide immediate personal benefits, but there are potential advantages for you, the &Beyond team and the scientific community

For you and your colleagues, this study offers a chance to discuss and reflect on water management practices, potentially leading to greater awareness and improved resource use at &Beyond's Ngala Safari Lodge and Tented Camp. Findings could help identify ways to reduce costs and enhance sustainability in daily operations.

For the scientific community, this research adds valuable knowledge on sustainable tourism and water management in wildlife lodges.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

Participation in this study is expected to involve minimal inconvenience or discomfort. The primary activity is a semi-structured, recorded interview, which will require approximately 10-20 minutes of your time. There are no foreseeable risks of physical or psychological harm associated with participation, as the questions focus on professional insights regarding water management practices and do not delve into personal or sensitive issues. As stated before, the recordings of the interviews will be anonymous and confidential.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

You have the right to insist that your Name will not be recorded anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research *[this measure refers to confidentiality]* OR your Name will not be recorded anywhere and no one will be able to connect you to the answers you give *[this measure refers to anonymity]*. Your answers will be given a code number, or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings *[this measure refers to confidentiality].*

With your permission, de-identified data from this study may be used for research purposes, including in reports, journal articles, and conference proceedings. Your privacy will be protected, and individual participants will not be identifiable in any publications resulting from this study

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your responses will be securely stored by the researcher in a locked cupboard at the UNISA Library for a minimum period of five years for academic and potential future research purposes. Electronic data, including the voice-recordings, will be stored on a password-protected computer. If the stored data is to be used for any future research unrelated to the initial objectives of this study, additional Research Ethics Review and approval will be sought.

At the end of the retention period, all information will be securely destroyed. Hard copies will be shredded, and electronic files will be permanently deleted from the computer using specialized software to ensure data is irretrievable.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

No payment or incentives will be granted for taking part in this study.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to receive the final research findings, please contact Christina de Kock via email at 21148198@myife.unisa.ac.za. The findings will be accessible for one year after the conclusion of the study.

If you have any concerns regarding the conduct of the research, you may reach out to the research supervisor, Professor Kevin Mearns, via email at mearnkf@unisa.ac.za

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

Christina de Kock

CONSENT TO PARTICIPATE IN THIS STUDY

I, ___________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunities to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the <insert specific data collection method>.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname………………………………………… (please print)

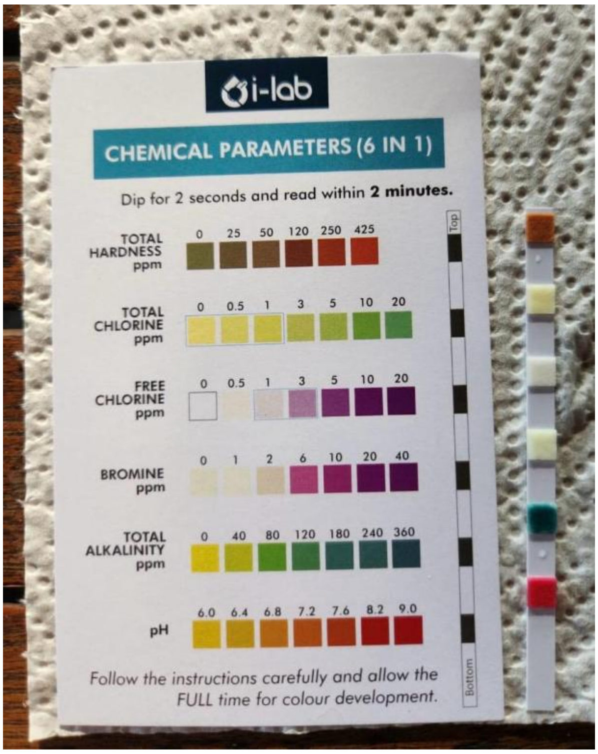
Participant Signature…………………………………………….Date…………………

Researcher's Name & Surname……………………………………(please print)

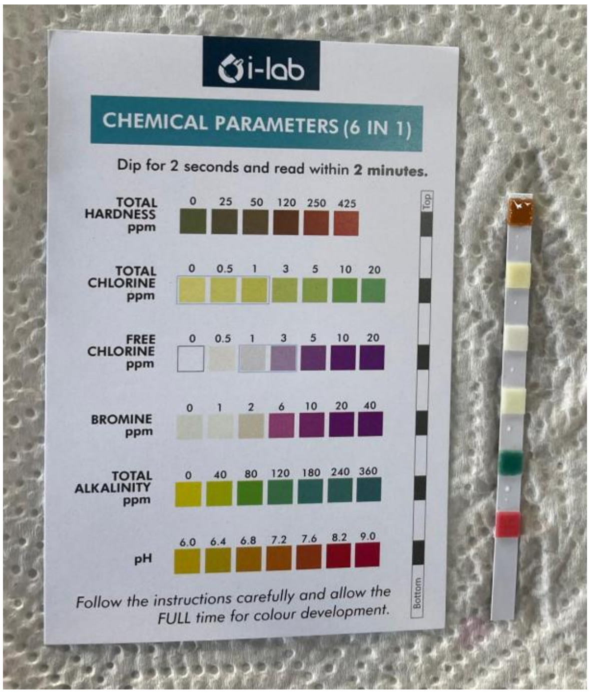
Researcher's signature…………………………………………..Date…………………

Appendix E – iLab Chemical Parameter Results

Ngala Safari Lodge

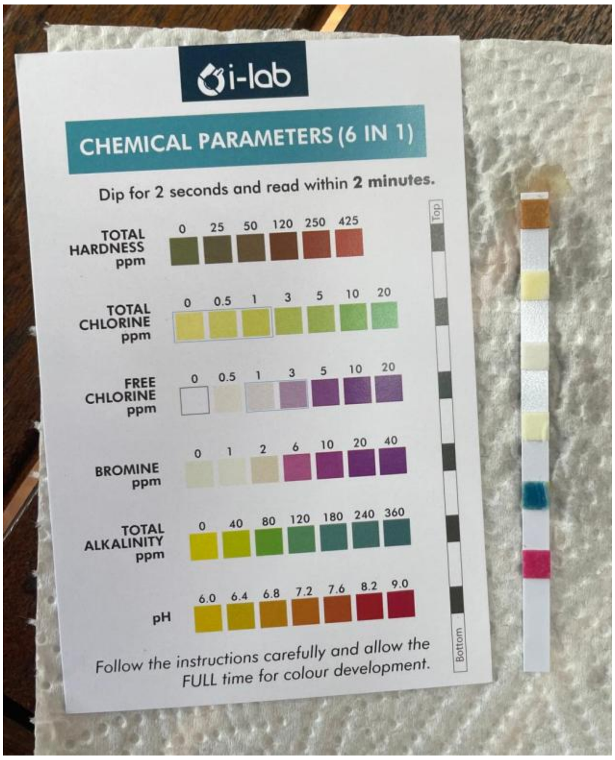


Drinking water

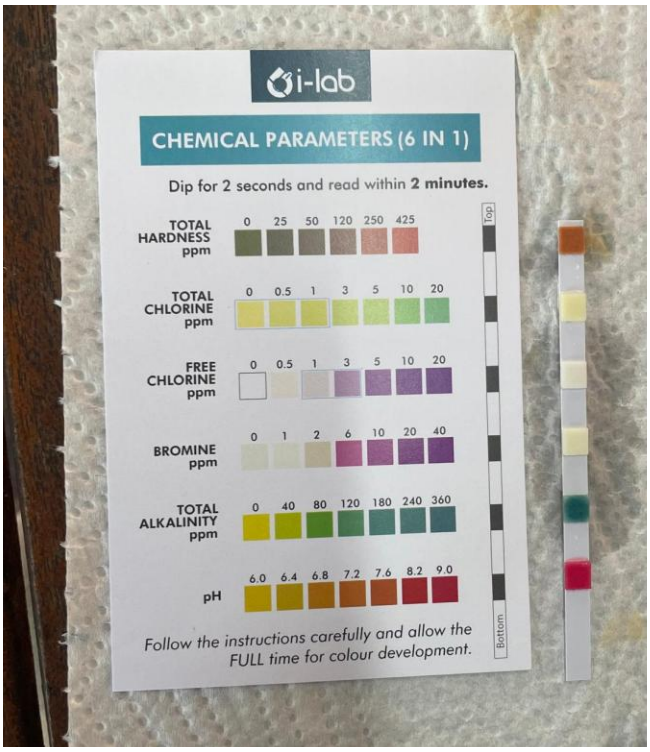


Effluent water

Ngala Tented Camp



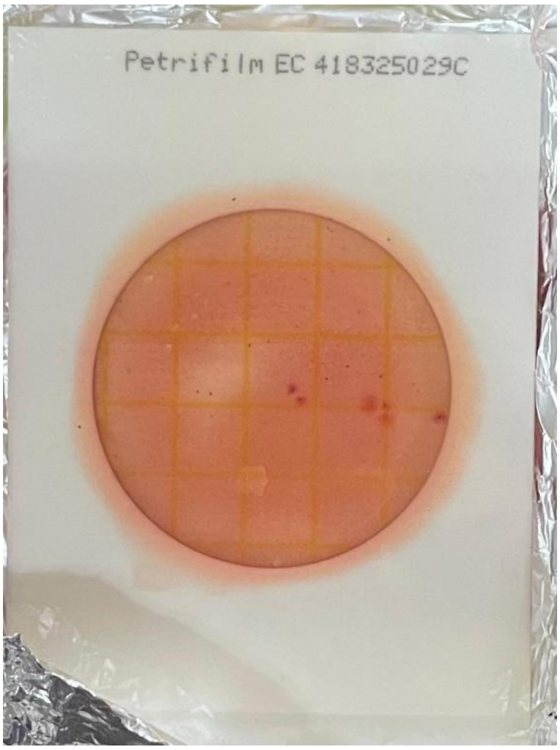
Drinking water



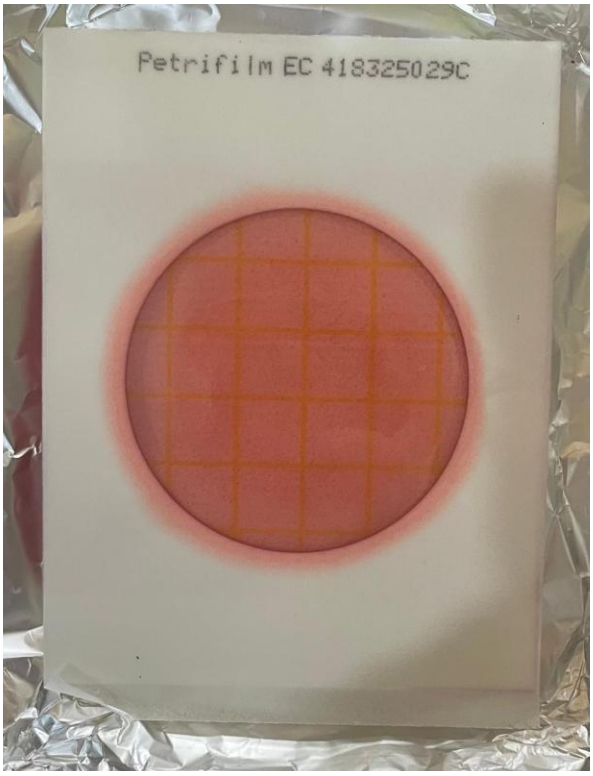
Effluent water

Appendix F - iLab Microbial Parameter Results

Ngala Safari Lodge

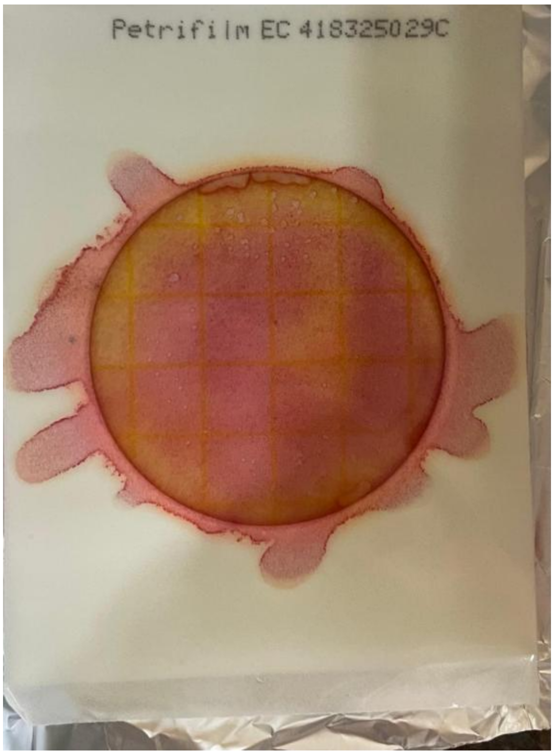


Drinking water

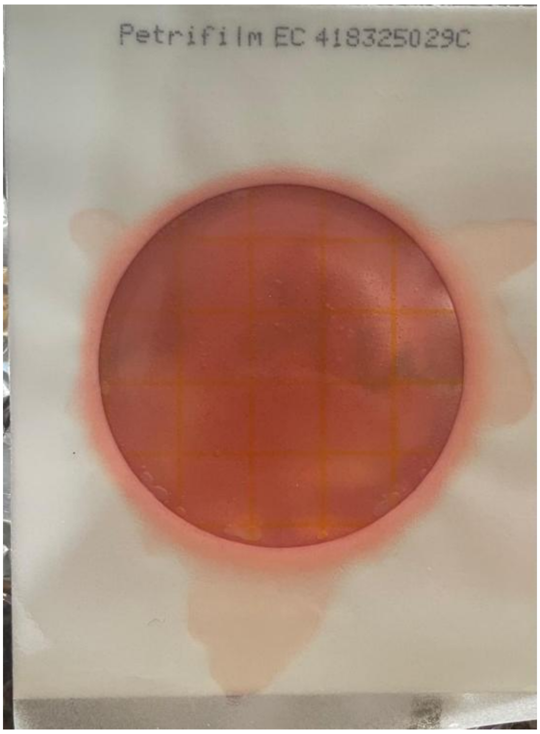


Effluent water

Ngala Tented Camp



Drinking water



Effluent water

Appendix G - Declaration on the Use of Artificial Intelligence Tools

I, Christina de Kock, with student number 21148198, declare that I used artificial intelligence tools, including ChatGPT, in an ethical and responsible way during the completion of this Master's dissertation. These tools were used to support language editing, improve clarity, and assist with sentence and idea structuring.

All research design, data collection, analysis, interpretation, and arguments are my own original work. AI tools were not used to generate data, results, or original scholarly content.

All sources were evaluated, cited, and referenced in line with academic integrity requirements.

This dissertation complies with the ethical and academic standards of the University of South Africa.

Signed:

Date: 2026/02/26

Appendix H – Language Editing Certificate

Mzansi Writers

CERTIFICATE OF EDITING

THIS IS PRESENTED TO

CORNELIA CHRISTINA DE KOCK

This certificate serves to confirm that your Dissertation has been professionally edited and proofread by editors at Allquill Solutions International (trading as Mzansi Writers). The editing process focused exclusively on language accuracy, grammar, spelling, and clarity. No changes were made to the content, meaning, interpretation, or scholarly arguments of the manuscript.

16-02-2026

DATE

EDITOR'S SIGNATURE