DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems Management

DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE UPPER ORANGE RIVER CATCHMENT

LINKING THE SOCIO-ECONOMIC AND ECOLOGICAL VALUE AND CONDITION OF THE WATER RESOURCES REPORT

WP 11422

Study Report No.

RDM/WMA13/00/CON/CLA/0324

September 2024

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Published by

Department of Water and Sanitation
Private Bag X313
Pretoria, 0001
Republic of South Africa

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This report is to be cited as:

Department of Water and Sanitation, South Africa. September 2024. Determination of Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River Catchment: Linking the Socio-Economic and Ecological Value and Condition of the Water Resources Report. Report No: RDM/WMA13/00/CON/CLA/0324

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Project Name:	*Determination of Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River Catchment: WP 11422*
DWS Report No:	*RDM/WMA13/00/CON/CLA/0324*
Status of Report:	*Final*
First Issue:	*August 2024*
Final Issue:	*September 2024*

Approved for the Professional Service Provider by:

.... 2024 . 10 . 22 ....

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TERMINOLOGY AND ABBREVIATIONS

Acronym	Description
CICES	Common International Classification of Ecosystem Services
COD	Chemical Oxygen Demand
CRA	Comparative Risk Assessment
DWS	Department of Water and Sanitation
EI	Ecological Infrastructure
ES	Ecosystem Services
EWR	Ecological Water Requirement
IEM	Integrated Economic Model
IPBES	International Panel on Biodiversity and Ecosystem Services
IPCC	The Intergovernmental Panel on Climate Change
IUA	Integrated Unit of Analysis
GDP	Gross Domestic Product
GVA	Gross Value Added
m^3/a	Cubic meters per annum
MARDV	Maximum Allowable Resource-directed Values
MEA	Millennium Ecosystem Assessment
NCP	Natures Contribution to People
n.e.c.	Not elsewhere classified
NT	National Treasury
NWM5	National Wetlands Map version 5
NWRS	National Water Resources Strategy
OECD	Organisation for Economic Co-Operation and Development
ORS	Orange River System
PES	Present Ecological State

Acronym	Description
QSAM	Quasi-Social Accounting Matrix
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
SAM	Social Accounting Matrix
SEcT	Socio-Economic Comparison Tool
Stats SA	Statistics South Africa
SWSA	Strategic Water Source Area
TEEB	The Economics of Ecosystems and Biodiversity
UVB	Unchanneled valley bottom
WDCS	Waste Discharge Charge System
WEM	Water Ecosystems Management
WMA	Water Management Area
WRCS	Water Resource Classification System

EXECUTIVE SUMMARY

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) has initiated a study for the determination of Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River Catchment. The determination of the water resource classes is necessary to facilitate a balance between protection and use of water resources. The Water Resource Classification System is applied taking account of the local conditions, socio-economic imperatives and system dynamics within the context of the catchment. The process also requires a wide range of complex trade-offs to be assessed and evaluated at several scales.

Step 2, as per the Water Resource Classification System (WRCS) gazetted steps (Regulation 810, Gazette No. 33541, 17 September 2010) (DWA, 2010) and the Water Resource Classification System (WRCS) guidelines (DWAF, 2007), requires that the quantification of the relationships that link the change in the configuration of scenarios to a resulting change in economic value and social wellbeing, be defined. This includes rationalisation of those values, by selecting a subset on which efforts can be concentrated for evaluating catchment configuration scenarios and, determination of the scoring system to be used to evaluate the catchment scenarios in later steps of the process. This report addresses these three objectives by demonstrating the linkages methods between the socio-economic and ecological value and condition of water resources as they currently stand in the Upper Orange River catchment.

The Upper Orange River catchment stretches across an area covering parts of the Free State, Northern Cape and Eastern Cape provinces, with the largest proportion within the Free State province.

In the Upper Orange River catchment, the largest contribution to the GDP is from the tertiary sector (74.5%), followed by the secondary sector (20.6%) and finally the primary sector (4.9%). The key contributions in the tertiary sector (service industry) are from financial services (20%), the wholesale & retail, catering & accommodation sectors (tourism playing an important role) contributing 17%, followed by general government (15%) and community, social and personal services (10%). Manufacturing, part of the secondary sector (creating or producing finished goods or services) contributes 12% to the overall catchment GDP. The construction sector and electricity and water sectors make up the remaining 9% of the secondary sector contribution to GDP. The primary sector's (output consists of raw materials) main contribution to the catchment GDP is from agriculture (4%), with mining only contributing 1%.

The Upper Orange River catchment has several densely populated rural settlements, and these areas have an important informal economy with a large dependence on a variety of aquatic ecosystem services. Thus, ecosystem services have been demonstrated to provide significant contributions to socio-economic wellbeing to both formal and informal economy beneficiaries within the catchment.

The key ecosystem services linked to the socio-economics of the Upper Orange catchment were identified to include the following:

1. Fresh Water Provisioning;
2. Water Quantity Regulation (Flow Regulation);

3. Food, Raw Materials and Wild Collected Products Provisioning;
4. Erosion Regulation / Soil Stability;
5. Water Quality Regulation: Purification and Waste Management;
6. Tourism, Recreational and Amenity Services; and
7. Biodiversity Support.

Important ecological infrastructure supporting these ecosystem services includes several national parks, nature reserves (both provincial and private) and protected areas, water resources infrastructure represented by surface water (rivers and streams), groundwater, strategic water resources areas (SWSA) and various types of wetlands.

Water provisioning is the key ecosystem service within the Upper Orange River catchment which is essential for the effective functioning of the main economic sectors including wholesale & retail, catering & accommodation, general government, manufacturing, agriculture and agricultural manufacturing, and community services sectors.

Although it is understood that economic productivity of key sectors is not fully reliant on ecosystem services, it is acknowledged that a proportion of the output be attributed directly to the services provided by ecological infrastructure within the catchment. This is particularly true for water provisioning services provided by the strategic water source areas within the catchment.

Findings show that the agriculture, agricultural manufacturing and other manufacturing sectors contribute significantly to the formal water economy through their purchases of both raw and treated water. This provides some indication of the level of reliance of these industries on water provisioning, although caution is needed when interpreting these results, as the contribution to the water economy, in financial terms, does not directly link to the volume of water required by each sector. Households, for example, represent the largest purchasers of water in monetary terms, whilst the agricultural sector consumes a larger portion by volume. This poses interesting challenges for the overall valuation of these ecosystem services.

During the next steps of the project where the management scenarios will be assessed, careful consideration will be given to the impact that changes in ecosystem services may have on the livelihoods of communities, particularly rural communities within the catchment.

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1 INTRODUCTION

1.1 Background

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) is presently undertaking a study to determine Water Resource Classes and associated Resource Quality Objectives (RQO) in the Upper Orange River catchment which falls within the Orange-Vaal Water Management Area (WMA 04).

Water Resource Classes, the Reserve and Resource Quality Objectives are protection-based measures that make up Resource Directed Measures (RDM), the protection principles contained in Chapter 3 of the National Water Act (Act No. 36 of 1998). RDM are intended to ensure comprehensive protection of all water resources. Resource Directed Measures are intended to ensure comprehensive protection of all water resources. Protection relates to the quantity and quality (overall health) of the water resource. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical, and affordable. Once the water resources class and the Reserve have been established, RQOs are determined to give effect to those water resource classes and the Reserve.

The DWS has progressively set water resources classes for all significant water resource systems in South Africa to ensure their protection and sustainable use and the Orange River System (ORS) comprising the upper and lower catchments, is the last system that requires classification and setting of RQOs.

1.2 Study Objective

The main objective of the study is to coordinate the implementation of the determination of water resources classes and associated resource quality objectives for all significant water resources in the Upper Orange River catchment within the Vaal-Orange Water Management Area (WMA04) as described in the revised reconfiguration that was gazetted as part of the National Water Resources Strategy 3 (NWRS3) under Gazette Notice 49225, dated 1 September 2023, in accordance with the Water Resource Classification System (WRCS)(DWA, 2010).

This is aimed at facilitating the management and regulation of water resources to ensure efficient and sustainable use, a balance between protection and use, while maintaining ecological integrity and specifically maintaining or improving the present ecological state (PES) of the water resources, in the Upper Orange River catchment.

Appropriate integration with water resource planning and management processes, as well as cooperation among stakeholders, will be key success factors in setting the water resource classes and RQOs. The outcomes of the process will result in the protection framework for the catchment that will guide actions, interventions, and needs, to ensure a sustainable water resource system that is able to balance water use and protection.

1.3 Purpose of this Report

The purpose of this *Linking the Socio-Economic and Ecological Value and Condition of the Water Resources* report is to demonstrate the linkages between the socio-economic and ecological value and condition of water resources as they currently stand in the Upper Orange River catchment. This addresses the requirement in terms of the water resource classification process, Step 2, as per the Water Resource Classification System (WRCS) gazetted steps (Regulation 810, Gazette No. 33541, 17 September 2010) (DWA, 2010) and the Water Resource Classification System (WRCS) guidelines (DWAF, 2007), which requires an analysis of the relationships that link the change in the configuration of scenarios to a resulting change in economic value and social wellbeing.

At this step in the water resource class 7 step process, the methodologies were used to establish an Integrated Economic Model (IEM) architecture and populate the modules using the best available data that represents the baseline scenario. The IEM developed here will be used in the valuation step to inform the evaluation of scenarios taking place at a later stage in the water resource classification process.

2 RATIONALE

As natural features in the landscape, ecosystems provide environmental, social and economic benefits to communities. The value of ecosystems in providing these free ecosystem services to a range of formal and informal beneficiaries has been vigorously demonstrated and there is ever growing recognition of their importance to human well-being at multiple scales (Perrings, 2006; Freeman, 2003; Pearce et al., 2006; Dasgupta, 2008 and 2010; Mäler, 1991; MEA, 2005, 2007; TEEB, 2010; WAVES, 2013).

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

The classification of the cause-and-effect relationships (or linkages) between ecological infrastructure and beneficiaries of ecosystem services is vital to appropriately manage natural resources in a sustainable manner. Informed appropriate natural resource management maximises natural benefits and opportunities towards contributing to optimal socio-ecological and economic well-being. The classification of these linkages requires an understanding of the role that ecological infrastructure and the presence of beneficiaries (at a landscape, local and regional scale) plays in the delivery of ecosystem services (See Annexure 1 for Decision Analysis Framework).

An established approach to defining these linkages is using Ecosystem Services Frameworks as formalised and refined through initiatives such as the Millennium Ecosystem Assessment (MEA 2005, MEA 2010), The Economics of Ecosystems and Biodiversity (TEEB, 2013) and the Final Ecosystem Goods and Services Classification System (Landers and Nahlik, 2013). This approach is refined using complimentary economic tools and methodologies such as environmental economic accounting (specifically water resource accounting) and quasi-input-output modelling.

The aim of this assignment was to demonstrate the linkages between the socio-economic and ecological value and condition of water resources as they currently stand in the Upper Orange catchment.

Demonstrating these linkages required the application and integration of the numerous socio-ecological, and econometric methodologies. This integration required the development of Ecosystem Services Classification and Modelling, Quasi-Social Accounting Matrix (QSAM) and use of information from the Water Account for the Upper Orange catchment. The results were the development of an Integrated Economic Model (IEM) for the Upper Orange catchment towards demonstrating socio-economic and ecological linkages.

The identification of linkages through the development of the IEM is a precursor to quantifying these linkages, which will be conducted further along in the water resource classification 7 step process in the scenario evaluation step. At that step, using ecosystem service valuation, the natural benefits provided by ecosystems will be quantified in socio-economic terms. This socio-economic yard stick will allow for a comparison of trade-offs to development towards understanding the costs of environmental damage and restoration to the economy. Furthermore, by understanding the flow of services from the environment to beneficiaries, decision makers will be empowered to identify opportunities towards maximising the natural benefits received. The opportunities may include the improvement in functionality of a system or even provide support services or infrastructure necessary for sustainable utilisation by beneficiaries.

3 APPROACH

Please note: This linkage step will be used to inform the evaluation of scenarios at a later stage in the water resource classification process. This step aimed to develop the IEM and to demonstrate linkages between the ecological and the socio-economic baseline in the Upper Orange River catchment. The flow of tasks is shown in Figure 1 with this linkage step being represented by Tasks 3 and 4 shown in Figure 1.

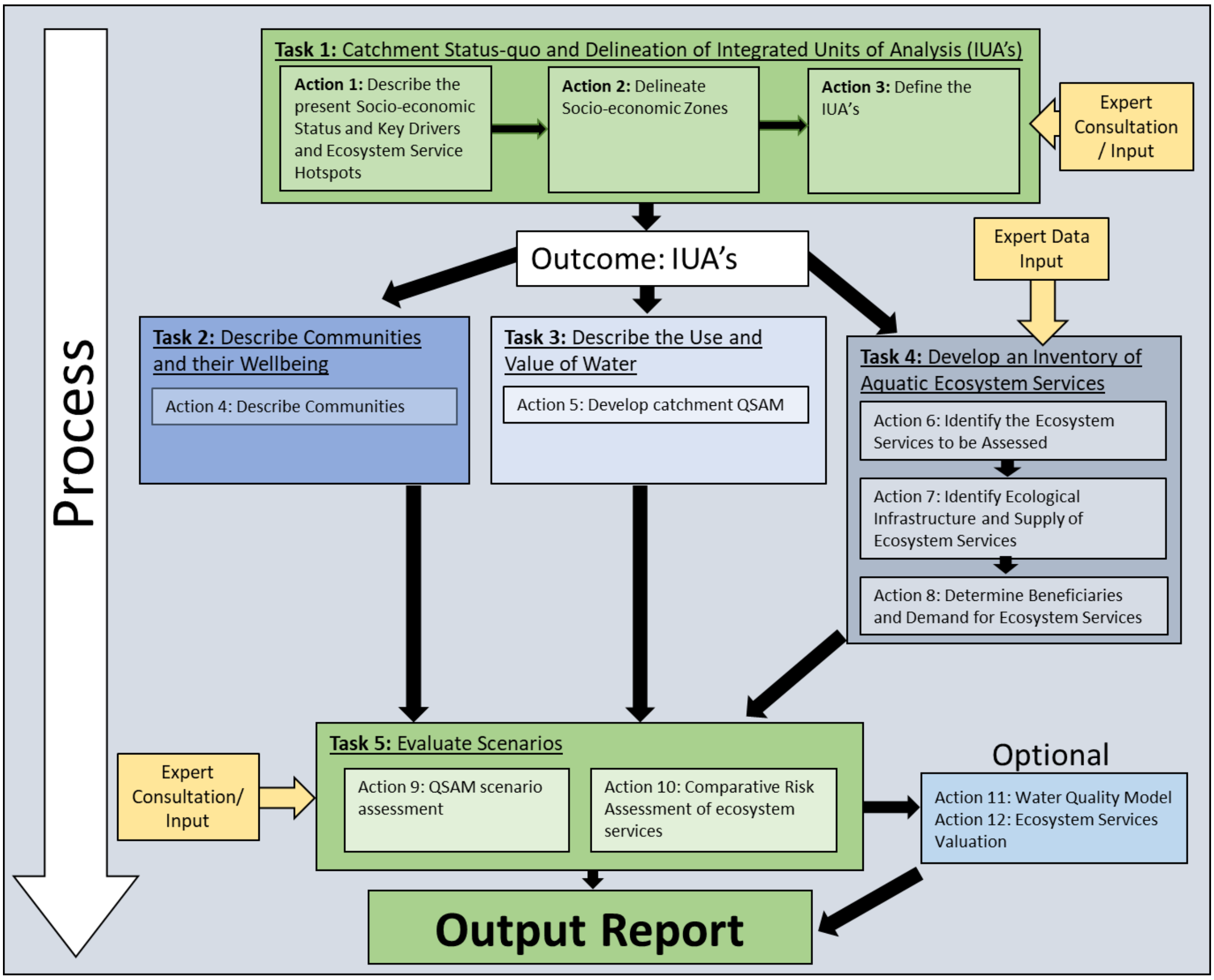

Figure 1: Flow of Tasks for completion of the socio-economic aspects for the larger water resource classification process

At this point of the water resource classification 7-step process the methodologies are used to establish the IEM architecture and populate the modules using the status quo catchment data obtained at a desktop level. The IEM will be updated during the scenario phase with the specific scenario results.

The broad approach taken to develop the IEM is provided in Figure 2. Key inputs, components and outputs of the process include the following:

1. The drivers of change, which in this report represent the current baseline scenario. This component will eventually represent various scenarios which will drive changes in the relationships defined at this point.
2. The ecological responses to change in development scenarios, which in this case are quantified change to hydrological (flows) and ecological (condition) indicators. In the evaluation of scenarios step these responses will be driven by each specific scenario; and
3. The classification of socio, ecological and economic characteristics within the target catchment linked to the effects of varying response inputs. The classification process

has been done through the use of three modular tools described below, which through the IEM link ecological responses to changing scenarios with a socio-economic response:

a. The ecosystem services evaluation approach aims to link the presence and condition of ecological infrastructure with key beneficiaries, using ecosystem services frameworks.

b. The Water/ water Quality Account module aims to define the use of water through physical flows and financial transactions. This allows analysis on how economic changes impact the environment, and conversely, how changes in water availability/ quality impact the economy; and

c. The QSAM module aims to quantify the size of the Upper Orange River catchment economy. The QSAM combines the suppliers and consumers of economic products into a single matrix (table of interacting economic sectors) to determine the magnitude of the macro-economic indicators of the Upper Orange River catchment economy.

4. The socio-economic response to change in development scenarios, which in this case is presented through key economic indicators such as Gross Value Added (GVA), jobs and value of ecosystem services. At this point the socio-economic response represents the current status-quo of the catchment.

Towards ensuring a robust and defendable output, this approach uses well established methodologies that have been formalised through the literature.

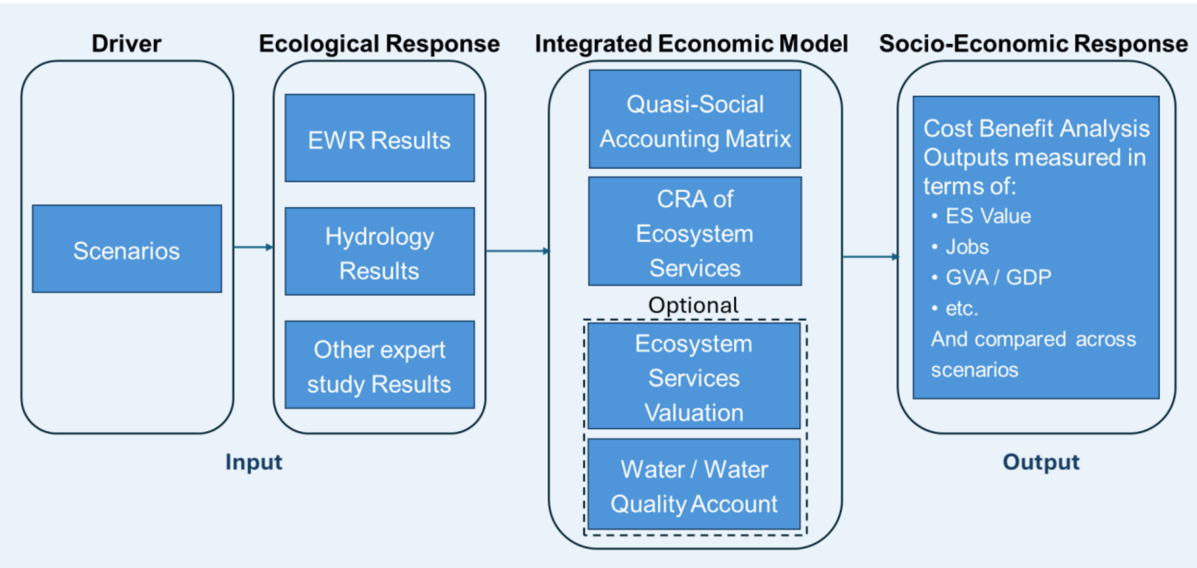

Figure 2: Approach to the development of the Integrated Economic Model that Demonstrates the Socio-Economic Linkages in the Upper Orange Catchment (Arrows indicate flow of data from input to output)

3.1 Ecosystem Services Framework Selection

Since the inception of the Millennium Ecosystem Assessment (MEA) in 2005, several frameworks have been developed to better categorize and disaggregate the benefits that people receive from ecosystem services, enabling a full evaluation of their economic value. These include the framework created by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019), The Economics of Ecosystems and Biodiversity (TEEB, 2010), and the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2013). Ecosystem Service Frameworks commonly utilised in classifying natural benefits are described in Table 1.

While each of these frameworks attempts to build on one another, they essentially follow a similar logic, where ecosystem services and the benefits derived therefrom by beneficiaries are classified into three broad categories:

- Provisioning services, where humans derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials).
- Regulation, where direct and indirect benefits are derived in the form of regular flows of biotic and abiotic components of ecosystems which allow for the regular, effective functioning of ecosystems; and
- Cultural services, where an intangible benefit is received in terms of intellectual, spiritual and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure.

A fourth category is added in some cases to distinguish between regulating or supporting services in a specific delineated ecosystem, and the global system. This may include the maintenance of options (IPBES); genetic diversity, biodiversity, and habitat (MEA, TEEB, IPBES); and large-scale planetary processes, such as nutrient cycling and soil formation (MEA) and evolutionary or biological processes (IPBES). These frameworks contain essentially the same services and processes, differing only slightly in where or how these processes are classified.

Two key distinctions are explicitly defined by the IPBES, which are tacitly implied within the other frameworks. These relate to the manner that benefits to people are derived from ecosystem services, and the role played by social and cultural factors in the valuation of these benefits. Firstly, regarding the benefits derived from ecosystems, the IPBES framework explicitly considers and distinguishes between the conversion of ecosystem services to benefits in terms of “nature’s contributions to people” or the role that ecosystem services play in relation to the human institutional and physical systems, and the neutral processes whereby human systems derive benefits from natural systems without the need for any conversion or additional effort, defined as “nature’s gifts to people”. The second distinction of the IPBES framework relates to the way it explicitly emphasises the importance of relational value of the benefits derived by different social and cultural groups from ecosystem services. Both these distinctions, while valuable, can be seen as implicit within the preceding frameworks of the MEA, TEEB, and CICES.

In the economic valuation of benefits derived from ecosystem services, specialists must consider the benefits received from the natural systems in relation to the value they represent in the social, cultural and economic systems in which they occur. It is understood by the former classifications, that it is the interplay between the human and natural systems in which the value of benefits to humans can be defined. There is value in the explicit acknowledgement of the interactive role played by the various social, economic and cultural systems with the ecosystems under review irrespective of the specific classification utilised. The ecosystem services that were considered in this analysis are as per TEEB Framework (TEEB, 2013).

Table 1: Review and comparison of popular Ecosystem Service Frameworks commonly utilised in classifying natural benefits

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

Ecosystem Services Typology as per MEA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES 2018; Diaz et al., 2018; Kadykalo et al., 2019)
		° soil formation and composition ° water conditions ° atmospheric composition and climate regulation	8. Formation, protection and decontamination of soils and sediments 9. Regulation of hazards and extreme events 10. Regulation of detrimental organisms and biological processes
Cultural Services - Aesthetic values - Spiritual/ religious values - Educational - Recreation and ecotourism - Inspirational - Sense of place - Cultural heritage	**Cultural and Amenity Services** - Recreation, mental and physical health - Tourism - Aesthetic appreciation - Spiritual experience and sense of place	**Cultural Services** - Physical and intellectual interactions with ecosystems and land-/seascapes ° Physical and experiential interactions ° Intellectual and representational interactions - Spiritual, symbolic and other interactions with ecosystems and land-/seascapes ° Spiritual and/or emblematic ° Other cultural outputs	**Non-Material NCP (includes material elements)** 15. Learning and inspiration 16. Physical and psychological experiences 17. Supporting identities
Supporting Services - Nutrient Cycling - Soil Formation - Primary Production - Habitat - Biodiversity	**Habitat Services** - Habitat for species - Maintenance of genetic diversity		**Material, Non-material and Regulating NCP** 18. Maintenance of options **Nature (Intrinsic) e.g.:** - Genetic Diversity, Species diversity - Evolutionary and ecological processes - Gaia, Mother Earth - Animal welfare / rights

3.2 Ecosystem Services Valuation Module

The Ecosystem Services Valuation Module functions to standardise the identification, quantification, and prioritisation of services towards assessing the value of ecosystem services present within the catchment. The four components, as presented in the Decision Analysis Framework, form the focus of the module. The Socio-Economic Comparison Tool (SEcT) (Naidoo et al., 2017) is used as the platform from which to frame relationships between various components. Although inputs draw largely from data collected (and presented) in the Status Quo and delineation of Integrated Units of Analysis and Resource Units Report (RDM/WMA13/00/CON/CLA/0224), additional data inputs were identified and included where necessary. Key data that are used as inputs into the module include the following:

1. The presence of Ecological Infrastructure (EI) segregated into type, extent and condition per IUA.
2. The socio-economic wellbeing of communities within the catchment represented by demographic breakdowns and spatial indicators of land use per IUA as well as indicators of vulnerability and wellbeing; and
3. Classification of beneficiaries per IUA into representative beneficiary categories present within standard Social Accounting Matrix (SAM). These were further segregated into formal and informal recipients of ecosystem services.

Utilising the data inputs, ecosystem services will be prioritised against the risk of impact on socio-economic wellbeing through impact to ecological infrastructure. The process involves undertaking a Comparative Risk Assessment (CRA) per IUA looking at the likelihood and consequences of impact to beneficiaries. The resulting output is a prioritised list of Ecosystem Services that are spatially aggregated across the WMA.

3.3 Quasi-Social Accounting Matrix (QSAM) Module

A Social Accounting Matrix (SAM) is a well-established macro-economic modelling tool, which has been used in several water resource classification studies in the past. A SAM quantifies all transactions between sectors and actors in the economy, in a specific calendar year. The sectors and actors include primary (agriculture, forestry and mining), secondary (predominantly manufacturing) and tertiary (all service sectors) sectors, as well as consumption by households and trade outside of the economy.

The underlying data used to construct a SAM is official economic data provided by Statistics South Africa. The SAM can be restructured into a modelling tool through which the impact of water resource management scenarios can be evaluated.

An Upper Orange Quasi-Social Accounting Matrix (QSAM) was developed with the aim to quantify the size of the Upper Orange economy. The QSAM module was developed from the Supply and Use tables published by Statistics South Africa (Stats SA) in June 2024 for the year 2021. The first step was to develop the Supply and Use tables for the Upper Orange River catchment. The Upper Orange Supply and Use Tables were then used to develop the Input-Output table.

An Input-Output table is a representation of national or regional economic accounts that records how industries produce and trade between themselves (i.e., flows of goods and services). The flows for input are recorded in the columns of the Input-Output table and the outputs are included in the rows of the table. These flows are recorded in a matrix, simultaneously by origin and destination (OECD, 2006). An input-output analysis is the standard method for measuring the propagation effects of changes in final demand for a product in an industry or sector (Surugiu, 2009). The Input-Output table was then extended into a QSAM by incorporating labour (compensation of employees) and households. The QSAM is a square matrix of transactions between the rows (incomes) and columns (expenditures) of the matrix representing the various sector accounts. In the square format of a QSAM the total receipts must equal total payments for each of its accounts (Van Seventer & Davies, 2019). The QSAM may be used to evaluate the socio-economic impact of exogenous changes to the Upper Orange River catchment economy.

The macro-economic indicators estimated in the QSAM model for the catchment are Gross Value Added (GVA) and Compensation to Employees as described in Table 2.

Table 2: Macro-economic indicators estimated in the economic model

Indicator	Unit	Description
Gross Value Added (GVA)	Rand Millions	Economic productivity metric measuring the contribution of each sector of the Upper Orange Catchment to the economy
Compensation to Employees	Rand Millions	Component of the GDP measuring the change in total salaries paid

The QSAM model also estimates economic multipliers from the Leontief inverse matrix. Multipliers indicate the increase in final income arising from the expenditures within economic sectors. The multiplier effect gives a measure of the impact that a change in economic activity such as investment or spending, will have on the total economic output.

The methodology followed to build the QSAM for the Upper Orange catchment is illustrated in Figure 3.

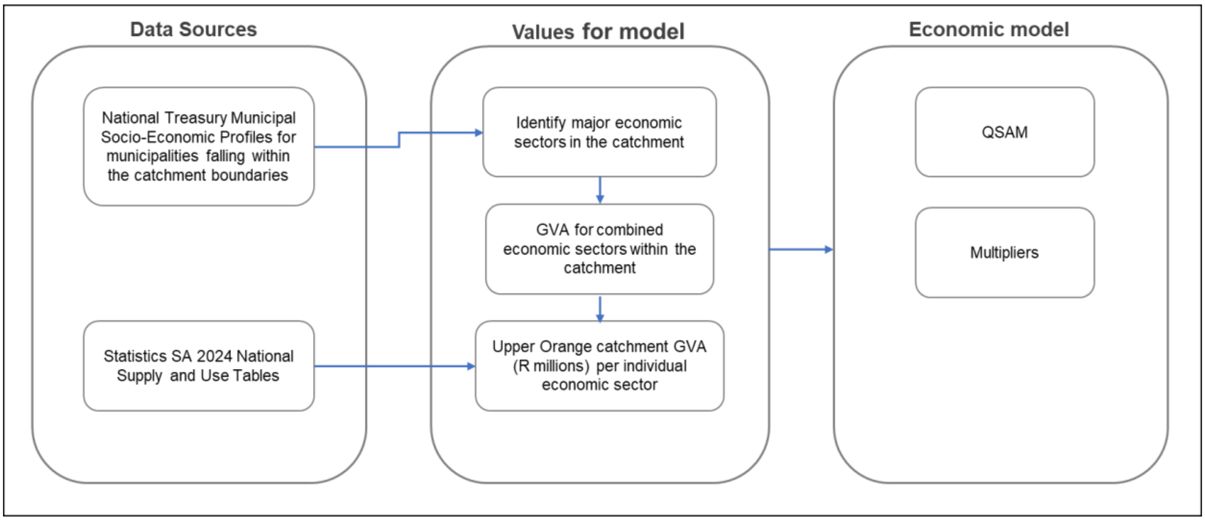

Figure 3: Schematic representation of the methodology used for the economic model development

The major economic sectors of the Upper Orange River catchment were identified using the economic data reported by National Treasury for each of the Local Municipalities that lie within the catchment.

The Upper Orange River catchment GVA was determined per sector based on the National Treasury economic data. The Upper Orange River catchment Supply and Use tables were developed by proportioning of the National Supply and Use Tables based on the National Treasury published economic data for the municipalities within the catchment area. To do this, an economic table was compiled from the National Treasury data, where the sector categories are as follows:

- Agriculture, forestry and fishing
- Mining
- Manufacturing
- Electricity & water
- Construction
- Wholesale & retail trade; catering and accommodation
- Transport & communication
- Financial services
- General government
- Community, social & personal services

The National Supply and Use Tables' categories were then summarised to fit these categories. An example is shown below using the Agriculture and Mining sectors.

Agriculture, forestry and fishing
Agriculture
Forestry
Fishing

Mining
Mining of coal and lignite
Extraction of crude, petroleum and natural gas
Mining of gold and uranium ore
Iron ore mining; chrome mining; copper mining; manganese mining; platinum mining; other metal ore mining
Dimension stone; Limestone and lime works; Other stone quarrying; Diamond mining; Chemical and fertiliser minerals, phosphates and other; Extraction and evaporation of salt; Other mining and quarrying not elsewhere classified (n.e.c.) (stones, asbestos and other minerals and materials)
Service activities incidental to mining of minerals

The Upper Orange GVA values for each sector were then split based on the national proportions of the individual sector categories to the combined sector. Using the National Supply and Use tables, each value's proportion to the National GVA was calculated and used to split the Upper Orange GVA to complete the tables. Once the Supply and Use tables were complete, they were then used to construct the Upper Orange QSAM. Finally, the multipliers were derived from the Upper Orange QSAM.

The aim of the QSAM is to combine the suppliers and consumers of economic products in a single matrix (table of interacting economic sectors) to determine the magnitude of the macro-economic indicators.

4 RESULTS

This section details the various aspects of the linking process followed as well as showing how the different aspects will be used during the later scenario phase of the project.

4.1 Ecosystem Services in the Upper Orange River catchment

The Upper Orange River catchment area is divided into 10 Integrated Units of Analysis (IUAs), which provide a comprehensive representation of the socio-economic drivers, well-being, and characteristics of the beneficiaries of ecosystem services in the area. These IUAs consider the distribution of ecological infrastructure, resulting in varying degrees of benefit from the flow and direct utilization of ecosystem services for each IUA. The beneficiaries are further categorized into formal and informal users, reflecting the additional variation among them.

Formal beneficiaries are individuals or entities whose use of consumptive ecosystem services, specifically provisioning services, is regulated through established frameworks. This regulation typically involves obtaining a water use license or adhering to municipal guidelines for extracting or using water. Municipalities, agricultural, manufacturing, mining, government services, electricity and water providers, as well as various households, fall under the category of formal beneficiaries within the catchment area.

On the other hand, informal beneficiaries are those who benefit from services that are not subject to formal regulations. These services are often associated with the subsistence use of resources in relatively undeveloped regions and on traditional lands. The primary beneficiaries in this group are rural communities whose livelihoods are closely tied to the advantages derived from natural ecosystems.

The impact of management on the flow of ecosystem services can vary depending on the type of beneficiary. Among these beneficiaries, rural populations are particularly vulnerable to changes in the delivery of ecosystem services. To better understand the spatial dynamics of ecosystem service flow and the specific types of services involved, an assessment was conducted. This assessment examined the distribution of beneficiaries in relation to ecological infrastructure, revealing how ecosystem services are spatially oriented and how they interact with different beneficiary groups.

While the catchment area encompasses various ecosystem services, only specific key services were chosen to be incorporated into the development process of the Integrated Economic Model (IEM). The selection of these services was guided by anticipated management scenarios and the potential impact these scenarios could have on the flow of ecosystem services. It is important to note that, during the evaluation of scenarios, if an ecosystem service is found to be at risk but was not initially included in the report, it will be retroactively included and taken into consideration. This ensures that all relevant ecosystem services will be accounted for and evaluated in the scenario analysis.

Key ecosystem services identified and prioritised across the Upper Orange River catchment include:

1. Fresh Water Provisioning
2. Water Quantity Regulation (Flow Regulation)
3. Food, Raw Materials and Wild Collected Products Provisioning
4. Erosion Regulation / Soil Stability
5. Water Quality Regulation: Purification and Waste Management
6. Tourism, Recreational and Amenity Services; and
7. Biodiversity Support.

4.1.1 Fresh Water Provisioning

Key Ecological infrastructure:	Rivers, Streams, Dams and Aquifers
Beneficiaries:	Agriculture; Mining; Manufacturing; General Government; Wholesale & retail trade, catering & accommodation; Community Services
Use:	Direct use value

Water provisioning is a crucial ecosystem service in the Upper Orange catchment, benefiting a significant number of individuals. Among the IUAs, IUA 08 (Vanderkloof Dam) stands out with the highest number of wetlands, accounting for 2.5% of the wetland habitat relative to its size. Following closely is IUA 10 (Modder/Riet), with 2% of wetland habitat and the highest number of priority wetlands. On the other hand, IUA 1 has the least number of mapped wetlands, only comprising 0.14% of its area. Despite its small size of approximately 43.53 ha, IUA 1 plays a critical role in freshwater provisioning.

The catchment is home to various large and small dams that primarily support irrigation but also cater to local domestic and rural water needs. These reservoirs play a pivotal role in ensuring sufficient water resources within the catchment.

Water provisioning in the catchment includes several inter-transfers and two transfers out of the catchment. The key water transfer out of the Upper Orange River catchment is the Orange-Fish Tunnel transfer which diverts water to the Eastern Cape where it is used for irrigation, urban and industrial use. The volume of water for the transfer is based on the total scheduled irrigation area in the Eastern Cape and the various quotas of water within these irrigation schemes for the applicable year, and the other requirements are for urban and industrial use. For the year 2012 this volume was determined as 620 million m^3/a, of which 577.6 million m^3/a, was for irrigation and 42.4 million m^3/a for urban or industrial purposes (DWS, 2015). The other transfer out is the Orange Vaal Transfer Scheme where volumes range from 120 to 142 million m^3/a depending on the water level and water quality in the Vaal River. This transfer is to mitigate shortages and increased salinity levels at the Douglas Weir on the Lower Vaal River (ORASECOM, 2012).

Land use in the Upper Orange River catchment is predominantly characterised by natural vegetation, with livestock farming being the primary economic activity. Extensive areas are dedicated to dryland cultivation, primarily for grain production, particularly in the northeastern parts. The Modder Riet catchment is largely dominated by agricultural activities, with limited mining operations and a few urban centres. Notably, significant areas along the main rivers have been developed for irrigation, focusing on the cultivation of grain and fodder crops downstream of irrigation dams. Subsistence agriculture in the catchment mainly involves the cultivation of annual crops, which can be a mix of dryland and irrigated crops. The irrigation methods employed for these crops are often informal, requiring manual water transfer from nearby streams or rivers to the fields.

The Upper Orange River catchment is home to a population of approximately 1.4 million in 2023 with about 476,000 households (Stats SA 2011 Census adjusted) which represent both formal and informal beneficiaries that use water. Households are separated into those with formal water distribution infrastructure (piped water) and those without. Major urban and industrial developments in the catchment include Mangaung (Bloemfontein), Botshabelo and Thaba ‘Nchu as well as Maletswai (Aliwal North). Smaller towns include Clarens, Ficksburg, Hobhouse, Fouriesburg, Hlohlolwane (Clocolan), Winnie Mandela (Brandfort), Ladybrand, Vanstadensrus, Wepener, Smithfield, Hanover and Noupoort also contribute to the region's growth and development.

According to the National Wetlands Map version 5 (NWM5) report (Van Deventer et al., 2018), approximately 30% of the wetlands in the catchment are considered to be in a relatively natural or near-natural state, indicating minimal changes to their original condition. Around 10% of the wetlands are considered moderately modified, while only 21% are classified as largely to seriously modified. The latter category is primarily attributed to various land use impacts in the catchment, including irrigated commercial croplands, mining-related barren areas, urbanised areas with hardened surfaces, poor land use management practices, and overgrazing (DWS, 2022). In terms of the mining sector, it contributes approximately 1% to the GDP, with activities mainly focused on alluvial diamond mining, salt works, sand mining, and quarrying.

Changes to the allocation of water within the system may affect different beneficiaries in a variety of ways. Greater allocation of water to commercial or industrial activities, may have a significant impact on some informal water users, although these may rely on smaller tributaries or groundwater. Similarly, the state of formal water distribution infrastructure will influence the flow of these water provisioning benefits to their final intended beneficiaries.

4.1.2 Water quantity regulation (Flow Regulation)

Key Ecological infrastructure:	**Wetlands, and Strategic Groundwater Areas**
Beneficiaries:	Agriculture; Mining; Manufacturing; General Government; Wholesale & retail trade, catering & accommodation; Community Services
Use:	Direct and indirect use

Water quantity regulation is an essential function that ensures the sustainable management and availability of water resources. It is a crucial ecosystem service provided by the diverse ecosystems within the Upper Orange catchment. This catchment encompasses several Strategic Water Source Areas (SWSAs) in IUA 4, 5, 7, 9, and 10, as well as various wetlands spread across the entire region. These ecosystems serve as vital water sources, providing freshwater for both the basin itself and the surrounding areas.

The service of water quantity regulation involves capturing precipitation through a range of processes. Healthy and intact soils play a pivotal role in facilitating effective infiltration, while different types of wetlands act as the primary ecological infrastructure associated with this ecosystem service.

Most of the rainfall is accumulated during the summer months, primarily in the form of ephemeral wetlands, seeps, unchanneled valley bottoms (UVB), and discontinuously channelled VB, all of which ultimately contribute to the SWSAs. These Strategic Water Source Areas hold immense importance as national water sources within South Africa, making them critical ecological infrastructure for this regulating service.

4.1.3 Erosion control/Soil Stability

Key Ecological infrastructure:	**Rivers, Tributaries, and Wetlands**
Beneficiaries:	Agriculture
Use:	Indirect use

Among the various essential services provided by ecosystems, erosion control stands out as one of the most fundamental. It plays a critical role in regulating water flow, maintaining soil productivity, and preventing erosion. Vegetation cover is key to these processes, as it helps retain soil integrity and supports important biological functions such as nitrogen fixation (FAO, 2020).

In the Upper Orange River catchment, robust terrestrial systems and wetlands serve as the primary ecological infrastructure for preserving soil stability and preventing erosion. These structures are particularly vital in areas with flat or gently sloping terrain, where they employ various methods to mitigate erosion. Vegetation, including plants and trees, plays a crucial role in stabilizing soil by enhancing the cohesion and strength of soil particles. The roots of herbaceous plants effectively interlock soil particles, reducing erosion caused by water flow. Wetlands act as natural barriers by capturing sediments and slowing water flow, thereby minimizing soil erosion. This is especially significant in IUAs 1, 2, 3, 4, 5 and 10, where mixed agriculture is prevalent.

The importance of erosion control services is evident, particularly for subsistence farmers who heavily rely on fertile soil for crop cultivation. Additionally, commercial agriculture indirectly benefits from these services by maintaining stable soils, which are crucial for sustaining productivity levels.

4.1.4 Water Quality Regulation: Purification and Waste Management

Key Ecological infrastructure:	**Wetlands and Strategic groundwater areas**
Beneficiaries:	Agriculture; Mining; Manufacturing; General Government; Wholesale & Retail Trade, Catering & Accommodation; Community Services
Use:	Indirect use

The ecological infrastructure responsible for water purification and waste management primarily includes wetlands and strategic water source areas. SWSAs are vital for maintaining and improving water quality through natural filtration, contaminant reduction, sediment control, nutrient regulation, and various other ecological processes. While wetlands act as highly effective natural water filters by regulating water flow, facilitating the settling of particulate matter. Additionally, both these ecological infrastructures have vegetation and soil that absorb and break down harmful contaminants, such as heavy metals and agricultural chemicals, through natural processes like phytoremediation and microbial activity.

With the majority (98%) of the population within the catchment area having access to formal water sources, including piped water in their dwellings, piped water in their yards, communal tap water within 200 meters of their households, and communal tap water more than 200 meters away. The primary beneficiaries of these natural water purification services are regional and local water boards. Without these services, these boards would need to allocate significant resources to construct artificial infrastructure for water purification. This advantage also extends to domestic and commercial water consumers, resulting in reduced water fees and access to naturally uncontaminated water. Furthermore, the natural environment provides valuable purification services to the 2% of water user population of the catchment dependent on the informal water sources.

In addition, ecosystems that provide water quality regulation services are typically located downstream of areas with land uses known to negatively impact water quality. These ecosystems receive contaminated water from upstream areas, often exacerbated by various land uses, and subsequently provide regulated or treated water to downstream beneficiaries. As a result, water quality ecosystem services are not expected to have significant value in high escarpment areas where water remains uncontaminated. Therefore, it is crucial that any modifications to water allocation carefully consider the well-being of these systems during the planning process.

4.1.5 Food, Raw Materials and Wild Collected Products Provisioning

Key Ecological infrastructure:	**Orange River and its tributaries; Wetlands**
Beneficiaries:	Community, Social & Personal Services; Agriculture (subsistence and commercial)
Use:	Direct use

In the Upper Orange River catchment, agriculture plays a pivotal role encompassing both commercial and subsistence farming, critical for regional food provisioning services. The fertile soil and ample water supply create optimal conditions for cultivating a variety of crops, with riparian vegetation also serving as vital grazing land for cattle, particularly important for subsistence farmers. The ability of the land to support agriculture is fundamental to the region's well-being and sustenance.

While the entire Upper Orange River catchment is commercially productive, the most economically robust areas are concentrated in IUAs 2, 4, 5, 8 and 9, evident from their high agricultural activity. Commercial agriculture benefits significantly from the land's capacity to foster diverse crop cultivation, serving as a primary economic driver across several municipalities in the region. It's important to note that substantial additional investments and resources are required for successful commercial crop cultivation.

Subsistence agriculture, although challenging to quantify, holds immense importance as the primary source of nutrition for rural populations, which constitute a significant portion of the region's inhabitants. This type of agriculture focuses mainly on staple crops, vegetables, and extensive grazing of livestock.

The benefits of food production extend beyond agriculture and subsistence farmers themselves. Secondary processing of agricultural products adds considerable economic value, generating income for numerous households and industries in the region, thereby fostering further economic development.

In more rural communities, wild food collection enhances food security, while gathering wood serves as a primary fuel source. Additionally, other wild-harvested medicinal products and foodstuffs from the surrounding environment may be traded within the informal economy.

Changes in water allocation policies are not expected to significantly impact beneficiaries of wild-harvested food and materials. However, reduced water flow could affect fish harvesting in rivers and have broader implications for ecosystems associated with the Orange River mouth estuary in the Lower Orange catchment. Alterations to the flow regime would influence processes such as sedimentation and flood events, impacting the duration of the mouth's openness, salinity gradients, species access, and inputs to marine systems from inland. Disruptions to these processes would significantly affect the provisioning services supported by the estuarine system.

4.1.6 Tourism, Recreational and Amenity Services

Key Ecological infrastructure:	**Protected Areas, Orange River and its tributaries and Wetlands**
Beneficiaries:	Community, Social & Personal Services; Trade, Catering & Accommodation
Use:	Direct use

Tourism plays a vital role in driving economic growth on a global scale, and the Upper Orange region is no different. This cultural ecosystem service not only enriches the experiences of visitors but also creates income opportunities for service providers in the nature tourism sector. The direct use value of tourism is intricately connected to a diverse array of ecological infrastructure, encompassing untouched natural landscapes like mountains, rivers, wetlands, and coastal areas renowned for their abundant biodiversity. These remarkable natural assets serve as magnets for tourists and significantly contribute to the local economy through activities such as wildlife observation, hiking, and engaging in water sports.

The Upper Orange catchment is home to numerous national parks, nature reserves (both provincial and private), protected areas, and heritage sites, all of which play a pivotal role in attracting tourists to the region. These include prominent destinations like Golden Gate Highlands National Park in IUA 1, Oviston Reserve in IUA 3 and 6, Balloch Protected Environment and Lammergeier Highlands Nature Reserve in IUA 4, Mount-Zebra Camdeboo protected area, High Karoo Park, and the Compass Berg protected environment in IUA 7. Additionally, Grootfontein Private Nature Reserve, Thanda Thula Reserve, Gemsbokpark Private Nature Reserve, Roodepoortjie 144, and the Zoutpansdrif 246 area in IUA 8 contribute to the natural allure. Other notable sites within the region include Soetdoring Nature Reserve, Dawn Valley Private Nature Reserve, Franklin Private Nature Reserve, Bergkraal Reserve, Kopano Nokeng area, Karee Reserve, De Kuilen Private Nature Reserve, Wag 'n Bietjie Private Nature Reserve, Kareefontein Private Nature Reserve, Auch Macoy Game Reserve, Grasslands Safaris, and a section of the Blesbok Private Nature Reserve in IUA 9. Lastly, Mokala National Park and Vaalbos National Park in IUA 10 complete the impressive list of attractions in the area.

Aquatic recreational activities, including boating, river rafting, kayaking, and fishing, have a magnetic effect on tourists and holidaymakers, drawing them to aquatic systems within the catchment. Fishing and boating are particularly popular in the larger dams of the catchment. The benefits of these services extend beyond the visitors themselves, as they also have a significant impact on the local communities where these attractions are located.

In addition to aquatic activities, tourists and holidaymakers also derive immense pleasure from engaging in pursuits such as hiking, game viewing, and bird watching in the numerous protected areas scattered throughout the region. It is widely recognized that spending time in nature provides substantial psychological, emotional, and physical benefits. These activities contribute to the overall well-being of individuals and foster a deeper appreciation for the natural environment.

The influx of tourists and recreational enthusiasts not only enhances the overall experience but also plays a vital role in bolstering local economies. The revenue generated from these activities creates income opportunities and job prospects in the hospitality and service sectors. Consequently, the preservation and promotion of these natural attractions are of utmost importance, as they contribute to both environmental conservation and the economic development of the region.

4.1.7 Biodiversity Support

Key Ecological infrastructure:	**Protected Areas and nature reserves**
Beneficiaries:	Agriculture; Community, Social & Personal Services; Trade, Catering & Accommodation
Use:	Indirect use

Support for biodiversity, including biological control, is an often-underappreciated service provided by thriving ecosystems, and it is intricately linked to many of the other services discussed earlier. Biodiversity offers wide-ranging benefits to human-natural systems, such as maintaining a delicate equilibrium between parasites, pests, and their predators, ensuring the presence of healthy populations of pollinators, and creating the necessary conditions for various food species, notably fish species, which are essential for human sustenance.

In this regard, the protected areas and significant ecological features found in each of the IUAs are key biodiversity hotspots. The Upper Orange catchment boasts diverse wetlands, which play a crucial role in regulating and supporting biotic processes. The nutrient-rich water flowing from the Upper Orange catchment to the Lower Orange catchment and into the sea sustains and drives the lifecycles of numerous commercially valuable aquatic species, including fish, crab, eel, and prawns.

The beneficiaries of this service are extensive and diverse. Agriculture benefits from the natural control of pests and parasites, leading to cost savings on pesticides and animal treatments. Healthy populations of pollinators contribute to increased crop yields. Households experience reduced disease prevalence, thereby benefiting from a healthier population. Consequently, healthcare systems also reap the rewards of improved overall well-being.

The reduction of flow can have significant consequences for the ability of specific areas within the catchment to provide biodiversity support services. It is essential to consider the impact of reduced flow on the ecological integrity of wetlands and its influence on the propagation of fish species.

4.2 Consolidated Beneficiaries

Beneficiaries, as per those identified through the QSAM, of prioritised ecosystem services have been consolidated per ecosystem service (Table 3). The value of the ecosystem services to each beneficiary varies depending on the size of the sector, the magnitude of environmental contribution received and the dependency of the sector on the benefit. A full description of the industry sector groupings as listed in Table 3 (QSAM beneficiary class) is provided in Annexure 2.

Table 3: Ecosystem Service linkages with QSAM beneficiaries in the Upper Orange River catchment

Intermediate Ecosystem Service	Final Ecosystem, Services	General Sector	QSAM Beneficiary Class
Water Quality Regulation: Purification and Waste Management Water Quantity Regulation Erosion Regulation / Soil Stability	Food Provisioning	Informal Households	Informal, illicit, non-profit, and households
		Agriculture	Agriculture
	Fresh Water Provisioning (water quantity)	Households (formal and informal)	Informal, illicit, non-profit, and households
			Households
		Agriculture (irrigation)	Agriculture
		Mining	Stone
		Manufacturing	Meat, fish, fruit, vegetables, oils and fats
			Dairy
			Grain and animal feeds
			Other food products
			Beverages
			Tobacco
			Textiles; Other textiles; Knitted fabrics; Wearing apparel
			Leather; Footwear
			Sawmilling of wood
			Wood products
			Paper
			Publishing
			Printing and reproduction
			Basic chemicals; other chemicals

Intermediate Ecosystem Service	Final Ecosystem, Services	General Sector	QSAM Beneficiary Class
			Rubber
			Plastic
			Glass
			Non-metallic minerals
			Iron and steel
			Casting of metals; Structural metal; Other fabricated metal
		Manufacturing	General purpose machinery
			Special purpose machinery
			Household appliances
			Computing machinery
			Electric motors; Other electric components
			Television and radios
			Medical appliances
			Motor vehicles; Vehicle bodies; Vehicle parts
			Equipment
			Furniture
			Other manufacturing
			Recycling
		Government Services	Electricity
			Water
			Sewage and refuse
	Raw Materials Provisioning (including medicinal resources)	Informal Households	Informal, illicit, non-profit, and households
	Tourism, Recreational and Amenity Services	Catering & accommodation	Hotels; Restaurants
			Real estate activities (Lease and Fee basis)
		Households	Informal, illicit, non-profit, and households
			Households
		Community, social & personal services	Recreation (Sporting and other recreational activities)

4.3 Approach to the Ecosystem Service Valuation

The ecosystem service valuation process, to be completed further along in the water resource classification 7 step process, will be conducted during the scenario evaluation step. The scenarios will include a range of management scenarios over a temporal scale to be tested against the baselines and linkages determined here. Ecosystem services at risk of impact will be identified through the use of inputs developed by all specialists and identifying key responses to scenarios by ecological infrastructure and their driving processes. Only ecosystem services identified to be at risk due to implementation of management scenarios will be valued. The valuation process will in this way, function to allow for the evaluation of trade-offs between management scenarios and therefore aid in the determination of management class per IUA.

Ecosystem service types will be valued broadly following the MEA and CICES frameworks and results of the valuation will be summarised. An example of the structure is provided in the table below.

Table 4: Ecosystem valuation step, post CRA process

Class	Ecosystem Service	Annual Flow Value R millions / annum	Asset Value R millions
Provisioning	1. Fresh water	Values to be estimated	Values to be estimated
	2. Food, raw materials		
	3. Cultivation		
Cultural	4. Nature-based tourism		
	5. Property value		
Regulating	6. Flow regulation (maintenance of base flows)		
	7. Erosion control/soil stability		
	8. Sediment retention		
	9. Water quality amelioration		
	10. Pollination		
	11. Flood attenuation		

4.4 Quasi-Social Accounting Matrix (QSAM) Module

The Upper Orange River catchment stretches across an area that covers parts of the Free State, Northern Cape and Eastern Cape provinces, with the largest proportion within the Free State province. The catchment contributed an estimated GDP of R255.5 billion (Table 5) based on municipal economic data of 2019 (NT, 2021).

In the Upper Orange River catchment, the largest contribution to the GDP is from the tertiary sector (74.5%), followed by the secondary sector (20.6%) and finally the primary sector (4.9%). The key contributions in the tertiary sector (service industry) are from financial services (20%), the wholesale & retail, catering & accommodation sectors (tourism playing an important role) contributing 17%, followed by general government (15%) and community, social and personal services (10%). Manufacturing, part of the secondary sector (creating or producing finished goods or services) contributes 12% to the overall catchment GDP. The construction sector and electricity and water sectors make up the remaining 9% of the secondary sector contribution to GDP. The primary sector's (output consists of raw materials) main contribution to the catchment GDP is from agriculture (4%), with mining only contributing 1%.

The Upper Orange River catchment QSAM model and multipliers will be used in evaluating the various scenarios based on the relevant values per sector for each scenario assessment.

Table 5: The Upper Orange River catchment GDP per sector (based on municipal data from NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R9,402	4%
Mining	R3,072	1%
Manufacturing	R29,730	12%
Electricity & water	R8,679	3%
Construction	R14,163	6%
Wholesale & retail trade; catering & accommodation	R44,642	17%
Transport & communication	R31,044	12%
Financial services	R51,052	20%
General government	R38,040	15%
Community, social & personal services	R25,648	10%
Total GDP	R255,473	100%

4.5 Water Quality Account

The Water Quality account provides information on the state of the quality of water resources. Water quality account assists in reporting the consequences of economic development that results in ecological degradation. The account will only be developed should there be a scenario that requires incorporating the impact of water quality in the catchment's economy.

Water quality relates to two types of regulating ecosystem services: water purification and waste assimilation. In the first instance, aquatic ecosystems have a natural ability to purify water and can therefore receive polluted water up to a certain threshold. Beyond that threshold it is not able to "treat" water, however, it can still function as a sink for pollutant load, hence the waste assimilation service. The waste assimilation service is a unique form of ecosystem service in that nature consequently serves as a "waste disposal area" for pollution load produced by anthropogenic activities. In both instances, we are dealing with the effects of water pollution on the economy.

Two broad approaches exist for internalising the effects of poor water quality into the economy. The first requires the analysis of damage caused by water pollution. This could include increased treatment costs downstream, reduced agricultural production, higher costs of maintenance, increased risk of water-related health costs, and so forth.

The second approach estimates the costs of treating polluted water and/or effluent to acceptable limits. The first approach is a bottom-up highly site-specific, and highly data intensive. The second approach is a top-down approach and is better suited to the water resource classification process.

Water pollution abatement costs can be estimated if a marginal abatement cost curve is available. Such a curve is a multivariate mathematical-statistical function, which should ideally be developed, based on empirical data sourced from the particular catchment area within which the pollution problem is located. The marginal abatement cost curve relates a set of independent variables to the cost of water pollution abatement. The Waste Discharge Charge System (WDCS) have identified five sets of water quality measures including salinity, pH, nutrient load, chemical oxygen demand (COD) and heavy metals, and these would thus form the independent variables of the abatement cost curve.

Water quality impact valuation through load modelling:

The cost of water pollution can be estimated by estimating the water quality externality benefits enjoyed by polluting industries. This can be accomplished by identifying the:

- most important water quality indicators representing the pollution associated with these activities,
- water treatment technologies required for the reduction of these identified pollutants,
- target water quality objectives for the identified pollutants and estimating the cost of treating to RQO requirements.

Linkage to RQOs

Damaging human activities are the discharge of wastes with pollutant concentrations that exceed the RQO of the identified pollutant. Therefore, central to the water resource classification, process is the setting of target concentrations (referring to recommended resource-directed value (RRDV) or effluent concentration) to achieve in-stream resource quality objectives applicable to the resource class, as well as maximum allowable resource-directed values (MARDV) to achieve the upper limit of the in-stream quality associated with the resource class for each water pollutant. Groundwater quality in the catchment is also important. Groundwater quality varies significantly in the catchment and is affected by natural (geological), climatological and anthropogenic effects. The anthropogenic effects include groundwater pollution due to poor solid waste management (rock/waste dumps), poor leachate management (tailings storage facilities), and poor wastewater management (RDM/WMA13/00/CON/CLA/0224).

5 DEMONSTRATING LINKAGES

The Upper Orange River catchment is characterised by a range of ecological infrastructure which provides a range of natural benefits to various formal and informal beneficiaries. Several key linkages and insights have been revealed through the development of the IEM.

The Upper Orange River catchment contributes an estimated R255.5 billion (preliminary based on municipal data from the National Treasury, 2021) to the economy of South Africa. This economy is relatively small representing only 4.6% of the national GDP of R6.3 trillion (NT, 2021). The largest economic sector in the catchment is the tertiary sector, the main contribution being from the financial services sector (20%) followed by the wholesale & retail, catering & accommodation (tourisms plays an important role) at 17% and the general government sector with a contribution of 15% to the catchment total GDP. The next largest contribution is from the manufacturing sector which contributes 12%. Agriculture, though only contributing 4% is one of the important economic activities in the catchment.

Several sectors within the Upper Orange River catchment can be directly linked as beneficiaries of ecosystem services (Table 3) and these links are predominantly through the provisioning and regulation of fresh water. There are, however, also links through cultural services including tourism, recreational and amenity values. Although the value added of the economic sectors in their entirety cannot be attributed directly to ecosystem services there is significant support provided by these services through enabling or opportunity benefits. Therefore, the natural contributions can be linked as a proportion of the total size of the sectors. The value of ecosystem services, as a proportion of the total size of a specific sector will vary between sectors depending on their reliance on the service. The value contribution, for example to the irrigated agriculture sector (as a highly water reliant sector) will be significantly larger than that of the glass manufacturing sector, for instance, whose reliance on water for production is not as high as agriculture.

Concerning the management of water, the agricultural sector (irrigated agriculture), agro-processing, households and government sectors are highlighted as key contributors to the water economy within the Upper Orange catchment. These contributions indicate linkages between the requirement of freshwater provisioning services on the sectors themselves and thus indicate linkages between production and natural benefits. It is important to note that these contributions to the water economy do not directly translate to the quantity of water that is utilised by a sector due to the different allocated tariffs for the water that is purchased. Tourism, as a prominent formal sector present within the catchment, although not a significant water consumer, is directly underpinned by cultural services provided by the ecosystems that are present within the catchment. The water provisioning services include natural water and treated water.

The agricultural sector is composed of dryland, irrigated and livestock agriculture with the latter two directly reliant on water provisioning services. This reliance on raw water is largely due to irrigation demand through the significant proportion of irrigation agriculture within the catchment, but additionally to livestock watering demand from the extensive livestock agriculture taking place within the Upper Orange River catchment. The sector contributes an estimated R9.4 billion to the Upper Orange River catchment total GDP (Municipal data from National Treasure (NT), 2021).

Agricultural manufacturing (agro-processing) represents a group of sectors that manufacture goods from the raw materials sourced directly from agriculture. These include several food processing sub-sectors, beverages, tobacco, textiles and paper production industries. Agricultural manufacturing contributes to the catchment water economy through both natural (raw water) and treated water purchases. This sector's functioning is largely reliant on water provisioning and links this sector to water provisioning services. This sector, particularly food processing and beverages, represents an important part of the overall manufacturing sector within the catchment. Other manufacturing within the catchment such as light manufacturing, service orientated industries and brick manufacturing also contribute to natural and treated water purchases.

Tourism is a key economic driver within the catchment and is represented here by the Hotel and Restaurants and Recreation (Sporting and other recreational activities) sectors. The linkages with cultural ecosystem services provided by key ecological infrastructure have direct linkages to the presence of ecological features associated with tourism and recreational activities, such as dams, particularly the two large dams of Gariep and Vanderkloof and their adjacent nature reserves, national parks (Golden Gate, Mokala, and Vaalbos), several game farms and nature reserves (government and private) and protected areas. This sector is part of the total Wholesale & retail trade; catering & accommodation sector contributing an estimated R44.6 billion to the catchment GDP (Municipal data from National Treasure (NT), 2021).

Although linkages between beneficiaries within the Upper Orange River catchment have been demonstrated and linked with the opportunity value of water, the total opportunity value may be considered underestimated when only looking at sectors within the Upper Orange catchment. The water transfers out of the catchment provide additional linkages to beneficiaries which represent increased opportunity value to sectors in the greater region.

The Upper Orange River catchment has several densely populated rural settlements throughout the catchment and these areas have a relatively small formal economy but where there is an important informal economy. These rural community beneficiaries have a generally reduced wellbeing from the perspective of reduced access to services, infrastructure development employment and education resulting in more subsistence-based livelihoods. Communities have an intimate relationship with natural systems represented by direct linkages to a broader range of ecosystem services. The benefits are derived through provisioning of food, collection of raw materials, medicine and fresh water, regulation of water and soils and cultural and spiritual services provided by the rural landscape. The dynamic relationship observed here is twofold: Firstly, the value of these natural benefits to communities who rely directly on them, coupled with limited access to alternatives translates very differently to Rands and Cents compared to economic production.

A typical example would be the value of drinking water (necessary for survival) versus the value of irrigation water (necessary for production). Secondly, the cause-and-effect relationships of economic development and social wellbeing need to be carefully balanced when implementing management scenarios that influence these beneficiaries. For example, an increased water allocation to industry may create jobs (economic wellbeing), however it could translate to a reduced condition of ecosystems and therefore impact on these vulnerable communities (reduced social wellbeing). Conversely, water management that increases flow (reduced extraction) would likely benefit these vulnerable communities through increased ecosystem services flow.

The linkages between ecosystems and socio-economics of the catchment demonstrated here provide valuable insights into the dynamic relationship between ecosystems and beneficiaries of the services they provide.

6 WAY FORWARD

6.1 Ecosystem Services Valuation: Comparative Risk Assessment

The analysis above demonstrates the socio-economic structure of the catchment is highly reliant on various ecosystem services. Given this contributing role that ecosystems provide to the wellbeing of the catchment it is vital that ecosystem services be considered and included in the evaluation of scenarios step to follow in the 7-step water resource classification process. The assessment of development scenarios in the next step will provide insights into the impact of the development scenarios on the ecological value, water resources availability, corresponding socio-economics and associated quality objectives. The ecosystem services valuation approach will be utilised towards evaluating trade-offs against varying water management scenarios. The approach will identify ecosystem services at risk, and value these to support informed allocation of management class per IUA.

The process involves undertaking a Comparative Risk Assessment (CRA) per IUA looking at the likelihood and consequences of impact to beneficiaries. The resulting output is a prioritised list of Ecosystem Services that are spatially aggregated across the WMA.

The CRA process involves defining the following linkages in the chain of causality:

1. *Environmental hazard*: The environmental hazard is the environmental stressor which drives change. The hazard is identified as the input which initiates the chain of causality and is determined through the changes initiated through varying scenarios. Examples in this case include decreased surface water flow through over abstraction from rivers. Note the environmental hazard would vary between ecological infrastructure and across scenarios.
2. *Environmental effect statement*: The environmental effect statement describes the physical impacts that the environmental hazard has on specific ecological infrastructure. In line with the example above, this would describe that decreased surface water flow would modify natural flows processes and restrict primary productivity within the channel and riparian areas.
3. *Risk rating of ecosystem services:* The risk to the flow of ecosystem services is assessed in terms of the likelihood and consequences of impact by the identified environmental effect on the specific ecological infrastructure providing the service. The process is further detailed below:

Ecosystem risk is the function of the likelihood and consequence of a scenario to which EI is exposed.

Thus: ***Risk = f (likelihood, consequence)*** of environmental effect on EI.

For each scenario-EI-ES combination, two questions will be asked:

Firstly, 'What is the likelihood that this ecosystem service, provided by the specific ecological infrastructure, will be affected under this scenario? This speaks to impacts that the scenario would have on the ability to provide the ecosystem service.

Secondly, ‘What would be the consequences of this scenario in this ecological infrastructure to the delivery of this ecosystem service?’ This speaks to the socio-economic consequences and therefore links directly to the relevant beneficiaries within the IUA.

The likelihood of an impact is the change in possibility that a specific scenario will have an impact on the EI and therefore the benefits received. The likelihood rating framework can be seen in Table 6. The consequence of the scenario is the change in the service from the environmental effect of the scenario on the exposed EI. A consequence rating framework can be seen in

Table 7. Likelihood and consequence categories are chosen for each ES. It is important that the certainty is recorded to ensure transparency of the level of confidence in categories chosen. Risks are then automatically ranked according to risk levels. A description of each risk is given (Risk Statement) which includes the underlying chain of causality between environmental effect and its consequence to ensure transparency of the ranking process.

Table 6: Qualitative and quantitative classes of likelihood of impacts (environmental effect, or resultant change in the flow of an ecosystem service) of a scenario having an ecological consequence to a service from EI. Adapted from the classification adopted by the IPCC (2007)

Likelihood rating	Assessed probability of occurrence	Description
Almost certain	> 90%	Extremely or very likely, or virtually certain. Is expected to occur.
Likely	> 66%	Will probably occur
Possible	> 50%	Might occur; more likely than not
Unlikely	< 50%	May occur
Very unlikely	< 10%	Could occur
Extremely unlikely	< 5%	May occur only in exceptional circumstances

Table 7: Qualitative measures of consequence to ecosystem services arising from impacts linked to scenarios. Adapted from the classification adopted by the IPCC (2007)

Consequence rating	Level of consequence	Environmental effect
Severe	1	Substantial permanent loss of environmental service, requiring mitigation or offset.
Major	2	Major effect on the EI or service, that will require several years to recover, and substantial mitigation.
Moderate	3	Serious effect on the EI or service, that will take a few years to recover, but with no or little mitigation.
Minor	4	Discernible effect on the EI or service, but with rapid recovery, not requiring mitigation.
Insignificant	5	A negligible effect on the EI or service.

Table 8: Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on EI. Adapted from the classification adopted by the IPCC (2007)

Likelihood Rating	Consequence Rating				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	High	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Very unlikely	Low	Low	Low	High	Extreme
Extremely unlikely	Low	Low	Low	Medium	High

The output of the CRA process is an aggregated risk assessment for each of the scenario-EI-ES combinations for each IUA. Not all of these combinations are valuable, and the results are used to prioritise the key ecosystem services at risk per scenario across all IUA’s.

The output is thus a prioritised list of risks, with diagnostic and causal descriptions for each priority risk. High and extreme risks are classed as priority risks. These risks and their relative weight (High risk=3, Extreme risk=4) are summed for each scenario to allow for a comparison of cumulative risks between scenarios. The beneficiaries of the identified ES will be at the greatest risk due to a specific scenario.

Post CRA process, ecosystem services that have been highlighted through the CRA process to be of special concern will be evaluated. The evaluation step looks at the magnitude of an impact, both on the demand and the EWR, and assesses it against the potential benefits of the various scenarios. The relative risks will be evaluated at a desktop level and together with specialists at the scenario trade-off workshops.

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8 ANNEXURE

8.1 Annexure 1: The Decision Analysis Framework

Demonstrating the linkages between ecological value and condition of the water resources and the socio-economic classification, utilised an ecosystem services approach which is framed by the Decision Analysis Framework. The Framework allows for the assessment of the implications of different catchment configuration scenarios at an IUA level on economic prosperity, social wellbeing and ecological condition.

This Framework is based on the interaction of four components (as have been defined and described in the socio-economic section of the Upper Orange River catchment status-quo report) (Figure 4):

i) Ecological infrastructure (EI)
ii) Ecosystem services
iii) Human wellbeing, and
iv) Economic production.

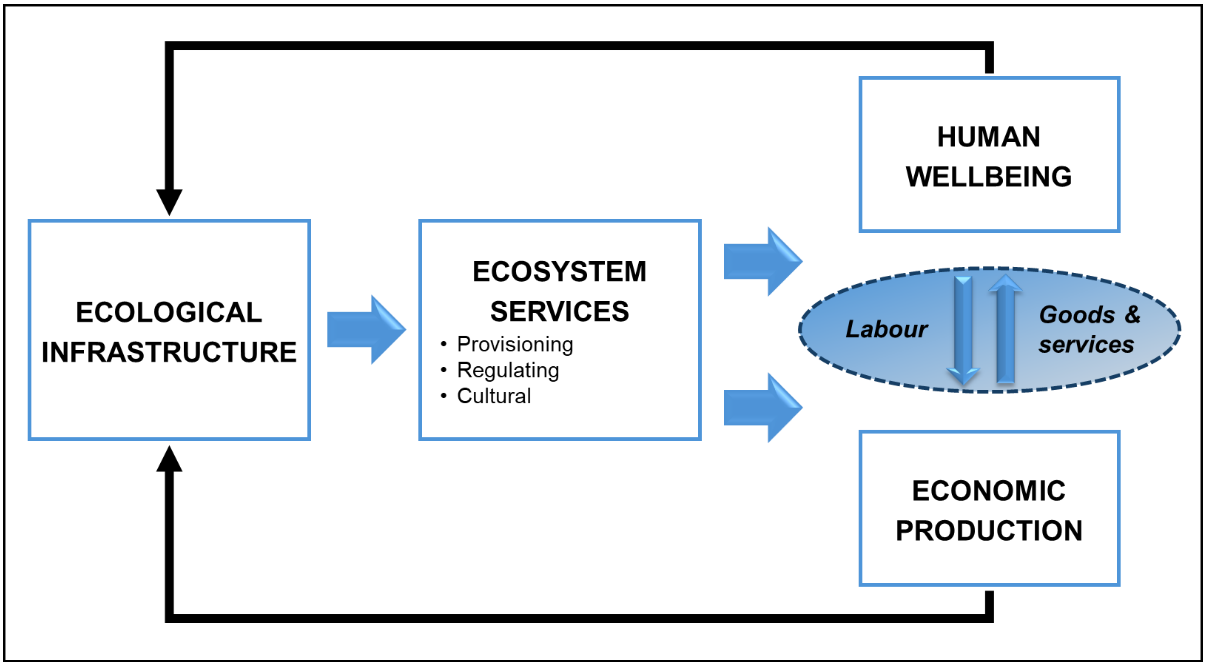

Figure 4: Schematic representation of the Decision Analysis Framework used to inform the assessment of the implications of different catchment configuration scenarios

Ecological infrastructure refers to naturally functioning ecosystems that deliver valuable ecosystem services to people, such as fresh water, climate regulation, soil formation and disaster risk reduction. In the case of catchment management, ecological infrastructure could include aquifers, wetlands and sub-catchments. The supply of ecosystem services is dependent on the type, condition and extent of the EI. EI in a good ecological condition would theoretically provide a robust flow of ecosystem services while EI in an impacted condition would deliver a less robust set of ecosystem services. The supply of ecosystem services is further dependent on the presence of beneficiaries, communities or economic sectors, in the landscape.

Figure 4 illustrates how aquatic ecosystem services are provided directly and indirectly to communities which influence human wellbeing and to the economy through providing natural services. Economic production, however, may have a negative impact on ecological infrastructure through activities such as over abstraction or pollution, which in turn has an impact on the delivery of ecosystem services. The same relationship exists with communities and ecological infrastructure, but to a lesser extent. The relationship between human wellbeing and economic production can be described in economic terms, with households providing labour into economic sectors, which provide goods and services in return.

The Decision Support Framework represents a significant simplification of the assessment process, although still complex, and requires transdisciplinary collaboration.

8.2 Annexure 2: Industry sector grouping description

A full description of the industry grouping sectors listed in Section 4.1.8 is provided in Table 9. These are the descriptions as provided in the Stats SA Supply and Use Tables publication (Stats SA, 2024).

Table 9: Industry grouping list and descriptions

Industry grouping	Industry grouping description
Agriculture	Agriculture, forestry and fishing, hunting, forestry and fishing
Metal ores	Iron ore mining; chrome mining; copper mining; manganese mining; platinum mining; other metal ore mining.
Stone	Dimension stone; Limestone and lime works; Other stone quarrying; Diamond mining; Chemical and fertiliser minerals, phosphates and other; Extraction and evaporation of salt; Other mining and quarrying n.e.c. (stones, asbestos and other minerals and materials)
Meat, fish, fruit, vegetables, oils and fats	Production, processing and preserving of meat and meat products; Processing and preserving of fish and fish products; Processing and preserving of fruit and vegetables; Manufacture of vegetable and animal oils and fats.
Dairy	Dairy products (milk, butter, cheese, ice cream, milk powder and other milk products)
Grain and animal feeds	Manufacture of grain mill products, breakfast foods, starches, starch products and prepared animal feeds.
Other food products	Bakery products; sugar including golden syrup and castor sugar; cocoa, chocolate and sugar confectionery and the manufacture of other food products n.e.c. (e.g. coffee, nuts, spices, condiments)
Beverages	Spirits and wines; beer, sorghum and other malt and soft drinks and mineral waters
Tobacco	Tobacco
Textiles	Spinning, weaving and finishing of textiles (animal fibres, vegetable fibres, wool)
Paper	Manufacture of paper and paper products
Printing and reproduction	Printing and service activities related to printing; and reproduction of recorded media
Basic chemicals	Basic chemicals; fertilisers and nitrogen compounds; and plastics in primary form and synthetic rubber
Other chemicals	Pesticides, other agro-chemical products; paints, varnishes, printing ink, mastics; pharmaceuticals, medicinal chemicals and botanical products; soap, detergents, polishing, perfumes and toilet preparations and manufacture of other chemical products (e.g. edible salt, explosives, adhesives)
Non-metallic minerals	Non-structural non-refractory ceramic ware; cement, lime and plaster; articles of concrete, cement and plaster; and other non-metallic mineral products n.e.c.

Industry grouping	Industry grouping description
Iron and steel	Basic iron and steel
Precious metals	Basic precious and non-ferrous metals
General purpose machinery	Engines and turbines and other general purpose machinery
Other electric components	Electronic valves, tubes, components, and television, radio transmitters and apparatus for line telephony and telegraphy
Vehicle parts	Parts, accessories for motor vehicles and their engines
Ships, boats	Building, repairing of ships and boats
Locomotives	Railway, tramway locomotives, rolling stock
Equipment	Manufacture of transport equipment n.e.c.
Furniture	Furniture
Other manufacturing	Other manufacturing n.e.c. (brooms, pens, signs, engraving)
Recycling	Recycling of metal waste and scrap n.e.c.; and recycling of non-metal waste and scrap n.e.c.
Hotels	Hotels, camping sites and other provision of short-stay accommodation
Restaurants	Restaurants, bars, canteens, take-away counters, caterers
Recreational	Sporting and other recreational activities
Lease	Real estate activities with own or leased property
Fee basis	Real estate activities on a fee or contract basis
Sewage and refuse	Sewage and refuse disposal, sanitation and similar activities
Electricity	Electricity and Gas - Production, collection, distribution
Water	Water - Collection, purification, distribution and own collection
Informal, illicit, non-profit, and households	Non-observed including informal, illicit, non-profit institutions, and households