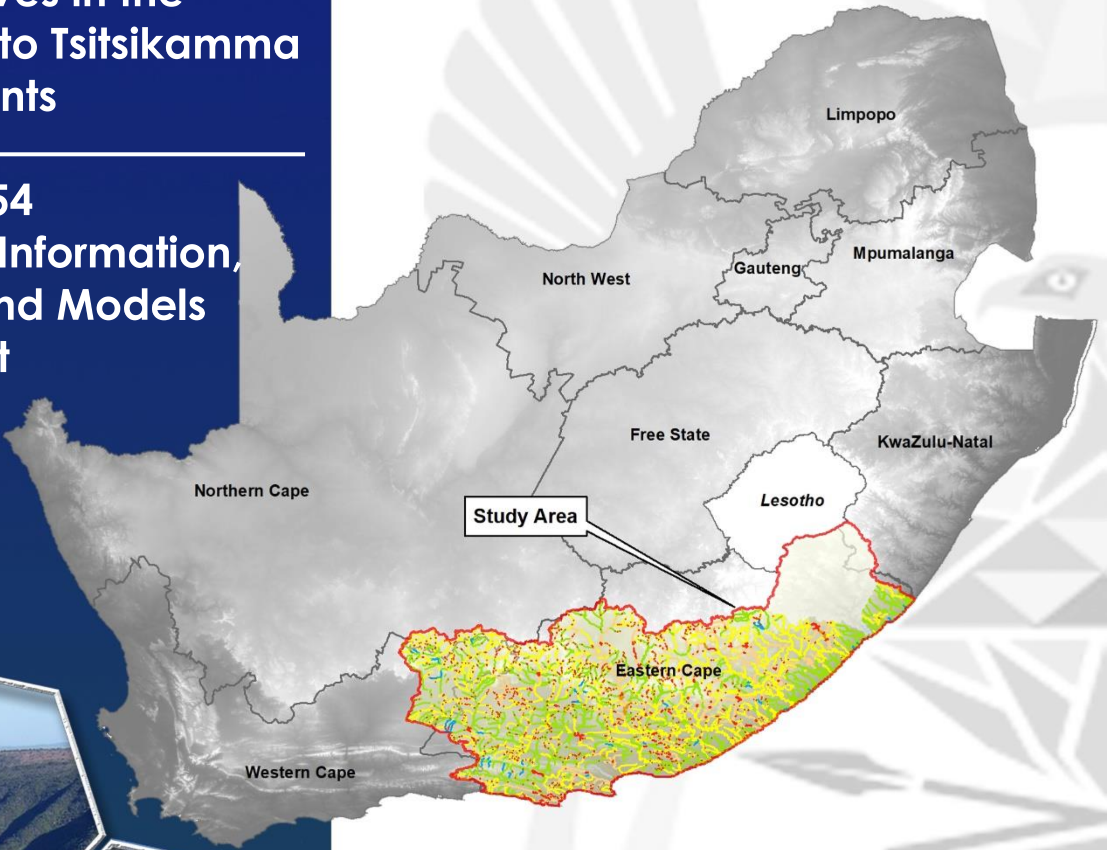
DEPARTMENT OF WATER AND SANITATION

Determination of Water Resource Classes, Reserve and the Resource Quality Objectives in the Keiskamma and Fish to Tsitsikamma Catchments

WP11354
Water Resources Information, Gap Analysis and Models Report



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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report

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1.0	WEM/WMA7/00/CON/RDM/0121	Inception Report
2.0	**WEM/WMA7/00/CON/RDM/0222**	**Water Resources Information, Gap Analysis and Models Report**

EXECUTIVE SUMMARY

This report (Gap Analysis Report) forms part of Task 2 of the overall approach adopted for this study, with the purpose to identify the gaps relevant to the determination of the Water Resource Classes, the Reserve and the associated Resource Quality Objectives for the significant water resources in the Keiskamma, Fish to Tsitsikamma catchments. Furthermore, the gap analysis phase forms part of Step 1 as per the Integrated Framework from the Development of Procedures to Operationalise Resource Directed Measures (DWS, 2017).

Several studies have been undertaken for the water resources of the study area. However, a number of these studies (reconciliation strategies, water availability assessments) were focussed around the metropolitan areas of Algoa and Amathole. Information is available for the smaller towns in the catchment through the All Towns studies that were undertaken.

Some Reserves studies have been undertaken for the rivers and estuaries in the study area, although a large number of systems have limited ecological data available, and no requirements were specified. Most of these studies have also been undertaken more than 10 years ago, resulting in the information being outdated and possible changes to the methodologies used to determine the EWRs.

Information from these studies will be useful and will be used as a basis, to collect additional data during the surveys to ensure high confidence results in this study, especially for the priority Resource Units.

Based on the review and analysis of the available datasets, GIS layers, information from previous studies, the project team has a better understanding of the availability, accessibility and usefulness of the information and data sources. However, various gaps do exist, of which some of these will be addressed during the study, through the collection of additional data during the seasonal field surveys.

The available information from these various data sources and reports are applicable, and with additional surveys that are scheduled, will provide adequate information for the determination of the Water Resource Classes, the Reserve and setting of RQOs.

The major gaps that will not be addressed during this study, as long-term monitoring is required are:

- Lack of adequate gauging weirs in the study area and the consequent lack of long-term flow data, especially daily data that is invaluable for the setting of EWRs; and
- Recent water quality data to determine the present state is not available for some rivers. However, data available from various other sources and studies, coupled with the planned surveys forming part of this study, will assist with mitigating this gap.

Thus, the best available, sensible data and information sources will be used to meet the objectives of this study, with guidance from the DWS where specific project direction is required.

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LIST OF ACRONYMS

AEH	Aquatic Ecosystem Health
BDI	Biological Diatom Index
BHN	Basic Human Needs
CBA	Critical Biodiversity Areas
CD: WEM	Chief Directorate: Water Ecosystems Management
DRDLR	Department of Rural Development and Land Reform
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EFZ	Estuarine Functional Zone
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
ES	Ecological Sensitivity
ESA	Ecological Support Areas
EWR	Ecological Water Requirements
FAII	Fish Assemblage Integrity Index
FBIS	Freshwater Biodiversity Information System
FEPA	Freshwater Ecosystem Priority Areas
FRAI	Fish Response Assessment Index
GAI	Geomorphic Assessment Index
GBIF	Global Biodiversity Information Facility
GDP	Gross Domestic Product
GHS	General Household Survey
GIS	Geographic Information System
HGM	Hydro-geomorphic
IDP	Integrated Development Plan
IHI	Index of Habitat Integrity
ISP	Internal Strategic Perspective
IUA	Integrated Unit of Analysis
MAP	Mean Annual Precipitation
MEA	Millennium Ecosystem Assessment
MPA	Marine Protected Areas
MIRAI	Macroinvertebrate Response Assessment Index
NBA	National Biodiversity Assessment
NCMP	National Chemical Monitoring Programme
NFEPA	National Freshwater Ecosystem Priority Areas

NGA	National Groundwater Archive
NWA	National Water Act
NWM5	National Wetland Map 5
NWSKS	National Water Services Knowledge System
NWU	Northwest University
PES	Present Ecological State
PSP	Professional Service Provider
QSAM	Quasi Social Accounting Matrix
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REMP	River Eco-status Monitoring Programme
RHP	River Health Programme
RQIS	Resource Quality Information Services
RQO	Resource Quality Objectives
RU	Resource Units
SAM	Social Accounting Matrix
SANBI	South African National Biodiversity Institute
SASS5	The South African Scoring System Version 5
SPI	Specific Pollution Sensitivity
SWSA	Strategic Water Source Areas
TEEB	Economics of Ecosystems and Biodiversity
VEGRAI	Vegetation Response Assessment Index
WAAS	Water Availability Assessment Study
WARMS	Water use Authorization and Registration Management System
WMA	Water Management Area
WMS	Water Management System
WR2012	Water Resources 2012
WRC	Water Research Commission
WRCS	Water Resources Classification System
WRPM	Water Resource Planning Model
WRYM	Water Resource Yield Model
WSS	Water Supply System
WSDP	Water Service Development Plan

1. INTRODUCTION

1.1 Background

The National Water Act (No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of water resource systems. To achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of Resource Directed Measures (RDM). These measures are protection-based and include Water Resource Classification, determination of the Reserve and the associated Resource Quality Objectives (RQOs). These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources, while allowing economic development.

The provision of water required for the maintenance of the natural functionality of the ecosystem and provision of Basic Human Needs (BHN) is the only right to water in the National Water Act (No. 36 of 1998) (NWA). The other water users from a strategic use who are second in line to other water users are subject to formal gazetted General Authorization and water use authorization as per Section 21 of the NWA.

The Department of Water and Sanitation, through the Chief Directorate: Water Ecosystems Management (CD: WEM), has initiated a study for the determination of Water Resource Classes, Reserve and associated Resource Quality Objectives for the identified significant water resources in the Keiskamma, Fish to Tsitsikamma catchments. The water resource components included for this study are rivers, wetlands, groundwater and estuaries. The Reserve determination include both the water quantity and quality of the Ecological Water Requirements (EWR) and Basic Human Needs (BHN). This will ensure the availability of water required to protect aquatic systems and that the essential needs of individuals that are directly dependent on these water resources.

1.2 Purpose of this study

The Keiskamma and Fish to Tsitsikamma catchments within the Mzimvubu to Tsitsikamma Water Management Area (WMA7) are amongst many waters stressed catchments in South Africa. These areas are important for conservation and have recognisable protected areas, natural heritage, cultural and historical sites that require protection. However, water use from surface as well as groundwater for agricultural and domestic purposes are high, especially in the more arid catchments, impacting on the availability of water resources for the protection of the aquatic ecosystems. Industrial practices and domestic water use are on the rise in some of these catchments, especially around the major towns and cities. Water transfers into the study area from adjacent WMAs and within the study area and numerous storage dams changes the flow patterns, impacting on the aquatic biota.

Thus, the main purpose of the study is to determine appropriate Water Resource Classes, the Reserve and associated RQOs for all significant water resources in the study area to facilitate sustainable use of the water resources while maintaining ecological integrity.

The aim is to:

(i) implement the Water Resource Classification System (WRCS) (Regulation 810, 2010) to determine the water resource classes,
(ii) follow the 7-step process to determine and set RQOs, and
(iii) determination of the Reserve for the water resources of the study area.

This will ultimately assist the DWS in the management of the water resources in the study area and making informed decisions regarding the authorisation of future water use and the magnitude of the impacts of proposed developments.

1.3 Purpose of this report

This Water Resources Information, Gap Analysis and Models Report documents the data, information and water resources models available from previous studies, as well as a summary of monitoring data for use during the remainder of the study. This is used to identify the gaps in information where additional surveys need to be undertaken as part of this study.

This report forms part of Task 2 of the overall approach (see Figure 4-1) adopted for this study, with the purpose to identify the gaps relevant to the determination of the Water Resource Classes, the Reserve and the associated RQOs for the significant water resources in the Keiskamma, Fish to Tsitsikamma catchments. Furthermore, the gap analysis phase forms part of Step 1 as per the Integrated Framework from the Development of Procedures to Operationalise Resource Directed Measures (DWS, 2017).

All maps referred to in the main report are presented in Appendices.

2. *STUDY AREA*

The study area forms part of the Mzimvubu to Tsitsikamma WMA (WMA7) as indicated in Table 2-1. The water resources of the Mzimvubu catchment (T31 – T36) are not included as part of the study area for the purposes of this study. Secondary catchments T40 (Mtamvuna) and T50 (Mzimkhulu) are also excluded and which form part of WMA4 (Appendix A, Figure 10-1). Appendix A further illustrates the Strategic Water Source Areas (SWSA, see Figure 10-3) identified within the study area.

A short overview of each of the water resources components, namely rivers, wetlands, groundwater and estuaries in the study area are provided below. Detailed descriptions for each component will be provided as part of the results of the Integrated Units of Assessment (IUA) and Resource Units (RU) delineation.

2.1 Rivers

The rivers in the study area ranges from large perennial to semi-ephemeral systems as well as small coastal rivers that all drains towards the Indian Ocean (Appendix A: Figure 10-1). It consists of five large drainage basins with several smaller rivers in-between. The larger drainage basins are the Mbashe River (part of drainage region T and includes T11, T12 and T13), Great Kei River (drainage region S), Great Fish (drainage region Q), Sundays (drainage region N) and the Gamtoos River (drainage region L).

The smaller drainage regions are the Mthatha River (drainage region T20), small coastal rivers in the Pondoland area (drainage regions T60 to T90), Keiskamma, Buffalo, Nahoon and Gqunube Rivers (drainage region R), Kowie, Kariega and Boesmans Rivers (drainage region P), Koega and Swartkops Rivers (drainage region M), Krom and Seekoei Rivers (drainage region K90), and Tsitsikamma and small coastal rivers in drainage region K80.

The study area consists of 342 quaternary catchments (see Table 2-1), covering an approximate area of 143 000 km^2 stretching across the Eastern Cape Province with only a small part (upper reaches of L1 and L2) in the Western Cape Province. For the purposes of this report, the overview of the rivers are presented per the following drainage regions:

A. K80, K90, L10 to L90 and M10 to M30 (Krom, Tsitsikamma, Gamtoos, Koega and Swartkops)

B. N10 to N40 and P10 to P40 (Sundays, Kowie, Kariega and Boesmans)

C. Q10 to Q90 (Great Fish)

D. R10 to R50 and S10 to S70 (Buffalo, Nahoon, Keiskamma, Great Kei)

E. T10, T20 and T60 to T90 (Mbashe, Mthatha, coastal systems)

The main catchment developments include water supply for the large metropolitan areas of Algoa and Amathole, including Gqeberha and East London for domestic and industrial uses. The water for domestic and industrial supply is sourced from various dams in the associated catchments and water transfers between catchments or from the Upper Orange River catchment via the Orange-Fish transfer scheme to the upper reaches of the Fish River. Smaller towns and villages are mostly dependent on local surface water sources or groundwater.

The larger irrigation areas include the Gamtoos (L9), Kouga (L8), lower Sundays River (N1 to N4), and mainstem of the Fish River and some of the Kei River catchments (S3, Klaas Smits and Black Kei Rivers). This water is from storage dams within the various rivers sourced from local sources or from transfers. The irrigation around the mainstem Fish River is mainly from the water transfer from Gariep Dam. Land-use in the Mbashe (T12C), Mthatha (T2) and Mngazi (T70A, T70B) catchments is mainly subsistence agriculture, with dryland sugarcane and limited irrigation occurring in these catchments. Large areas of dryland cultivation occur mostly in the drier interior of the study area.

Forested areas occur in the wetter areas, namely the Tsitsikamma, (K8) Gamtoos (L9), Swartkops (M10), Kat (Q9), Keiskamma (R10), Buffalo (R2), Kubusi (S6), Mbashe and Mthatha catchments with smaller areas in T60. Livestock grazing is present in most of the catchments of the study area.

A large number of dams have been constructed for domestic and irrigation water supply and for the transfer of water between catchments. The larger dams in the study area includes Impofu Dam (Kromme), Kouga Dam (Kouga), Darlington Dam (Sundays), Grassridge Dam (Fish), Bridle Drift Dam (Buffalo), Xonxa Dam (White Kei), Lubisi Dam (Indwe), Ncora Dam (Tsomo), Wriggleswade (Kubusi) and Umtata Dam (Mthatha). Numerous smaller dams are scattered throughout the study area.

The Orange-Fish transfer is the only transfer into the study area, with a number of transfers between catchments, including the Kubusi (Wriggleswade) to Buffalo River and the Fish River to Sundays River and to Gqeberha. Water supply to the larger Algoa system is through various transfers between the dams on the Kromme and the Gamtoos Rivers and the supply dams within the M catchment.

Table 2-1: The sub-catchments within the study area

Primary catchment	Quaternary catchments	Main River	Associated Rivers	Catchment Area (1) (km^2)
K80, K90, L10 to L90 and M10 to M30				
K	K80A-F	Tsitsikamma	Elandsbos, Kleinbos, Storms, Elands, Groot, Klasies, Klipdrift	1 206
	K90A-G	Krom	Seekoei, Kabeljous	1 558
L	L11A-G, L12A-D, L21A-E, L22A-D, L23A-D, L30A-D, L40A, B, L50A, B, L60A, B, L70A-G, L81A-D, L82A-J, L90A-C	Gamtoos	Sout, Buffels, Kariga, Plessis, Heuningklip, Groot, Baviaanskloof, Kouga	34 816
M	M10A-D, M20A, B, M30A, B	Swartkops	Van Stadens, Maitland, Bakens, Papkuils, Coega	2 630
N10 to N40 and P10 to P40				
N	N11A, B, N12A-C, N13A-C, N14A-D, N21A-D, N22A-E, N23A, B, N24A-D, N30A-C, N40A-F	Sundays	Kamdeboo, Gats, Melk, Bul, Voel, Kariega	21 248
P	P10A-G, P20A, B, P30A-C, P40A-D	Boesmans	Diepkloof, Boknes, Kariega, Kowie, Kasouga, Riet, Wes-Kleinemonde, Oos-Kleinemonde	5 322
Q10 to Q90				
Q	Q11A-D, Q12A-C, Q13A-C, Q14A-E, Q21A, B, Q22A, B, Q30A-E, Q41A-D, Q42A, B, Q43A, B, Q44A-C, Q50A-C, Q60A-C, Q70A-C, Q80A-G, Q91A-C, Q92A-G, Q93A-D, Q94A-F	Great Fish	Groot-Brak, Pauls, Tarka, Baviaans, Koonap, Little Fish, Kat	30 243
R10 to R50 and S10 to S70				
R	R10A-M, R20A-G, R30A-F, R40A-C, R50A, B	Keiskamma	Tyume, Buffalo, Nahoon, Qinira, Gqunube, Kwelera, Kwenxura, Quko, Tyolomnqa, Gxulu, Bhirha, Mgwalana	7 936
S	S10A-J, S20A-D, S31A-G, S32A-M, S40A-F, S50A-J, S60A-E, S70A-F	Great Kei	White-Kei, Indwe, Klipplaat, Klaas Smit, Black-Kei, Tsomo, Kubusi, Gcuwa	20 485

Primary catchment	Quaternary catchments	Main River	Associated Rivers	Catchment Area (1) (km^2)
T10, T20 and T60 to T90				
T	T11A-H, T12A-G, T13A-E, T20A-G, T60A-K, T70A-G, T80A-D, T90A-G	Mbashe	Xuka, Mgwali, Mthatha, Mzamba, Mtentu, Msikaba, Mzintlava, Mntafufu, Mngazi, Mngazana, Mtakatye, Mdumbi, Nenga, Mncwasa, Xora, Nqabarha, Shixini, Qhorha, Kobonqaba	17 938
			Total catchment area	**143 382**

(1) WR2012 data

The desktop assessment of the Present Ecological State (PES) of the river systems throughout the study area are primarily moderately modified (Category C) or largely natural with few modifications (Category B) (DWS, 2014). However, just over 10% of the rivers within the study area falls within the E and F categories of a seriously to critically modified state. These unsustainable rivers are mostly within the Bushmans (P area), Sundays (N area), Great Fish (Q area), Great Kei (S area), Keiskamma (R area), and the Tstisikamma (K80 area). These seriously to critically modified systems will be highlighted during the selection and prioritising of Resource Units (RU).

Many of the river reaches which have a PES Category A (natural, near pristine) or B (largely natural with few modifications) occur within conservation areas (Appendix A: Figure 10-2), and any future human manipulation of these reaches would require very strong motivation within this study area.

The biodiversity within the study area is diverse in all its forms and all its interactions and comprises eight (8) of South Africa's nine (9) biomes, in accordance with Mucina and Rutherford, 2006. A number of national parks, nature reserves and heritage sites are present in the study area and include:

- National Parks (Addo Elephant, Tsitsikamma, Garden Route, Mountain Zebra);
- Provincial Nature Reserves (Mkambati, Hluleka, Dwesa-Cwebe, Hamburg, Great Fish, Mpofu, Groendal, Baviaans Kloof, Formosa, Doubledrift);
- Private Nature Reserves (Black Eagle Nature Reserve);
- World Heritage Sites (Primary Catchment L includes portion of the Cape Floral Region); and
- Threatened Ecosystems (2011) (includes Langkloof Shael Renosterveld, Albany Alluvial Vegetation, Mount Thesiger Forest Complex, Algoa Sandstone Fynbos, Mthatha Moist Grassland, Ngongoni Veld, Transkei Coastal Forest, Mthatha Moist Grassland and some Midlands Mistbelt Grasslands.

Two main areas are considered for biodiversity targets, namely Critical Biodiversity Areas (CBA - areas required to meet biodiversity targets for ecosystems, species and ecological processes) and Ecological Support Areas (ESA - not essential for meeting biodiversity targets but play an important role in supporting the ecological functioning). The identified CBA and ESA areas will be used during the final prioritisation of RUs and the possible impacts considered where future water resource developments are planned. This consideration is particularly pertinent where water resource development activities impact on the supply of water resources to these areas and hence their long-term ecological sustainability.

2.2 Major dams and transfers

A number of large dams and transfers between catchments are present within the study area, with the most significant the water that is transferred into the study area from the Gariep Dam (Upper Orange) to the upper reaches of the Great Fish River (Grassridge Dam) mostly for irrigation and domestic use within the Great Fish River catchment. Further to the latter is the transfer of water to the Algoa System for domestic water use. These transfers and dams provide water for domestic, industrial and irrigation water use. There are numerous other smaller dams within the catchment, mainly for irrigation and local domestic and rural water use purposes. The effects of the numerous dams and transfers on the water resources in the study area, have impacted on the wellbeing of the water resources health.

With regards to future proposed dams and water transfers, the DWS are investigating such options and thus will be covered by the Development of a reconciliation strategy (Algoa and Amathole systems) for S60 (Kubusi), R20 (Buffalo), R30E and R30F (Nahoon), K80, K90 Krom and Tsitsikamma, M10, M20, M30 (Koega and Swartkops), N40 (Lower Sundays downstream of Darlington Dam).

It is vital, that the above mentioned and considering the main future development options, that these are assessed to ensure the protection of the aquatic ecosystems.

2.3 Wetlands

The study area has been divided into 11 sub-catchments to provide broad management units within which wetland prioritisation and assessments will be undertaken. Most of the wetlands in the study area occur within the Kei, Mbashe, Tsitsikamma and Fish catchments. A brief overview of wetlands and their ecological condition are given for each sub-catchment (Table 2-2), following a few key trends across these catchments that were identified.

Table 2-2: Area[1] of wetland per sub-catchment

Sub-catchment	Primary catchment	Wetland types	Hectares	%
Gamtoos	L	Channelled/ unchannelled valley bottom, depression Seepage-slope rare	1274	4.2
Sundays	N	Depression and combination of channelled valley bottom and depression Seepage-slope rare	899	3.0
Fish	Q	Depression or channelled valley bottom	3,296	10.9
Tsitsikamma	K	Depression and channelled valley bottom	3,236	10.7
Algoa	M	Depression and channelled valley bottom	2,357	7.8
Bushmans	P	Depression	634	2.1
Kei	S	Seepage-slope, channelled valley bottom	9,329	30.9
Amatola	R	Channelled valley bottom and seepage	1,827	6.1
Mbashe	T	Seepage and channelled valley bottom	4,304	14.3
Mtata	T	Channelled valley bottom	1,102	3.7
Wild Coast	T	Channelled valley bottom and unchannelled valley bottom	1,913	6.3
Total			**30,171**	**100**

[1]Area of wetland was determined based on NWM5, but supplemented with additional information for the Gamtoos, Sundays and Wild Coast, where a high level of under-mapping was confirmed.

A few key trends across the sub-catchments were identified that will be considered during the selection and prioritisation of the wetlands. These include:

Wetland occurrence in relation to the aridity gradient: The hinterland of the overall study area extends broadly across a strong aridity gradient, being generally most arid in the west (Gamtoos, Sundays, Fish and Kei areas) and becoming progressively less arid as one moves eastwards. This results in a low total extent of wetlands in the west, with increasing extent in the east.

The coastal areas of the study area show a different pattern to the hinterland, with Mean Annual Precipitation (MAP) being relatively high in the west (Tsitsikamma), declining in the Algoa and Bushmans sub-catchments then increasing again thereafter. Thus, it is not surprising that the Tsitsikamma sub-catchment, where, although confined to a narrow coastal strip, has a relatively high wetland extent relative to the overall small size of this area.

Some of the eastern sub-catchments, while having wetland extents that are higher than in the western hinterland, are lower than expected given the high MAP and topography which is not very steep. Of note here are the Mtata and Wild Coast sub-catchments, where possible considerable under-mapping for these catchments might occur.

Present Ecological State in relation to land-use and the aridity gradient: The greatest proportion of wetlands in a D, E and F category was found in the Tsitsikamma sub-catchment, where high impact land-uses associated with cultivation and forestry are extensive, followed by Algoa sub-catchment, where high impact urban/industrial land-uses are extensive.

Wetlands were least impacted in the three major arid to semi-arid sub-catchments (i.e. Gamtoos, Sundays and Fish), where most wetlands were placed in an A or B (natural to largely natural) PES category. While this may be a reasonable approximation, it should be acknowledged that certain impacts are poorly represented in the land-cover map used for the assessment, particularly those within areas mapped as natural vegetation. Widespread livestock utilization of the natural vegetation in the Karoo can lead to degradation of the vegetation, in particular in the valley bottoms, where most of the naturally vegetated wetlands are located. Therefore, it is anticipated that a field-based assessment of PES, would reveal that some of the wetlands in arid to semi-arid sub-catchments which are mapped with predominantly natural vegetation would have a somewhat lower PES than that assigned based on desktop assessment.

2.4 Groundwater

The major aquifer systems associated with the Cape and Karoo Supergroups are mainly of a fractured type, where groundwater occurrence, is as a result of secondary deformation relating to faults, fissures, fractures, bedding planes and joints. The Karoo Supergroup also constitutes a fractured and intergranular aquifer over widespread areas associated with intrusive and extrusive igneous rocks, i.e. dolerite sills and dykes and well as basalt. The quaternary sand and alluvium constitute limited intergranular aquifers in the study area where groundwater occurrence is because of pore spaces between sand particles. Borehole yields in the fractured aquifers vary greatly depending on the lithological unit intersected during drilling and the arenacous: argillaceous ratio within the respective lithological units.

Groundwater quality is generally good over most parts of the catchment area with exceptions found along parts of the coast and at some inland locations where the recharge is low and the geology is not favourable.

Several stressed quaternary catchments have been identified in the area where the estimated groundwater use exceeds the estimated groundwater recharge (Appendix A, Figure 10-4).

2.5 Estuaries

There are 251 coastal drainage systems within the study area, comprising 154 estuaries and a further 97 microsystems. The latter are a relatively new class of estuary which accounts for very small systems (<2 ha, or <200m length) (Van Niekerk, *et al.,* 2020). There is currently insufficient data on many of these microsystems, and therefore additional data will be collected if any of these systems are included as a priority estuary.

Most of the estuaries in the study area are within the warm temperate marine bioregion (>60%) with the rest within the subtropical bioregion. Five of the nine different types of estuaries are present in the study area. These include small or large temporarily closed, small or large fluvially dominated and predominantly open estuaries. Large fluvially dominated systems that are mostly open throughout the year experience generally low salinities as a result of the dominant river processes, as well as high sediment turn-over, are rare (1%), with only one in each bioregion represented by the Great Kei (warm temperate) and the Mbashe (subtropical) systems.

The biodiversity importance of estuaries is based on individual assessments of size, type, rarity, habitat biodiversity and biotic diversity (Turpie and Clark, 2007). Only 27% of the estuaries in the study area are ranked as being important to highly important in terms of the biodiversity they support, and most of these are located in the warm temperate bioregion.

A large number of estuaries are adjacent to Marine Protected Areas (MPA), including 25 systems in the warm temperature bioregion, such as the Tsitsikamma, the Great Kei and the Pondoland MPAs (Van Niekerk *et al.,* 2019). These estuaries adjacent to MPAs will be considered when undertaking the final prioritisation of RUs and the possible impacts considered where future water resource developments are planned.

The results of the National Biodiversity Assessment (NBA, 2018) indicate that most of the estuaries are in a near to largely natural condition (Category A/B to B) with few modifications. However, 5% of the estuaries in the study area are in heavily to critically modified state (Category D or lower), indicating that they have experienced a major shift in natural processes and function, and a significant loss of biota and habitat has occurred. These systems are all located within the warm temperate bioregion, and their degraded state is associated with dense urban development, severe modifications and high to very high cumulative pressures. These systems include the Papkuils, Baakens, Coega, Swartkops, Seekoei, Kromme, Buffalo, and Blind estuaries.

3. INFORMATION REVIEW

3.1 Previous Studies

A number of studies have been conducted in this study area, with the most comprehensive being the water resource assessment studies in 2003, as part of the development of the Internal Strategic Perspectives (ISP). Reconciliation strategies for the larger metropolitan areas and smaller towns were developed for most of the study area. Detailed feasibility studies for water provision infrastructure have been undertaken for the construction of dams (e.g. Lukanji Regional Water Supply).

The information and data from the 2014 Desktop PES/EI/ES rivers assessment undertaken for the study area will form the basis for the initial assessment of the rivers on a sub-quaternary level. These will be enhanced through the selection of EWR sites, where detailed surveys and assessments will be undertaken.

The groundwater component of this study will draw on the data and information available from the WR2012 study for a high level for the delineation of groundwater resource units. Additional information from surveys and local knowledge will be required to identify certain "hot spot" areas, notably where the groundwater potential is low and the demand is high.

Various national spatial layers relating to wetlands, their importance and possible delivery of specific ecosystem services are available for wetlands. However, most of these spatial layers have been created at a national scale, the extent and associated attributes may not be accurate at a fine scale. As such, infield verification will be necessary to review the characteristics of the wetlands that have been prioritised and amend the final prioritisation accordingly. Some of the main sources of information for wetlands include the National Wetland Map 5 (NWP5) spatial dataset, the National Freshwater Ecosystem Priority Areas (NFEPAs) wetland shapefile, GIS coverages of important water supply dams, wetlands which interacted with the surface and ground water strategic water source areas (SWSAs) and the HGM unit type, which was used to determine the level to which each system may provide ecosystem services, etc.

Although studies were undertaken for some of the estuaries in the study area, the information and results of the 2018 NBA study for estuaries will form the basis for the initial assessment of the estuaries to select and prioritise those systems where surveys need to be undertaken.

An extensive list of previous studies and available information and datasets has been included in the Inception Report (DWS, 2021) that will be used as key sources of information available for this study. Any gaps identified from these studies and data sources will be discussed in the next section of this report. The information from these studies, data available from previous surveys and databases and the various spatial layers have been assessed as to where the information will be used in this study. Table 3-1 lists available key sources of information for use during this study and in which integrated step of the framework for operationalising RDM it will be used.

Table 3-1: Previous studies conducted in the catchment area per integrated step

Year	Study Name	Integrated steps*
General		
2002	Mzimvubu to Keiskamma Water Management Area: Water Resources Situation Assessment	1,2
2002	Fish to Tsitsikamma Water Management Area: Water Resources Situation Assessment	1,2
2004	Albany Coast Situation Assessment Study	1,2
2008	Development of a Reconciliation Strategy for the Amatole Bulk Water Supply System	2, 4
2011	Water Reconciliation Strategy Study for the Algoa Water Supply Area	2, 4
Rivers (quantity and quality)		
1995	The development of the Hydraulic Biotope Concept within a Catchment Based Hierarchical Geomorphological Model – Site descriptions for the Great Fish River as part of Wadesons PhD	1, 2
2002	Fish to Tsitsikamma Water Management Area: Water Resources Situation Assessment – Main Report – Volume 2 of 2: Appendices	2
	The Value of water in the Fish-Sundays Scheme of the Eastern Cape. School of Economics University of Cape Town. WRC Report 987/1/02	2, 3
2004	Eastern Cape River Health Programme. Technical Report: Buffalo River monitoring, 2002 – 2003. Compiled by Scherman *et al.* (2004)	1, 3
2006	Conservation planning for river and estuarine biodiversity In the Fish-to-Tsitsikamma Water Management Area	1
	Assessment of the Geomorphological Reference Condition: an application for Resource Directed Measures and the River Health programme. The Kat River was used as example of GAI PES. Compiled by Du Preez and Rowntree	1, 3
	Lukanji Regional Water Supply Feasibility Study: Appendix 2 – Ecological Reserve (Quantity) on the Kei River	3, 4
	Eastern Cape River Health Programme. Technical Report. Mthatha River Monitoring 2004 – 2006.	3
2008	State of Rivers Report No. 14. Mthatha River System	3

Year	Study Name	Integrated steps*
	Development of a reconciliation strategy for the Amatole bulk water supply system. Final report. Department of Water Affairs and Forestry.	2, 4
2010	Algoa Water Resources Bridging Study (DWS)	2, 4
2011	Water Reconciliation Strategy Study for the Algoa Water Supply Area: Algoa reconciliation strategy. Department of Water Affairs.	2, 4
2012	Amatole water supply system reconciliation strategy: status report 2012 – Rev 3. Department of Water Affairs.	2, 4
2013	Municipal Services Strategic Assessment (MuSSA) for Eastern Cape Province 2012	2, 4
	The Development of Water Supply and Drought Operating Rules for Stand-Alone Dams or Schemes Typical of Rural/Small Municipal Water Supply Schemes: Southern Cluster – Final Report April 2013. Prepared by IWR on behalf of the Department of Water Affairs, Directorate Water Resource Planning Systems	3, 4
2014	A Desktop Assessment of the PES, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM.	1, 3, 5
	Support to the Implementation and Maintenance of Reconciliation Strategies for Towns in the Southern Planning Region: Status Report Eastern Cape October 2014. Prepared by Umvoto Africa (Pty) Ltd in association with WorleyParsons and UWP Consulting on behalf of the Directorate: National Water Resource Planning. DWS Report No. 14/4/12/12/2	2, 4
2015	Water Resources of South Africa 2012 (WR2012) (WRC)	2, 3, 6
2018	National Biodiversity Assessment	1, 2, 3, 5, 6
	River Ecostatus Monitoring Programme State of Rivers Report 2017-2018.	1, 2, 3
	Mzimvubu-Tsitsikamma Water Management Area: Validation and Verification (V&V) of Existing Lawful Water Use (DWS)	1, 2, 3
	Algoa Reconciliation Strategy Status Report: Status Report 5. DWS. Ref. 112546	2, 4
Groundwater (quantity and quality)		
2010	Eastern Cape Groundwater Masterplan	1, 2, 3
2015	Water Resources of South Africa 2012 (WR2012) (WRC)	1, 2, 3

Year	Study Name	Integrated steps*
2017 to Current	Groundwater exploration in the Nelson Mandela Bay Municipality area	1, 2, 3
2018	Algoa Reconciliation Strategy Status Report: Status Report 5. DWS. Ref. 112546	1, 2, 3, 4
Wetlands[1]		
2003	Illgner, PM, Haigh E H and Holland H, 2003. Identification, mapping and assessment of the present state of the wetlands in the Baviaanskloof River catchment. Institute for Water research (IWR), Rhodes University, Makhanda. (Gamtoos (Baviaans portion)	2
2007	Nsor AC, 2007. Plant Community Distribution and Diversity, and Threats to Vegetation of the Kromme River Peat Basins, Eastern Cape Province, South Africa. MSc thesis. Rhodes University, Makhanda. (Kromme)	2
2009	The Wetland Rehabilitation Project in the Kromme River Wetlands, Eastern Cape (Haigh *et al.* 2009)	1, 2
	Haigh EH, Illgner PW, Wilmot J, Buckle J, Kotze D, and Ellery W, 2009. The Wetland Rehabilitation Project in the Kromme River Wetlands, Eastern Cape. In: Kotze D and Ellery W (Eds.) WET-OutcomeEvaluate: An evaluation of the rehabilitation outcomes at six wetland sites in South Africa. WRC Report No TT 343/08. Water Research Commission, Pretoria. (Kromme)	1, 2
2010	Sinchembe M and Ellery WN, 2010. Human impacts on hydrological health and the provision of ecosystem services: a case study of the eMthonjeni–Fairview Spring Wetland, Grahamstown, South Africa. African Journal of Aquatic Science 35: 227–239. *(Bushmans)*	2
	Wilson MI, 2010. Geomorphic evolution and sedimentology of a blocked-valley wetland: the Ngciyo Wetland, Eastern Cape, South Africa. Honours thesis, Rhodes University, Makhanda. *(Bushmans)*	2
2011	Hugo CD, 2011. The influence of fire and plantation management on wetlands on the Tsitsikamma plateau. MSc thesis, Nelson Mandela Metropolitan University, Gqeberha. (Tsitsikamma)	2
2010-2021	Department of Environmental Affairs (DEA). Environmental Programmes: Natural Resource Management. Working for Wetlands Phase 1 and 2 wetland rehabilitation planning assessment reports (within the Eastern Cape, but	1, 2, 6

[1] *The studies listed deal explicitly with wetland extent, PES and EIS, and in the reference section several additional studies are given relating to wetland origin, structure and/or function, including, amongst others: Glenday (2015), Hugo (2011), McNamara (2018), Pulley et al. (2018), Rebelo et al al. (2015; 2018), Smith-Adao (2016), and Tanner et al. (2019).*

Year	Study Name	Integrated steps*
	excluding the Mzimvubu catchment - a number of reports exist but need to be sourced and reviewed in detail to obtain the relevant information).	
2011	NFEPA Wetlands Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. 2011. Technical report for the national freshwater ecosystem priority areas project. WRC Report No. 1801/2/11. Water Research Commission, Pretoria, South Africa	1, 2
	Mtshali H. 2011. Wetland vegetation of coastal Pondoland. Honours thesis, University of the Free State, Qwaqwa Campus, Phuthaditjhaba. (Wild Coast)	2
2012	Rebelo A J, 2012. An ecological and hydrological evaluation of the effects of restoration on ecosystem services in the Kromme River system, South Africa. MSc thesis. University of Stellenbosch. (Kromme)	2
2014	SANRAL N2 Wild Coast Toll Highway: Specialist Aquatic Assessment Report (Eco-Pulse 2014) [permission required for release of data]	1, 2, 3, 6
	Macfarlane DM, van Deventer R, Kotze D and Teixeira-Leite A, 2014. SANRAL N2 Wild Coast Toll Highway: Specialist Aquatic Assessment Report. Unpublished report prepared by Eco-Pulse Consulting for CCA Environmental.	1, 2
	Omar M Y, Le Roux PAL, van Tol JJ, 2014. Interactions between stream channel incision, soil water levels and soil morphology in a wetland in the Hogsback area, South Africa, South African Journal of Plant and Soil, DOI: 10.1080/02571862.2014.944593. (Kei)	2
	Wallace C, 2014. An Examination of the Causes and Geomorphic Consequences of Erosion in Wetlands: A Case Study of the Fairview Spring Wetland, Grahamstown, South Africa. Honours thesis. Rhodes University, Makhanda. (Bushmans)	2
	Gluckman L, 2014. Gully erosion and deposition in the Featherstone Kloof wetland, a headwater wetland in the Eastern Cape, South Africa. Honours thesis. Rhodes University, Makhanda. (Bushmans)	2
	Silbernagl R, 2014. Origin and Dynamics of the Featherstone Kloof Wetland (Eastern Cape, South Africa). Honours thesis. Rhodes University, Makhanda. (Bushmans)	2
2015-2017	Factors influencing wetland distribution and structure, including ecosystem function of ephemeral wetlands, in Nelson Mandela Bay Municipality (Schael et al. 2015; Melly 2016; Melly et al. 2016; Melly et al. 2017)	1, 2
	Glenday J A, 2015. Modelling the Hydrologic Impacts of Vegetation and Channel Network Change for a Semi-arid, Mountainous, Meso-scale	2

Year	Study Name	Integrated steps*
	Catchment: the Baviaanskloof, South Africa. PhD thesis, University of California, Santa Barbara, USA. (Gamtoos (Baviaans portion)	
	Powell R, 2015. Recent degradation along the upper-middle reaches of the Baviaanskloof River floodplain: An examination of drivers of change and best rehabilitation practices. PhD thesis. Rhodes University, Makhanda. (Gamtoos (Baviaans portion)	2
	Rebelo AJ, Le Maitre DC, Esler KJ, and Cowling RM, 2015. Hydrological responses of a valley-bottom wetland to land-use/land-cover change in a South African catchment: Making a case for wetland restoration. Restoration Ecology, 23: 829–841. (Kromme)	2
	de Haan V, 2015. The Effects of Erosion-control Structures and Gully Erosion on Groundwater Dynamics along the Kromrivier, Eastern Cape, South Africa. MSc thesis. Stockholm University, Stockholm, Sweden. (Kromme)	2
	de Haan V, 2015. The Effects of Erosion-control Structures and Gully Erosion on Groundwater Dynamics along the Kromrivier, Eastern Cape, South Africa. MSc thesis. Stockholm University, Stockholm, Sweden. (Kromme)	2
	Melly BL, 2016 Factors influencing wetland distribution and structure, including ecosystem function of ephemeral wetlands, in Nelson Mandela Bay Municipality (NMBM), South Africa. PhD thesis, Nelson Mandela Metropolitan University, Gqeberha. (Algoa)	2
	Schael D M, Gama P T, and Melly B L, 2015. Ephemeral Wetlands of the Nelson Mandela Bay Metropolitan Area: Classification, Biodiversity and Management Implications. WRC Report No. 2181/1/15. Water Research Commission, Pretoria. (Algoa)	2
	Melly BL, Schael DM, and Gama PT, 2017. Perched wetlands: An explanation to wetland formation in semi-arid areas. Journal of Arid Environments 141: 34-39. (Algoa)	2
	An evaluation of the ecological outcomes at the Wetland Management Area 01, Hogsback, Eastern Cape	1, 2, 6
	Walters D, 2016. An evaluation of the ecological outcomes at the Wetland Management Area 01, Hogsback, Eastern Cape. Unpublished report submitted to Working for Wetlands, Pretoria. (Kei)	2
	Tuswa A, 2016. Assessing heavy metal content in urban wetland macrophytes and sediments in NMBM. Honours thesis. Nelson Mandela Metropolitan University, Gqeberha. (Algoa)	2

Year	Study Name	Integrated steps*
	Melly B L, Schael D M, Rivers-Moore N A, and Gama P T, 2016. Mapping ephemeral wetlands: manual digitisation and logistic regression modelling in Nelson Mandela Bay Municipality, South Africa. J. Environ. Manage. 25, 313–330. doi: 10.1007/s11273-016-9518-7. (Algoa)	2
	Rebelo A J, 2017. Ecosystem Services of Palmiet Wetlands: The Role of Ecosystem Composition and Function. PhD thesis. Department of Biology, University of Antwerp, Antwerp, and Conservation Ecology, Stellenbosch University, Stellenbosch. (Kromme)	2
	Schlegel, 2017. Spatial variation in modelled hydrodynamic characteristics associated with valley confinement in the Krom River wetland: implications for the initiation of erosion gullies. MSc thesis, Rhodes University, Makhanda. (Kromme)	2
	Lagesse J, 2017. Discontinuous Gully Erosion as a Mechanism for Wetland Formation: a case study of the Kompanjiesdrif Basin, Kromrivier, Eastern Cape, South Africa. MSc Thesis. Rhodes University, Grahamstown. (Kromme)	2
2018	Focused Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity (Eco-Pulse 2018b, c and d)	1
	National Wetland Map 5 South African National Biodiversity Assessment. Technical Report. Volume 2a: South African Inventory of Inland Aquatic Ecosystems (SAIIAE). Version 3, final released on 3 October 2019. Council for Scientific and Industrial Research (CSIR) and South African National Biodiversity Institute (SANBI): Pretoria, South Africa. Report Number: CSIR report number CSIR/NRE/ECOS/IR/2018/0001/A; SANBI report number http://hdl.handle.net/20.500.12143/5847.	1, 2
	Eco-Pulse Consulting, 2018a. Proposed Wild Coast SEZ, Eastern Cape. Wetland Habitat Impact Assessment Report. Unpublished report prepared by Eco-Pulse Environmental Consulting Services for WSP. Report No. EP341-02. Version 0.1 (DRAFT). 10th July 2018. (Amatola)	2
	Eco-Pulse Consulting. 2018b. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase 1: Regional Prioritization Report. Unpublished report prepared for ICLEI - Local Governments for Sustainability – Africa. (Amatola)	2
	Eco-Pulse Consulting. 2018c. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase2: Desktop wetland mapping and condition assessment for wetlands in	2

Year	Study Name	Integrated steps*
	the Mnquma Local Municipality. Unpublished report prepared for ICLEI – Local. Governments for Sustainability – Africa. (Amatola)	
	Eco-Pulse Consulting. 2018d. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase 3: Prioritisation and Selection of Sites for Wetland Rehabilitation. Unpublished report prepared for ICLEI - Local Governments for Sustainability – Africa. (Amatola)	2
	Ellery S, 2018. The origin of bedrock depression wetlands in the southern Cape of South Africa: a changing perspective. MSc thesis, Rhodes University, Makhanda (Algoa)	2
	Rebelo A J, Emsens W-J, Meire P, Esler K J, 2018. Quantification of water purification in South African palmiet wetlands. Water Science and Technology 78: 1199-1207. (Kromme)	2
	Pulley S, Ellery W N, Lagesse J V, Schlegel P K, McNamara S J, 2018. Gully erosion as a mechanism for wetland formation: An examination of two contrasting landscapes. Land Degrad Dev. 29:1756–1767. (Kromme)	2
	Pulley S, Ellery W N, Lagesse J V, Schlegel P K, McNamara S J, 2018. Gully erosion as a mechanism for wetland formation: An examination of two contrasting landscapes. Land Degrad Dev. 29:1756–1767. (Sundays)	2
	McNamara S, 2018. The influence of landscape dis-connectivity on the structure and function of the Krom River, Eastern Cape, South Africa. MSc thesis, Rhodes University, Makhanda. (Kromme)	2
2019	Integrated health assessment and ecosystem service provision of two urban wetlands in Port Elizabeth (Larson 2019).	1, 2, 6
	Department of Environmental Affairs (DEA). Environmental Programmes: Natural Resource Management. 2019. Working for Wetlands: Eastern Cape Provincial Strategic Plan: 2019-2024. Unpublished Report.	1, 2, 6
	Department of Environmental Affairs (DEA). Environmental Programmes: Natural Resource Management. 2019. Working for Wetlands: Western Cape Provincial Strategic Plan: 2019-2024. Unpublished Report.	1, 2, 6
	Larson M R, 2019. Integrated health assessment and ecosystem service provision of two urban wetlands in Port Elizabeth, Eastern Cape (South Africa). MSc thesis. Nelson Mandela University, Gqeberha. (Algoa)	2
	Tanner JL, Smith C, Ellery W and Schlegel P, 2019. Palmiet wetland sustainability: a hydrological and geomorphological perspective on system	2

Year	Study Name	Integrated steps*
	functioning. WRC Report No. 2548/1/18. Water Research Commission, Pretoria. (Kromme)	
	Smith C, 2019. Determining the hydrological functioning of the palmiet wetlands in the Eastern and Western Cape of South Africa. MSc thesis, Rhodes University, Makhanda. (Kromme)	
2020	Ellery WN, 2020. The current status of the Ngciyo Wetland and the Ghio Wetland Nature Reserve. Unpublished report. Geography Department, Lucas Avenue, Rhodes University, Makhanda	1, 2, 6
	Ellery WN, 2020. The current status of the Ngciyo Wetland and the Ghio Wetland Nature Reserve. Unpublished report. Geography Department, Lucas Avenue, Rhodes University, Makhanda. *(Bushmans)*	2
	Job N, Roux DJ, Bezuidenhout H and Cole NS, 2020. A Multi-Scale, Participatory Approach to Developing a Protected Area Wetland Inventory in South Africa. Front. Environ. Sci. 8:49. doi: 10.3389/fenvs.2020.00049. (Fish)	2
	Freeman A, 2020. Investigating wetland structure and origin in the context of landscape geomorphic history: A case study of the wetlands of Makhanda. Honours thesis, Rhodes University, Makhanda. (Bushmans)	2
2021	A project to predict wetland occurrence and type in the Western Cape for improved mapping and management (Kotze and Rivers-Moore 2021)	1, 2, 6
	Characterising wetland features and occurrence near Hogsback (Eichhoff in prep) [scheduled for completion in Dec 2021]	1, 2, 6
	Kotze D C, and Rivers-Moore N, 2021. A project to predict wetland occurrence and type in the Western Cape for improved mapping and management. Unpublished report submitted to South African Biodiversity Institute, Cape Town. (Gamtoos remaining portions)	2
In prep	Glenday J, Jumbi F, Tanner j, Smith C and Smith-Adao L. In prep. Connectivity and climate: monitoring surface and groundwater flows to valley-bottom wetlands in the Baviaanskloof and Kromme catchments, the eastern end of the Table Mountain Group. (Gamtoos (Baviaans portion)	2
	Eichhoff J, in prep. Characterizing wetland features and occurrence near Hogsback, Eastern Cape: application of the genetic geomorphic classification system. Honours thesis, University of Stellenbosch, Stellenbosch. (Amatola)	2
Estuaries		
2007	Turpie JK, Clark B. Development of a conservation plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health	1, 2, 3, 6

Year	Study Name	Integrated steps*
	and economic costs and benefits. Final Report. Anchor Environmental Consultants.	
2015	Van Niekerk L, Taljaard S, Adams JB, Fundisi D, Huizinga P, Lamberth S, Mallory S, Snow G, Turpie J, Whitfield A, et al. Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa. Report to the Water Research Commission by Council for Scientific and Industrial Research. 156p.	1, 2, 3, 6
2019	Van Niekerk L, Adams JB, Lamberth SJ, MacKay CF, Taljaard S, Turpie JK, Weerts SP, Raimondo DC. *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.* Pretoria: South African National Biodiversity Institute.	1, 2, 3, 6
2020	Van Niekerk L, Adams JB, James NC, Lamberth SJ, MacKay CF, Turpie JK, Rajkaran A, Weerts SP & Whitfield, AK. An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management, African Journal of Aquatic Science, 45:1-2, 199-216, DOI: 10.2989/16085914.2019.1685934	1, 2, 3, 6
Socio-economics		
2011, 2016	National Census data (Stats SA), General Household Survey (latest population densities)	2
2018	DEA (egis.environment.gov.za) (Latest land use/cover)	2
2018/Latest Municipal IDPs	Stats SA (Supply-use table/ Municipal IDPs (Economic contributors)	2
2016	Department of Water and Sanitation (DWS) (catchment boundaries)	2
2011	South African National Biodiversity Institute (SANBI) (water resources)	1, 2
Latest	Google Earth™ (Satellite imagery)	1, 2

** Steps:*
Step 1: Delineate and priories RUs and selected study sites
Step 2: Describe status quo and delineate the study area into IUAs
Step 3: Quantify BHN and EWR
Step 4: Identify and evaluate scenarios with IWRM
Step 5: Determine water resource classes based on catchment configuration for the identified scenarios
Step 6: Determine RQOs (narrative and numerical limits) and provide implementation information
Step 7&8: Gazette water resource classes, RQOs and the Reserve

3.2 On-going Monitoring Programmes

Several continuous monitoring programmes/initiatives are undertaken in the study area. These include (i) monitoring of flows and water quality for rivers and groundwater and (ii) aquatic biomonitoring/Aquatic Ecosystem Health (AEH) monitoring through various platforms and programmes, including:

- The River Eco-status Monitoring Programme (REMP) conducted by DWS. These are conducted quarterly, and which include aquatic macroinvertebrates, fish and at times riparian vegetation. All the EcoStatus models are run for contribution and the results form part of the State of Rivers Reports. Data and models will be sourced from the Department prior to the seasonal surveys, and for the purpose of the Ecoclassification phase of the study. The REMP sites and information are indicated within Table 3-2; and
- Management of the biomonitoring data, using the Freshwater Biodiversity Information System (FBIS) by the South African National Biodiversity Institute (SANBI).

Table 3-2: DWS REMP sites within the study area

Site	Latitude	Longitude	River	Main River	Ecoregion	Geozone
Secondary Catchment K						
K8ELAN-LOWER	-33.9668	23.7748	Elandsbos	Elandsbos	20.02	D
K8GROO-LOWER	-34.0350	24.2076	Groot	Groot	20.02	E
K8LOTT-UPPER	-33.9330	23.7295	Lotterings	Lotterings	20.02	D
K8LOTT-LOWER	-33.9729	23.7472	Lotterings	Lotterings	20.02	C
K8STOR-LOWER	-33.9886	23.9193	Storms	Storms	20.02	D
K8STOR-UPPER	-33.9492	23.9195	Storms	Storms	20.02	C
K9KROM-BOJAN	-33.8808	24.0753	Kromme	Kromme	20.02	D
K9KROM-MELKH	-33.9373	24.2721	Kromme	Kromme	20.02	D
K9KROM-DEWIL	-33.9558	24.3491	Kromme	Kromme	20.02	E
Secondary Catchment L						
L7WITR-GROOT	-33.6603	24.5350	Wit	Groot	19.02	C
L8KOUG-BOKOU	-33.7166	23.4113	Groot	Kouga	19.08	D
L8KOUG-OPKOM	-33.7884	24.0253	Kouga	Gamtoos	19.02	E
L9GAMT-PATEN	-33.7609	24.6936	Gamtoos	Gamtoos	19.02	E
Secondary Catchment M						
M1KWAZ-VYEBO	-33.7221	25.3007	Kwazungu	Swartkops	20.01	E
Secondary Catchment P						
P4BLOU-BRIDG	-33.3905	26.7071	Bloukrans	Kowie	19.01	D
P4BLOU-RAILW	-33.3237	26.6000	Bloukrans	Kowie	19.01	D
P4KOWI-UPPER	-33.3493	26.5601	Kowie	Kowie	19.01	D
P4KOWI-BARTH	-33.5069	26.7446	Kowie	Kowie	20.01	E
Secondary Catchment Q						
Q9KATR-BRIDG	-32.5783	26.6795	Kat	Kat	18.02	E
Q9BALF-SODOM	-32.5450	26.6728	Balfour	Kat	16.07	D
Q9ELAN-SEYMO	-32.5456	26.7983	Elands	Kat	16.07	D
Secondary Catchment R						

Site	Latitude	Longitude	River	Main River	Ecoregion	Geozone
R1KEIS-BEAMW	-32.7598	27.0685	Keiskamma	Keiskamm	16.07	E
R1KEIS-BESAN R1KEIS-BESAD	-32.7383	27.0986	Keiskamma	Keiskamm	16.07	D
R1KEIS-BESMA	-32.6832	27.1549	Keiskamma	Keiskamm	16.07	E
R1KEIS-BEXEB	-32.8186	26.99427	Keiskamma	Keiskamm	18.02	E
R1KEIS-EWR01	-32.8701	26.9731	Keiskamma	Keiskamm	18.02	E
R1KEIS-GCINI	-33.0236	27.0863	Keiskamma	Keiskamm	31.01	E
R1KEIS-SMBRI	-32.6405	27.1906	Keiskamma	Keiskamm	16.07	D
R1TYUM-BECON	-32.9017	26.9278	Tyume	Keiskamm	18.02	D
R1TYUM-FORTH	-32.7782	26.8563	Tyume	Keiskamm	18.02	E
R1TYUM-HOGSB	-32.6111	26.9478	Tyume	Keiskamm	16.07	B
R2BUFF-BPASS	-33.0060	27.8234	Buffalo	Buffalo		
R2BUFF-EWR01	-32.7693	27.3629	Buffalo	Buffalo	16.07	D
R2BUFF-EWR02 (BEND)	-32.9583	27.5257	Buffalo	Buffalo	31.02	E
R2BUFF-HORSE	-32.8225	27.3803	Buffalo	Buffalo	31.02	E
R2BUFF-MADEN (AMAID)	-32.7322	27.2937	Buffalo	Buffalo	16.07	C
R2BUFF-ZWELI	-32.9136	27.4103	Buffalo	Buffalo	31.02	E
R2MGQA-PIRIE	-32.7881	27.2497	Mgqakwebe	Buffalo	16.07	D
R2NXAM-POTSD	-32.9852	27.6388	KwaNxamkwane	Buffalo	31.02	D
R2YELL-LONSD	-32.8079	27.4699	Yelloweoods	Buffalo	16.07	E
Secondary Catchment S						
S1WKEI-BXOND	-31.8553	27.1896	18.02	White Kei	Great Kei	E
S1WKEI-STMAR	-32.0138	27.3742	18.02	White Kei	Great Kei	E
S3BKEI-BULLH	-32.0345	26.6558	18.02	Black Kei	Great Kei	E
S3BKEI-TURNS	-32.1786	27.3304	18.02	Black Kei	Great Kei	E
S3KLIP-PLAAT	-32.2568	26.8658	18.02	Klipplaat	Black Kei	E
S4GKEI-GUIKA	-32.2833	27.6525	18.02	Great Kei	Great Kei	E
S5TSOM-KOMKH	-31.6093	27.6765	16.05	Tsomo	Great Kei	E
S5TSOM-R56BR	-31.3673	27.6707	16.04	Tsomo	Great Kei	E
S5TSOM-UPPER	-31.2580	27.8300	16.04	Tsomo	Great Kei	D
S6KUBU-BRIDG	-32.5073	27.7316	16.06	Kubusi	Great Kei	D
S7GKEI-GLENK	-32.5448	28.1939	16.06	Great Kei	Great Kei	E
S7GKEI-KEIBR	-32.5072	27.9732	16.06	Great Kei	Great Kei	E
Secondary Catchment T						
T1MBHA-MVEZO	-31.9587	28.4727	Mbhashe	Mbhashe	16.06	E
T1MBHA-N2BRI	-31.9226	28.4542	Mbhashe	Mbhashe	16.06	E
T1MGWA-MAKHO	-31.8467	28.3143	Mgwali	Mbhashe	16.06	E
T1MGWA-NGCAC	-31.7693	28.1228	Mgwali	Mbhashe	16.06	E
T1MGWA-R61BR	-31.7330	27.94935	Mgwali	Mbhashe	16.06	E
T1MGWA-TORHA	-31.8207	28.1769	Mgwali	Mbhashe	16.06	E
T1MNYO-BRIDG	-31.5172	28.2905	Mnyolo	Mbhashe	16.05	D
T1NTSU-UPPER	-31.7775	28.3644	Unknown	Mbhashe	16.06	D

Site	Latitude	Longitude	River	Main River	Ecoregion	Geozone
T1XUKA-CONFL	-31.7143	28.3288	Xuka	Mbhashe	16.06	E
T1XUKA-MHLOP	-31.7271	28.2694	Xuka	Mbhashe	16.06	E
T1XUKA-R61BRI	-31.6681	28.1120	Xuka	Mbhashe	16.06	E
T1XUKA-SLIND	-31.5795	27.9596	Xuka	Mbhashe	16.05	D
T2MTHA-ASAWM	-31.4931	28.4770	Mthatha	Mthatha	16.06	D
T2MTHA-BESAW	-31.4825	28.4933	Mthatha	Mthatha	16.06	E
T2MTHA-EYE	-31.5069	28.3935	Mthatha	Mthatha	16.05	C
T2MTHA-KAMBI	-31.4713	28.6151	Mthatha	Mthatha	16.06	E
T2MTHA-MDUMB	-31.9259	29.1362	Mthatha	Mthatha	31.01	F
T2MTHA-TAKAT	-31.6856	28.8206	Mthatha	Mthatha	31.01	E
T2NGQU-LOWER	-31.8521	28.8201	Ngqungqu	Mthatha	16.06	E

3.3 Reserve Studies

Several Reserve studies have been undertaken in the catchment area, although at different levels of detail and not for the entire catchment. These include:

- Rapid level 3 studies were done pre 2005 on the small coastal systems in the Pondoland area and the Tsitsikamma coast. There is limited information available from these studies;
- Intermediate Reserve studies have been undertaken for the following rivers and estuaries:
  - Tsitsikamma River and Estuary (2005);
  - Kat River (2006);
  - Kei River and main tributaries;
  - Kromme/ Seekoei Rivers and Estuaries (2006); and
  - Buffalo, Kubusi and Nahoon (2003).

Additionally, a number of desktop studies have also been conducted to evaluate water use licenses. Where information from previous studies are available, it will be used during this study to enhance the confidence in the final EWR results for the evaluation of management scenarios for trade-offs.

As most of the previous studies were undertaken more than 10 years ago, the present state of these systems might have changed due to developments and water use impacts. Thus, surveys will be undertaken at these sites to confirm/ update the present state and re-assess the EWRs if part of a priority RU. The locality of the EWR sites from the previous studies are presented in the table below.

Table 3-3: Locality of EWR sites from previous studies

Site no.	River	Latitude	Longitude	Catch-ment	Level	Date	Comment
K80 and K90 catchments							
Krom_EWR1	Kromme	-33.9318	24.2613	K90A	Comprehensive	2007	Reports available
Krom_EWR2	Kromme	-34.0137	24.4978	K90D	Comprehensive	2007	
Krom_EWR3	Kromme	S 34º 06.3	E 24º 43.6	K90E	Rapid	2007	
GHB_EWR4	Geelhout-boom	-34.1050	24.7267	K90E	Rapid III	2007	

Site no.	River	Latitude	Longitude	Catch-ment	Level	Date	Comment
Seekoei_EWR5	Seekoei	-33.5997	24.7019	K90F	Rapid III	2007	
Swart_EWR6	Swart	-34.0008	24.8472	K90F	Rapid III	2007	
Diep_EWR7	Diep	-34.0220	24.5926	K90D	Rapid III	2007	
Sdrift_EWR1	Sanddrift	-33.9733	23.9792	K80C	Rapid III	Pre 2005	No additional information available
Klip_EWR1	Klip	-34.0125	24.1987	K80D	Rapid III	Pre 2005	
Groot_EWR1	Groot	-34.1321	24.1959	K80D	Rapid III	Pre 2005	
Tkamma_EWR1	Tsitsikamma	-34.0961	24.4427	K80E	Intermediate	Pre 2005	
Kdrift_EWR1	Klipdrift (Oos)	-34.1169	24.5372	K80F	Rapid III	Pre 2005	
Slag_EWR1	Slang	-34.1081	24.6091	K80F	Rapid III	Pre 2005	
Kruis_EWR1	Kruis	-34.0322	24.1961	K80C	Rapid III	Pre 2005	
Palmiet_EWR1	Palmiet	-34.0725	24.4628	K80E	Rapid III	Pre 2005	
Q primary catchment							
Kat_EWR1	Kat	-32.5700	26.7217	Q94B	Intermediate	2006	Reports available
Kat_EWR2	Kat	-32.6217	26.6850	Q94D	Intermediate	2006	
Kat_EWR3	Kat	-32.8867	26.6850	Q94F	Intermediate	2006	
Kat_EWR4	Balfour	Gorge upstream of confluence with the Kat River		Q94C	Rapid	2006	
R primary catchment							
KKamma_EWR1	Keiskamma	-32.7111	27.1372	R10B	Rapid III	2005	No additional information available
KKamma_EWR2	Keiskamma	-32.8684	27.9767	R10E	Rapid III	2005	
YWoods_EWR3	Yellowwood	-32.8092	27.4528	R20E	Rapid III	2005	
Buffalo_EWR1	Buffalo	-32.7694	27.3625	R20A	Intermediate	2002	Reports available
Buffalo_EWR2	Buffalo	-32.9569	27.5306	R20F	Intermediate	2002	
Buffalo_EWR3	Buffalo	-33.0061	27.8253	R20G	Intermediate	2002	
S primary catchment							
Kei_EWR5	Kei	-32.5050	27.9594	S70A	Rapid III	Pre 2005	No additional information available
Kei_EWR1	Klipplaat	-32.2567	26.8558	S32G	Intermediate	2006	Reports available
Kei_EWR2	Black Kei	-32.0625	27.0300	S32K	Intermediate	2006	

Site no.	River	Latitude	Longitude	Catch-ment	Level	Date	Comment
Kei_EWR3	Black Kei	-32.1750	27.3717	S32M	Intermediate	2006	
Kei_EWR4	White Kei	-32.0433	27.3667	S10J	Intermediate	2006	
Kubusi_EWR4	Kubusi	-32.5972	27.4211	S60A	Intermediate	2002	
Kubusi_EWR5	Kubusi	-32.5669	27.6861	S60B	Intermediate	2002	
Kubusi_EWR6	Kubusi	-32.5072	27.7311	S60E	Intermediate	2002	
T10, T20, T60-T90 catchments							
Xuka_EWR1	Xuka	-31.6677	28.1122	T11C	Rapid 3	2011	Report available
Caca_EWR1	Caca	-31.6675	28.1329	T11C	Rapid 3	2011	
Mtata_EWR1	Mtata	-31.7817	28.8850	T20E	Intermediate (1)	Pre 2005	No additional information available
Mtata_EWR2	Mtata	-31.9325	29.1400	T20G	Intermediate (1)	Pre 2005	
Mzamba_EWR2	Mzamba	-31.0494	30.0219	T60A	Rapid III	Pre 2005	
Mtentu_EWR3	Mtentu	-31.1303	29.7564	T60C	Rapid III	Pre 2005	
Msikaba_EWR4	Msikaba	-31.1983	29.6081	T60E	Rapid III	Pre 2005	
Mtanf_EWR5	Mtanfufu	-31.4975	29.5286	T60K	Rapid III	Pre 2005	
CMzintl_EWR6	Coastal Mzintlava	-31.4253	29.5372	T60J	Rapid III	Pre 2005	
Xura_EWR1	Xura	-31.3270	29.4869	T60F	Intermediate	2014	Reports available
Msikaba_EWR2	Msikaba	-31.2518	29.7489	T60G	Intermediate	2014	
Mngazi_EWR1	Mngazi	-31.5528	29.7059	T70A	Rapid	Pre 2005	No additional information available
Mtak_EWR1	Mtakatye	-31.6153	29.0592	T70E	Rapid	Pre 2005	
Nenga_EWR1	Nenga	-31.9752	29.1448	T80A	Rapid III	Pre 2005	
Mpako_EWR1	Mpako	-32.0431	29.0794	T80A	Rapid III	Pre 2005	
Nzuk_EWR1	Nzulwini	-32.0314	29.0909	T80A	Rapid III	Pre 2005	
Xora_EWR1	Xora	-32.0069	28.8563	T80C	Rapid	Pre 2005	
Mbany_EWR1	Mbanyana	-32.2124	28.8888	T80D	Rapid III	Pre 2005	

Site no.	River	Latitude	Longitude	Catch-ment	Level	Date	Comment
Nqabara_EWR1	Nqabara	-32.2809	28.7809	T90B	Rapid III	Pre 2005	

(1) Due to flow conditions during surveys, final results on rapid/ desktop level

Reserve studies for groundwater are not well documented.

Various estuarine Reserve studies have been conducted for the estuaries (approximately 20 estuaries) on various levels of detail. These include studies for the Kromme, Seekoei, Tsitsikamma, Sundays, Great Fish, Nahoon, Mthatha, Xora, Mngazi, Mtakatye, etc. The results from these studies will be evaluated and updated where required. The information from these studies is presented in Table 3-4.

Table 3-4: Estuarine information from presious Reserve studies in the study area

Estuary name	Latitude	Longitude	Date	Level
Groot	-34.059895	24.195019	2003	Desktop
Tsitsikamma	-34.135593	24.438326	2003	Rapid
Kromme	-34.142967	24.842728	2007	Comprehensive
Seekoei	-34.086670	24.910743	2007	Intermediate
East Kleinemonde	-33.539026	27.049325	2008	Intermediate
Sundays	-33.721836	25.853725	2008	Intermediate
Great Fish	-33.495228	27.140684	2013	Rapid
Nahoon	-32.986438	27.951704	2001	Intermediate
Mbanyana	-32.228383	28.927825	2000	Desktop
Ntlonyane	-32.194703	28.956662	2000	Desktop
Xora	-32.158634	28.995585	2000	Rapid
Mncwasa	-32.082706	29.076077	2000	Desktop
Mpako	-32.040237	29.107695	2000	Desktop
Nenga	-31.985485	29.151810	2000	Desktop
Mnenu	-31.807562	29.330090	2000	Desktop
Mngazi	-31.677184	29.463134	2000	Rapid
Mtata	-31.952963	29.183758	2000	Intermediate

Estuary name	Latitude	Longitude	Date	Level
Mdumbi	-31.931450	29.216299	2000	Desktop
Mtakatye	-31.859270	29.270247	2000	Desktop
Mngazana	-31.692177	29.422861	2000	Desktop

3.4 Current and parallel studies

A number of studies have been initiated in the study area and include:

(i) Algoa Water Assessment and Allocation Study for the Kouga, Baviaans, Gamtoos and Krom Rivers;
(ii) Development of a Reconciliation strategy for Algoa and Amathole Systems; and
(iii) SANBI wetland inventory in the Wild Coast catchment area (ongoing project between SANBI and Department of Economic Development, Environmental Affairs and Tourism).

4. GAP IDENTIFICATION

An assessment and review of data and information availability from previous studies, various monitoring databases and GIS spatial layers for the study area was undertaken. This was to identify any gaps, where no or little data, is available to ensure these are collected during this study to improve the detail, confidence, level of ecological specifications and management conditions and to formulate practicable indicators for compliance monitoring and monitoring of the ecological health and integrity of the water resources in the study area. This assesment forms part of Task 2 of the scope of work (see Figure 4-1 below) and Step 1 as per the Integrated Framework (DWS, 2017).

The evaluation of the various gaps per component was undertaken according to criteria for each component (rivers, wetlands, estuaries and groundwater) as well as the socio-economics, based on the data availability and suitability for use, along with proposed solutions and/or mitigations, in which to address these identified data gaps.

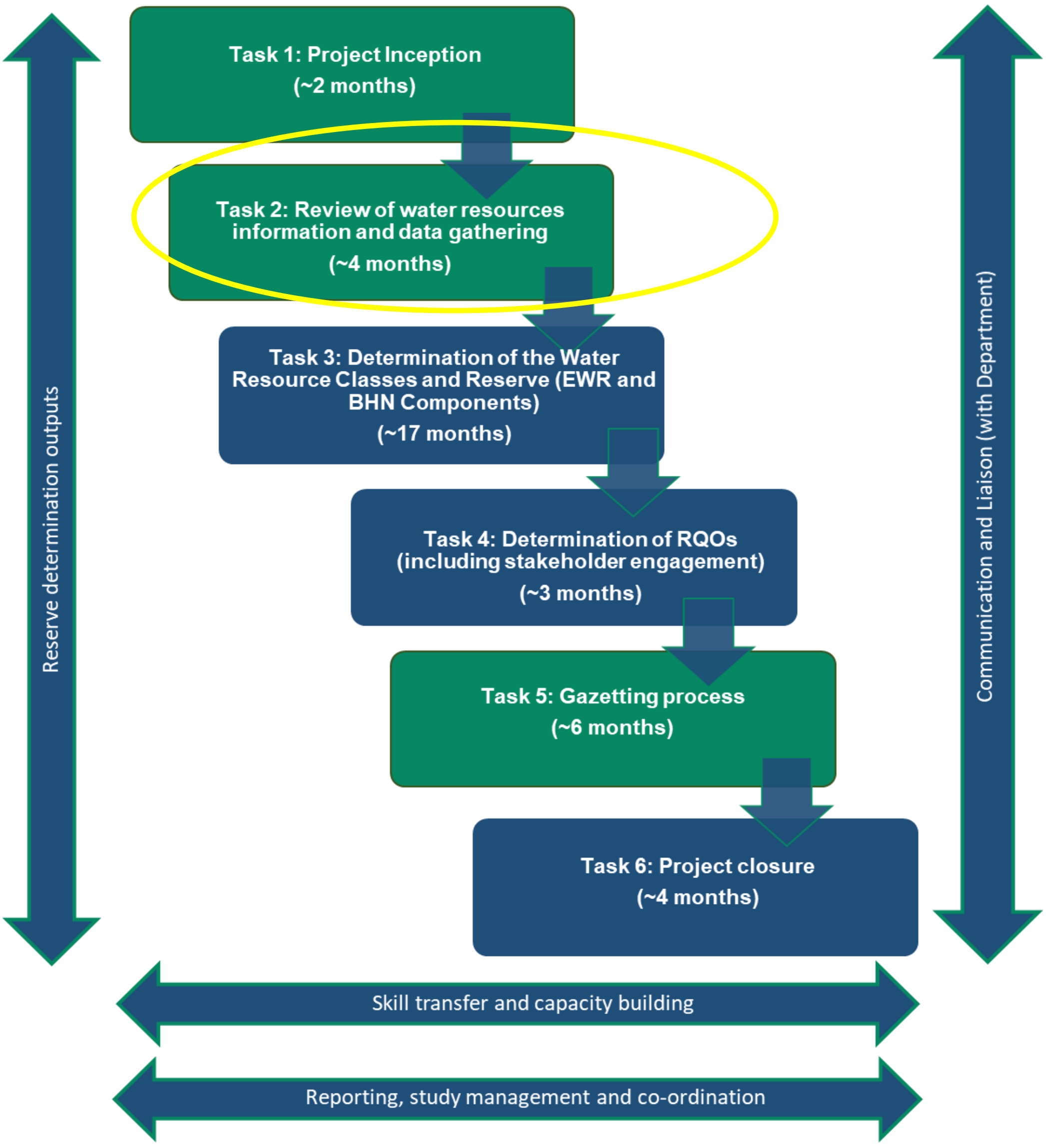

Figure 4-1: Proposed scope of work and approximate timelines

4.1 Rivers

A number of the rivers have been described in terms of their PES. The Buffalo River (Scherman *et al.,* 2004) and Mthatha River (Scherman *et al.,* 2006) have PES descriptions for several sites as part of the Eastern Cape River Health Programme. Furthermore, the River Ecostatus Monitoring Programme (REMP) further provides an overview and ecological state assessment of the aquatic macroinvertebrates, fish, riparian vegetation (including information about alien vegetation in the respective study areas) and geomorphology. The State of Rivers Report (2017-2018) further provides information and data, although only reflecting the condition of the macroinvertebrates through the various drainage regions.

Previous EWR studies which include the various biological components are the Kat (2006), Kromme (2005) and Kromme / Seekoei (2007) studies. These studies however used outdated methodology namely the RVI which was never developed to a level of reliability and was replaced with the VEGRAI. Although the PES, EIS, IHI, flow requirements and species list data are available for the small proportion of the rivers, it is `15 years old, thus a gap that needs to be filled.

The PES-ES-EI data (DWS, 2014) that are available for the study area show a mixture of ecological categories within the study area for each component. Within the PES calculation, particularly for the riparian and wetlands habitats, they are rated on a scale of 0 to 4 (where 0 is natural, akin to a category A, and 4 is poor/compromised, akin to a category E) for riparian / wetland zone modification and for riparian / wetland continuity modification. Although these data relate to the sub-quaternary scale, they are directly beneficial to this study and provide riparian zone context and historic information.

Scattered MIRAI, FRAI, GAI and VEGRAI (PES and Reference state), EIS and IHI assessments exist (Table 4-3) as part of other smaller studies, but vastly underrepresent the current study area. Data and assessments are however useful to this study.

4.1.1 Aquatic Biota

(i) Fish

The use of aquatic biota to detect, measure and track changes in the environment is based on the premise that the presence or absence of biotic assemblages at a given site reflects its level of environmental quality. Depending on their diversity, fish species assemblages provide convenient and potentially full-time monitors of the aquatic environment as they integrate their responses through time and react to all synergistic and antagonistic effects of combined pollutants and stressors imposed on their environment. Fish species display differing tolerances and preferences to environmental attributes, allowing the assessment of the fish assemblage to infer potential impacts.

Fish-based indices of biotic integrity have been developed and used in Southern Africa for bio-assessments and biomonitoring purposes for several years, with the current approach being the Fish Response Assessment Index (FRAI) (Kleynhans, 2007). The FRAI is essentially an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers. Although the FRAI uses essentially the same information as its predecessor (the Fish Assemblage Integrity Index, or FAII) (Kleynhans, 1999), it does not follow the same procedure. The FAII was developed for application in the broad synoptic assessment required for the River Health Programme (now the River EcoStatus Monitoring Programme, or REMP) and does not have a particularly strong cause-and-effect basis. The purpose of the FRAI, on the other hand, is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived reference condition.

According to data available from previous RHP and the current REMP studies at the time of writing, knowledge on the ecological state of the fish assemblages across much of the study area remains unknown, with only a select few catchments having previously been assessed. For example, previous RHP studies have been undertaken on the Buffalo River and Mthatha River catchments, while more recently it appears that only selected sub-catchments of the primary catchments R, S and T have been assessed for fish during REMP studies.

(ii) Macroinvertebrates

Macroinvertebrate families vary in their pollution tolerances. Due to the diversity of taxa, this makes them ideal indicators of water quality in freshwater ecosystems, and which react quickly to pollution events and can colonise previously disturbed/polluted habitats if conditions improve. Additionally, they integrate water quality conditions over time and account for synergistic and additive effects of different water quality parameters.

The South African Scoring System version 5 (SASS5) (Dickens and Graham, 2002) was developed as a rapid technique for determining aquatic ecosystem health using aquatic macroinvertebrates as bio-indicators. The SASS5 technique has been accredited to ISO 17025 standards and forms part of one of the DWS river eco-classification models for EcoStatus determination. This protocol is a biotic index to determine the condition of a river or stream, based on the resident macroinvertebrate community, whereby each taxon is allocated a score according to its level of tolerance to river health degradation (specifically organic impacts) (Dallas, 2007 Information generated by the SASS is used in the MIRAI (Macroinvertebrate Response Assessment Index) that enables assessment of macroinvertebrate information beyond physicochemical evaluation to use in e-flow requirements for lotic systems and setting of biomonitoring objectives (Thirion, 2007). The MIRAI will be used for this study.

Changes and responses within the aquatic macroinvertebrate (and fish) communities are a result of impacts on primary system drivers (hydrology, physicochemical conditions and geomorphology that culminates in changes to flow velocities, habitat availability and ecological water quality. Long-term anthropogenic pressures, system modifications, through high sedimentation loads, dams, irrigation and water transfer schemes, and widespread urbanisation, continues to affect the health and integrity of the macroinvertebrate communities in the catchment.

In accordance with data available from previous RHP and the current REMP studies, as well as the State of Rivers Report (2017 – 2018), Table 4-1 below, includes information with regards to the condition of the aquatic macroinvertebrate assemblages within the study area.

Table 4-1: Information regarding the macroinverebrate communities within the study area (State of Rivers Report: 2017 – 2018)

Drainage region	Macroinvertebrate communities
Drainage region K	Most sites within the K8 (Tsitsikamma etc.) drainage regions were identified to be in a moderately modified condition (Category C), with only the Elandsbos River in a largely natural to moderately modified state (Category B/C) and the upper Storms River in a moderately to largely modified condition (C/D). The upper reaches of these rivers are mostly in reasonably pristine mountainous regions. The Kromme/Seekoei system (K9) are generally in a moderately modified condition (Category C), mostly

Drainage region	Macroinvertebrate communities
	due to impacts from agricultural activities, flow regulations from Churchill and Mpofu Dams and the town of Kareedouw.
Drainage region L	Only L7 to L9 have been sampled from a macroinvertebrate community perspective in this entire drainage region. Systems within L7 and L8 were mostly in a moderately modified state (Category C), while the Gamtoos River in L9 was in a largely modified condition (Category D). Primary impacts resulting in a modification in the macroinvertebrate community in each drainage region include reduced flows from drought conditions and abstractions, agricultural activities, and modified flows respectively.
Drainage region M	The KwaZungu River is the only river being sampled as a REMP site and was classified to be in a natural to moderately modified condition (Category B/C). Sites further downstream are hampered from considerable sewage and thus the macroinvertebrates are not monitored there.
Drainage region P	The macroinvertebrate community ecological categories were classified as moderately modified (Category C) in the Bloukrans and Upper Kowie River sites, influenced by agriculture and urban impacts. Whilst the Kowie River further downstream was in a largely natural condition (Category B).
Drainage region Q	Only the Kat River and Balfour tributary are monitored to avoid transfer scheme influences on flows in a large part of the catchment. Both systems were in a largely natural to moderately modified condition (Category B/C)
Drainage region R	As drainage region R1 is relatively undeveloped and mostly utilised from stock grazing or dry land cultivation, the macroinvertebrate communities monitored on the various river systems range from largely natural condition (Category B) (Tyume River) to largely modified conditions (Category D) (Keiskammahoek). The conditions recorded within R2 include largely natural conditions (Category B/C) in the upper reaches of the Mgqkwebe River, although the integrity of the macroinvertebrate communities

Drainage region	Macroinvertebrate communities
	declines towards the lower reaches of this drainage region indicating largely modified conditions (Category D).
Drainage region S	Limited monitoring takes place within this region. Only the Klipplaat River and upper reaches of the Tsomo River are assessed in terms of their macroinvertebrate communities, which were moderately modified (Category C) and moderately to largely modified (Category C/D) – largely owing to cultivation of the riparian zone and agricultural activities.
Drainage region T	Limited monitoring takes place within T1, T2 and T6-T9. River systems located in T1 were mostly moderately modified (Category C), with primary impacts being erosion, commercial dryland agriculture and commercial forestry.

4.1.2 Geomorphology

There are some data available on changes to drivers (sediment and flow) for the study area. Land cover maps are available for 2020 and the potential water erosion risk has been modelled for the study area by Le Roux *et al.,* (2008). These resources give an overview of land use and resultant erosion and sediment supply for the various catchments. Some of the larger dams have been mapped by Lehner *et al.,* (2011) and give a spatial overview of river reaches that are likely to be bedload starved. Spatial data on weir location and size is unfortunately not available. The hydrological data should indicate to what extent the flow duration has changed from natural. Based on the available data there are no broad scale gaps in terms of changes to the drivers. There might be gaps at a finer site scale level, especially where there are no hydrological data available.

Several academic geomorphic studies have been undertaken on rivers within the study area (Huchzermeyer, 2017; McGregor, 1999; Powell, 2016; Van der Waal, 2015; Wadeson, 1995), but very few present a reference description suitable for this study. There are reference descriptions for the Kromme system only and was part of the Kromme EWR in 2005. The geomorphic zones have been determined along all the rivers (part of the NFEPA dataset) and this can be used as a starting point for the reference description (Rowntree, 2013). These broad-scale reference descriptions based on the geomorphic zone need to be updated for the sites based on historical aerial imagery and the existing descriptions.

Flow requirements have been part of the EWRs for the Kat (2006) and Kromme (2005) Rivers. There is a need to provide the flow requirements for the other rivers in the study area and update the existing data.

Sediment quality has been studied for several of the rivers and estuaries of the study area. Metals have been studied for the: Swartkops Estuary (Binning and Baird, 2001); Umtatha River (Fatoki et al., 2002); lower Buffalo River and tributaries (Watling et al., 1985); Tyume River (Awofolu et al., 2005); lower Sundays River (Watling and Watling, 1982); lower river/estuary of the Great Fish, Kowie, Kariega and Bushmans Rivers (Watling and Watling, 1983); Kromme to Nahoon Estuary (Newman and Watling, 2007); and the Buffalo, Keiskamma, Umtata, Tyume Rivers (Fatoki and Awofolu, 2003). Hydrocarbons were studied along the Buffalo Estuary (Adeniji et al., 2019, 2017). Many of these studies can be used as baseline information to identify likely problematic areas, but ongoing monitoring and source tracing are needed to inform adaptive management of problem areas.

4.1.3 Riparian vegetation

The riparian zone is the interface between terrestrial and aquatic ecosystems. Plant communities along river margins are called riparian and are characterized by hydrophilic plants to greater or lesser degrees. Riparian zones are significant in ecology, environmental management, and civil engineering because of their role in soil conservation, their biodiversity, and the influence they have on aquatic ecosystems. Riparian zones have frequently been referred to as interfaces, which possess specific physical and chemical attributes, biotic properties, and energy and material flow processes, and are unique in their interactions with adjacent ecological systems (Risser, 1995; Naiman & Décamps, 1997). They operate as both ecosystem drivers (flood attenuation, sediment dynamics, instream and riparian habitat provision) and biotic responses (Table 4-2).

Table 4-2: Uses and importance of the riparian zone

Riparian zones	References
Control energy and material flux, longitudinally and between adjacent landscapes	Holland *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; Naiman & Décamps, 1997
Are potentially sensitive sites for interactions between biological populations and their controlling variables	Holland *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; Naiman & Décamps, 1997
Possess an unusually diverse array of species and environmental processes	Holland *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; Naiman & Décamps, 1997; Naiman *et al.*, 1993; 1997
Maintain critical habitat for rare and threatened species	Holland *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; Naiman & Décamps, 1997
Are refuge and source areas for pests and predators, especially alien plant species	Holland *et al.*, 1991; Nilsson *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; DeFerrari & Naiman , 1994; Naiman & Décamps, 1997; Rountree, 1991
Are corridors for longitudinal migration	Décamps *et al.*, 1987; Schneider & Sharitz, 1988; Holland *et al.*, 1991; Hansen & di Castri 1992; Risser, 1995; Machtans *et al.*, 1996; Pollock *et al.*, 1997; Naiman & Décamps, 1997
Are vehicles for the mass movement of materials through the landscape	Griffiths, 1980; Hupp & Simon, 1986; Myers & Swanson, 1992; Beeson & Doyle, 1995; Naiman & Décamps, 1997
Influence channel morphology and dynamics	Griffiths, 1980; Hupp & Simon, 1986; Myers & Swanson, 1992; Beeson & Doyle, 1995; Naiman & Décamps, 1997

Riparian zones	References
Directly affect sediment dynamics via riparian vegetation	Lowrance *et al.*, 1986; Hubbard *et al.*, 1990; Abt *et al.*, 1994
Alter channel hydraulics	Nakamura & Swanson, 1993; Hupp *et al.*, 1995
Influence river / stream microclimate	Naiman & Décamps, 1997; Brosofske *et al.*, 1997
Are key landscape components in maintaining biological connections along extended and dynamic environmental gradients	Nilsson *et al.*, 1991; Naiman *et al.*, 1993; Pollock *et al.*, 1997
Are sources of nourishment for aquatic organisms and herbivorous fauna	Weigelhofer & Waringer, 1994
Act as filters in the landscape	Triska *et al.*, 1993a, 1993b
Are sources of specialized habitat	Malanson 1993; Naiman & Décamps, 1997
Reduce / control flooding	Tabacchi *et al.*, 2000
Improve water quality	Dosskey *et al.*, 2010
Water storage	Naiman & Décamps, 1997

The vegetation within the study area is highly variable, comprising eight vegetation biomes and notable azonal vegetation (Figure 4-2; Mucina & Rutherford, 2006; 2018), and ranges from Nama-Karoo to Forest and Indian Ocean Coastal Belt along a dry-wet gradient. These biomes include Nama- and Succulent Karoo, Fynbos, Albany Thicket, Savanna, Indian Ocean Coastal Belt, Grassland and Forest. It is reasonable to assume that such variability in the terrestrial context for riparian vegetation will likely also produce a highly variable range in riparian vegetation structure and composition within the study area.

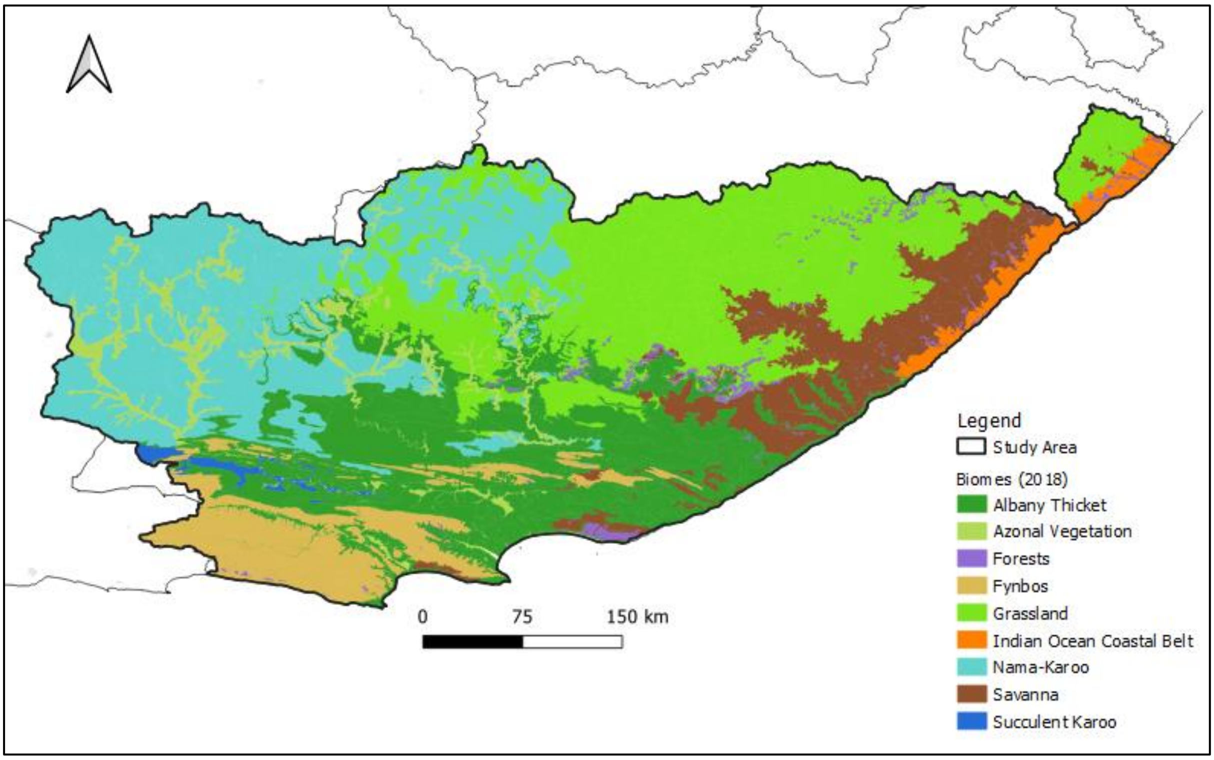

Figure 4-2: Vegetation Biomes within the study area (from Mucina & Rutherford, 2018)

Most of the older biomonitoring reports did not sample or report on riparian vegetation and vegetation reporting was simply an overview of the terrestrial vegetation types. Examples include Buffalo River Biomonitoring (2010), Shixini River assessment (2010), Mbashe River trends report (2007-2010), Keiskamma River biomonitoring trends (2010) and biomonitoring of the Great Kei River system (2010).

Previous EWR work that includes riparian vegetation assessments are the Kat (2006) and Krom / Seekoei (2007) studies. Both these studies used outdated methodology however: These studies both used the RVI which was never developed to a level of reliability and was replaced with the VEGRAI. PES, EIS, IHI, flow requirement and species lists are however pertinent for the relevant river systems.

4.1.4 Water quality

Information from the DWS Resource Quality Information Services (RQIS) water quality database and the Water Management System (WMS) will be used as the primary source of the water quality data for the assessment and analysis for the study area. In terms of the water quality data assessment, the water quality monitoring stations are largely concentrated on main stem rivers and major tributaries. Data gaps do potentially exist where monitoring has been discontinued and for the smaller tributaries with largely natural present states and ecologically important and sensitive. Also, some of the monitoring sites may not be situated in prioritised RUs. Furthermore, the adequacy and reliability of data might be a gap, particularly the more recent data where we are aware that there have been some challenges with laboratory analyses at RQIS.

Wherever possible, other data sources (theses, reports, surveys (e.g. RHP, State of Rivers reports), previous Reserve studies, the FBIS biological database (which sometimes records basic in situ chemical analyses), diatom samples at selected smaller tributaries, etc.) will be used to infill on some of these gaps. Various key universities and research institutes in the catchment area (NNMU, Rhodes, Walter Sisulu, and Fort Hare) are known to have various levels of expertise and interest within the aquatic environment and may provide useful data via theses.

The requirements of the various water users and aquatic ecosystems in the catchment and the potential impacts need to be assessed. Some localised water quality issues around the towns with non-functional wastewater treatment works, general littering and related to agricultural practices have been identified. These are key to understanding the extent of the impact on the larger catchment and ultimately on the aquatic ecosystems and where particular requirements will be specified. These ecological specifications can then be used for the development of RQOs and numerical limits. Lack of recent monitoring information may impact the process. Although some baseline information is available from previous Reserve and other assessments, the Reconciliation Strategies and All Towns studies, these are mainly based on large-scale catchments and do not provide the detailed information required for smaller tributaries.

The WMS database primarily includes monitoring data for several parameters/ variables, including Electrical Conductivity (EC), Total Dissolved Salts (TDS), pH, Sodium, Magnesium, Calcium, Hardness, Potassium, Fluoride, Chloride, Sulphate, Phosphate as P, Total Alkalinity as $CaCO_3$, Ammonium as N, Nitrate + Nitrite as N, Chemical Oxygen Demand (COD), and E. coli. The monitoring points of the National Chemical Monitoring Programme (NCMP) (WMS data) within the catchment are primarily located on the main stem rivers and the major tributaries. Specific indicators will be selected to assess the status quo and for setting ecological specifications and RQOs. These will be informed by specific catchment developments and guided by future developments as incorporated into the Reconciliation Strategies. There is uncertainty that there has been sampling and analyses by RQIS since early 2018. Thus, determination of the current water quality conditions will possibly be at least, partly reliant on available data collected by the Regional Offices, from previous surveys, as well as from the surveys that will be undertaken and forming part of this study. However, the frequency and extent of monitoring vary considerably, as does the integrity and reliability of the more recent data. A challenge posed for this study is the determination of the water quality status at more remote sites where no monitoring is currently undertaken – specifically if a sub-quaternary reach is identified in a smaller tributary catchment with a high PES/EI/ES.

The South African diatom collection will be interrogated and more recent data from that use to infer water quality state from the diatom results.

4.1.5 Hydrology

The natural or reference hydrology of the study area varies from region to region and across catchments. This variance is both due to the natural climate variation across the large study area, but also in terms of the sources and confidence and detail in the information. Some of the catchments linked to larger water supply systems for metropolitan supply, have been studied in more detail with focused hydrological and water resources planning studies being previously conducted. These include the Amatole and Algoa Water Supply Systems (WSS). For the catchments linked to these systems, hydrology update studies are currently being undertaken. For the sake of terminology, these will be referred to as level 1 catchments or study areas.

Other catchments have been part of smaller stand-alone reconciliation strategy or drought operating rule assessments. These studies, while focused on the individual catchment and smaller water supply system, have typically used hydrology data developed through national studies such as the WR2012. This hydrological data is typically studied at a lower level of detail due to the larger effort needed to cover all catchments in the country. Thus, while there is local hydrology available linked to water resources models and existing focused assessments, the hydrology is typically not developed to the same level of detail or confidence. There may however be exceptions where a revision of update to the smaller system was done as part of all towns' strategy or drought operating rules assessments, or part of a feasibility study, but these would typically be the exception. For the sake or terminology, catchments and study areas linked to these previous assessments and initiatives will be referred to as level 2 catchments.

Lastly, there are catchments for which little detailed hydrological and water resources assessment modelling has been undertaken. For these, the national level hydrological studies such as the WR2012 are the main source of data with no follow on WRYM models developed, i.e., the hydrology has not been embedded in a water resources scenario analysis model. These catchments will be referred to as level 3 catchments.

These three levels of catchments and associated hydrological information and availability of water resources models is carried through into the gap analysis based on the information assessment for the river's component in Table 4-3.

Table 4-3: Evaluation of information available and identification of gaps for rivers

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Rivers EWR information				
EWR site details	Available for most of the previous Reserve studies. Only a few rivers have been assessed on intermediate or comprehensive levels.	Yes	Only site coordinates available for most of the rapid level 3 studies done pre-2005.	Results from these studies are outdated and existing sites will be re-visited to undertake the various surveys and revise the EWRs.
PES/ EIS/ REC	Available from most of the previous studies and the 2014 Desktop PES/EI/ES per SQ reach.	Yes	-	-
EWR output (rule & tab tables)	Limited information available.	There may be a need to adjust for existing sites - depending on the changes to PES and REC and reference hydrology.	Summary tables are not available for all the sites, especially the rapid studies undertaken pre-2005.	Re-assess the sites and generate summary tables.
Ecological specifications	Limited information available, except for intermediate and comprehensive studies.	Will be used as an indication of how the system has changed over time.	Outdated as most studies were undertaken more than 10 years ago.	Will be updated with more recent data.
Sustainable Development Goals (6) and Co-operative governance link with SANBI	Environmental information apart from the Department for co-operative governance. NFEPA / FEPA data.	Yes	-	Ensure latest data is requested from SANBI.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Early /historical aerial imagery – for all components	Data available from Mark Rountree, in addition to Rhodes University and Dr Bennie van der Waal which has a strip of all Wild Coast estuaries from Brian Colloty. Estuaries: SAEON Olwandlile node	Yes	-	-
Strategic Water Source Areas (SWSA)	Gazetted SWSA shapefiles	Yes	-	A study area map will be overlayed with the SWSA to ensure this is taken account of, particularly when assessing the IUAs and RUs within the study area.
Site selection and permits				
Site selection and permits for surveys	-	-	Accessibility constraints in some areas (formal farming, conservation areas). Permits required to sample in conservation areas.	Liaise with Stakeholder engagement team for farmer contact details and arrange site access. Cape Nature etc. are linked in to site selection Gerhard / Nancy Job/ Pierre de Villiers / Eddie Riddel

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Hydraulics				
Benchmarks	Will assess for pegs on site where co-ordinates are available fom previous studies.	Existing benchmarks will be used if available and sites are still suitable	-	New sites will be selected and new benchmarks installed
Hydraulics model and output	Information from previous studies will be requested.	Modelling data will be suitable if the old cross-sections can be located and river channels didn't change due to floods, etc.	-	Hydraulic modelling will be carried out at the new hydraulic cross sections and at existing sites where no information avalable of benchmarks could not be located.
DWS gauging stations data	If in close proximity to the EWR sites (and if still working/ functional/ calibrated etc.)	Yes, can use for more accurate discharge during field surveys.	Gauges might not be in close proximity of EWR sites.	Undertake on-site discharge with flow meter.
Geomorphology				
Reference conditions	Eastern Pondoland 2001 – no Geomorph component Kromme 2005 – EWR1 Melkhoutboskraal, EWR2 Krommerivierspoort, EWR3 Dyke, EWR4 Geelhoutboom, EWR5 Seekoei River, EWR6 Swart River Kat 2006 - none	Yes, but Kromme only.	Reference descriptions not available for most rivers.	Include reference descriptions for new intermediate sites.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
GAI output	Buffalo 2004 – Geomorph PES for RHP sites Kat 2006 - PES for EWR1 (C), EWR2 (D), EWR3 (C) and Balfour River (A/B) Kromme 2005 – EWR1 Melkhoutboskraal (D), EWR2 Krommerivierspoort (E), EWR3 Dyke (D), EWR4 Geelhoutboom (C), EWR5 Seekoei River (D), EWR6 Swart River (C) Mthatha 2008 – Geomorph PES for RHP sites	Yes, but dated for sites available.	Dated or unknown PES for most rivers.	Include PES assessments for new intermediate sites.
Flow requirements	Kromme 2005 – EWR1, EWR2, EWR3 none, EWR4, EWR5, EWR6 Kat 2006 - EWR1, EWR2, EWR3	Yes, but dated for sites available.	Dated or unknown flow requirements for most rivers.	Include PES assessments for new intermediate sites.
Sediment quality	Swartkops Estuary (Binning and Baird, 2001) – heavy metals Umtatha River – (Fatoki et al., 2002)- Dissolved trace metals in water. Lower Buffalo River and tribs – (Watling *et al.,*	Yes, will allow problem areas to be identified where data are available.	Some rivers do not have data or data are dated.	Include in RQO as a non-flow related pollution objective. No resources available to sample and analyse sediment for this study, will require a separate project.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	1985) – sediment and water metal concentrations. Tyume River – (Awofolu *et al.,* 2005) – Water and sediment Trace metals. Buffalo Estuary (Adeniji *et al.,* 2019, 2017) – Hydrocorbons of water and sediment. Lower Sundays River - (Watling and Watling, 1982) – metals in water, surface and core of sediment. Lower/estuary of Great Fish, Kowie, Kariega and Bushmans Rivers (Watling and Watling, 1983) – Metals in water, surface sediment and sediment. Kromme to Nahoon Estuary - (Newman and Watling, 2007) - Baseline			

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	metal concentrations in sediment. Buffalo, Keiskamma, Umtata, Tyume Rivers (Fatoki and Awofolu, 2003) – Water and sediment samples from rivers and dams.			
Fish				
Reference species	Available from most of the previous RHP/ Reserve studies and PES/EI/ES 2014.	Yes The PES/EI/ES will provide a good indication of the state, sensitivity and importance of the smaller tributaries per SQ reach that have not been assessed as part of previous Reserve studies.	-	-
	Kat EWR (2006): fish surveyed at 4 sites (EWR1, EWR2, EWER3, EWR4) and included PES (FRAI), EIS, trends and flow requirements	Moderate suitability for use - provides historic context (reference)	Data older than 10 years	Include PES assessments for all new EWR sites
	Kromme / Seekoei EWR (2007): 6 sites (EWR1 – EWR6) which included the Kromme River, the Geelhoutboom River, the	Moderate suitability for use - provides historic context (reference)	Data older than 10 years	Include PES assessments for new EWR sites

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	Seekoei River and the Swart River, FRAI, IHI, PES, flow requirements, ecospecs and EIS			
	Freshwater Biodiversity Information System (FBIS).	Moderate suitability for use - provides historic context (reference)	Data is limited to lower portions of catchments	Inclusion of data into reference lists and non-native species impacts for PES assessments for new EWR sites
	Global Biodiversity Information Facility (GBIF)	Yes	Possible reveiw of taxonomy required	Inclusion of data into reference lists and non-native species impacts for PES assessments for new EWR sites
REMP data	DWS REMP data	Moderate suitability for use	Limited to selected catchments, most notably for parts of the Keiskamma, Mbhashe and Mthatha systems. Buffalo system has only a single site whereas Great Kei has two sites. All other catchments do not have REMP FRAI data available.	Include PES assessments for new EWR sites. New FRAI models to be set up for new EWR sites where REMP data is lacking.
	State of Rivers Report: Mthatha (2008) and Buffalo (2004) River systems.	Moderate suitability for use - provides historic context (reference)	Fish data is limited to Mthatha and Buffalo catchments, with no reporting on other catchments	Include PES assessments for new EWR sites. Contact Dean Impson to request information/

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				data on their Eastern Cape counterpart. Contact Dr Neels Kleynhans/ Anton Bok/ SAIAB with regards to any other relevant fish data/information or other contacts.
FRAI model setup & output	REMP FRAI models likely set up for selected catchments	Moderate suitability for use	Limited to selected catchments, most notably for parts of the Keiskamma, Mbhashe and Mthatha systems. Buffalo system has only a single site whereas Great Kei has two sites. All other catchments do not have REMP FRAI data available.	New FRAI models to be set up for new EWR sites where REMP data is lacking
Macroinvertebrates				

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Reference taxa	Available from most of the previous/ Reserve studies PES/EI/ES 2014	Good suitability for use. The PES/EI/ES will provide a good indication of the state, sensitivity, and importance of the smaller tributaries per SQ reach that have not been assessed as part of previous/Reserve studies	-	-
	Kat River EWR (2006): macroinvertebrates surveyed at 4 sites (EWR1, EWR2, EWER3, EWR4) and included PES (MIRIA), EIS, trends and flow requirements	Moderate - suitability for use. Provides historic context (reference)	Data older than 10 years	Include PES assessments for new EWR sites
	Kromme / Seekoei EWR (2007): 6 sites (EWR1 – EWR6) which included the Kromme River, the Geelhoutboom River, the Seekoei River and the Swart River, MIRIA, IHI, PES, flow requirements, ecospecs, EIS	Moderate suitability for use - provides historic context (reference)	Data older than 10 years	Include PES assessments for new EWR sites

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	FBIS	Moderate suitability for use	Data is limited to lower portions of catchments	Inclusion into reference lists PES assessments for new EWR sites
REMP Data	DWS REMP data	Moderate suitability for use	Limited to selected secondary catchment areas that have available SASS5 data, ecological categories and MIRIAs set up from between 2017 to 2020. These include: • K8 – K9 (Elandsbos, Groot, Lotterings, Storms and Kromme); • L7-L9 (Wit, Groot, Kouga Rivers); • M1 (Kwazungu, tributary of the main stem Swartkops River); • P4 (Bloukrans (tributary of the Kowie River) and main stem Kowie River; • Q9 (Balfour and Elands, tributaries of the main stem Kat River and on the Kat River itself);	Include PES assessments for new EWR sites MIRAI models to be set up for new EWR sites where REMP data is lacking

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
			• R1-R2 (Keiskamma River, Tyume River - tributary of the Keiskamma, Buffalo River and smaller systems namely Mgqakwebe, KwaNxamkwane and Yellowoods, tributaries of the Buffalo River; • S1 (White Kei), S3-S7 (Black Kei, Klipplaat, Tsomo, Kubusi – all tributaries of the Great Kei River and two sites on the Great Kei itself; and • T1-T2 (Mbhashe River, Mgwali, Mnyolo, Xuka - tributary of Mbhashe, main stem Mthatha River, including Ngqungqu – tributary of the Mthatha River). • All other secondary catchment areas do not have REMP MIRAI data available.	
	State of Rivers Reporting (2017 – 2018) State of Rivers Report (Mthatha and Buffalo River systems)	Moderate suitability for use - provides historic context (reference)	As above	Include PES assessments for new EWR sites. Contact Dean Impson to request information/

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				data on their Eastern Cape counterpart. Contact Dr Christa Thirion regarding any other relevant contacts for macroinvertebrate data and other contacts.
MIRAI setup & output	REMP MIRAI models likely set up for selected catchments (including latest 2020 updated models for some secondary catchment areas.	Moderate suitability for use	Limited to selected secondary catchment areas as per above. All other secondary catchment areas are not monitored by the Department and thus do not have REMP MIRAI data available.	MIRAI models to be set up for new EWR sites where REMP data is lacking
Riparian vegetation				
Reference vegetation types	Skead, C. J. (compiler; 2009). Historical plant incidence in southern Africa. Strelizia 24. South African National Biodiversity Institute, Pretoria	Yes: Anecdotal account from all early explorers to southern Africa, highlighting vegetation properties, species and their distrubution. Data from as early at 1600's. With updated names and arranged geographically in a broad sense. Many references to rivers and their vegetation.	Fragmented coverage.	Historical resource for reference state determination – no mitigation.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	POSA (http://posa.sanbi.org/): Southern African plant names and floristic details from the South African National Biodiversity Institute (online resource of plant species distribution)	Yes: Distribution of plant species based on observed / collected material. Useful for compiling preliminary species lists for sites. Some collections date back to early 1900's, therefore also represent early reference.	Fragmented dataset, both temporally and spatially; point-source data requiring extrapolation / interpolation for sites not directly covered.	Used to giude field work, no mitigation necessary but can be updated with data collected at site.
	Global Biodiversity Information Facility (GBIF): Online species distribution data, interactive	Yes: Similar to POSA above but has global coverage and includes all taxa not just plants.	Fragmented dataset, may not cover area of interest.	Collect additional information for new EWR sites.
	National vegetation types mapping and classification (Mucina and Rutherford, 2006, updated in 2012, updated in 2018).	Yes: Provides baseline vegetation context.	Is predominatly terrestrial in nature with the exception of azonal vegetation types	Use as is to provide context for riparian zones which are generally at smaller scales than this dataset.
	Historical aerial photographs. At least some are usually available for selected sites.	Yes: Provides historical overview and potential trends	May not be available, may be poor resolution, usually only a few dates available	
	REMP data (quarterly results however only for some catchments)	Yes: If vegetation component has been included.	Only focusses on marginal zone vegetation	Use only to augment marginal zone, wet bank or fringe vegetation

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				component of assessment.
Ecostatus / condition	PES/EI/ES (DWS, 2014)	Yes: There are two riparian zone / wetland metrics rated to assess integrity and continuity on a sub-quaternary scale	Assessment is broad in that it represents the riparian zone with only 2 metrics and these are assessed from satellite imagery so often omit important finer-scale detail	Can be used as a guide and refined with site visits at EWR sites
VEGRAI/IHI setup & output	T9 - Nqabara (2013): VEGRAI (PES & Reference state) T9 - Shixini (2015): VEGRAI (PES & Reference state) Q93 - Great Fish (2011): VEGRAI (PES & Reference state), EIS Qinira (2012): VEGRAI (PES & Reference state), EIS Q93D - Kap River (2012): VEGRAI (PES & Reference state), EIS, IHI P40D – East Kleinemonde (2019): VEGRAI (PES & Reference state), EIS, IHI P40D - West Kleinemonde (2019): VEGRAI (PES & Reference state), EIS, IHI P40D – Riet (2019): VEGRAI (PES & Reference state), EIS, IHI Q94 – Kat (2011): VEGRAI (PES & Reference state), EIS, IHI	Yes, PES and Reference state, but dated and placed for sites available	May be outdated, some are level 3	Include PES assessments for new intermediate sites

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	S3 – Komani (2012): VEGRAI P4 – Kowie (2012): VEGRAI (PES & Reference State) S10 – Dubeni, tributary of White Kei (2010): VEGRAI (PES & Reference state), EIS, IHI			
EWR (that included vegetation assessments)	Kat EWR (2006): 4 sites, vegetation profiles surveyed, vegetation species, PES (RVI), EIS, Trend, flow requirements.	Moderate, data and methodology outdated, but provides historic context (reference)	RVI (still under development) was used, PES scores therefore low confidence	Use updated methodology e.g. VEGRAI
	Krom (Kromme) / Seekooi EWR (2007): 7 sites includes the Kromme River, the Geelhoutboom River, the Seekoei River, the Swart River, and the Diep River, IHI, PES, flow requirements, ecospecs and EIS	Yes, methodology outdated, but provides historic context (reference)	RVI (still under development) was used, PES scores therefore low confidence	Use updated methodology e.g. VEGRAI
Diatoms				
Reference species Specific Pollution Sensitivity Index (SPI) Biological Diatom Index (BDI) percentage of pollution tolerant valves (%PTV)	Data on diatom communities is available through parts of the study area from Dr Jonathan Taylor from the national diatom collection from the University of Northwest (NWU)	Moderate suitability for use	Limited to certain secondary catchment.	Diatom samples will be collected at all selected sites where biological, rapid and/ or intemediate sites will be surved.
Water quality				

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Water quality parameters, reference conditions and present state	The historical data will give at least some trends and indications of the major drivers of WQ in the catchment.	The more recent monitoring data is deficient in some areas, partly due to a lack of analyses by RQIS laboratories.	Current water quality status unknown for some of the catchments.	Additional data is available from the DWS Regional Office in East London that will provide information on the present state for the rivers being monitored. Assess various other provincial EIA studies/ reports as supplementary source of information/data availability. Where possible, sourcing of other data via theses, inference from on-site diatom collections, and interrogation of the national diatom collection (housed at NWU – Potchefstroom), will be undertaken. Determine the current water quality conditions with data collected from the seasonal surveys to be undertaken as part of this study.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Water quality requirements and specifications	Results from previous Reserve determination studies.	Yes	Limited to a few intermediate studies undertaken for the study area	Assessment of water quality at new EWR sites
Water quality linkages with gauging stations	Summary of gauging stations and data availability in Study Area provided in Table 4-4 based on information from DWS (2015) and obtained from the DWS HYDSTRA database.	Data availability varies across the Study Area, depending on location of gauging stations, status (open or closed), data period and data quality.	General lack of or sparseness noted in the following secondary catchments as described in further detail below under hydrology gaps.	Assess selected EWR site locations relative to gauging stations and data availabilty.
Hydrological data				
Gauged daily data	Summary of gauging stations and data availability in Study Area provided in Table 4-4 based on information from DWS (2015) and obtained from the DWS HYDSTRA database.	Data availability varies across Study Area, depending on location of gauging stations, status (open or closed), data period and data quality.	Extensive stream flow gauging in Study Area, but general lack of or sparseness noted in the following secondary catchments: • K9 • L3, L4, L5 • M2, M3 • N3 • P2, P3, P4 • Q2 • R4, R5 • S1	Mitigation approach depends on selected EWR site locations relative to location of gauging stations and data availabilty, but may inlcude: • Daily disaggregation of monthly modelled catchment runoff from WR2012 and other basin studies. • Scaling stream flows from upstream / downstream

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
			• S4 • S7 • T6, T7, T8, T9 Furthernore, many or all stations closed in the following secondary catchments: • L1, L2, L3, L7, L9 • N1, N3 • P1 • Q3, Q5, Q7 • R1	stations for selected EWR sites. Inferring flow characteristics based on data from stations located in close proximity or on rivers with comparable stream flow characteristics.
Monthly natural flows	Long term monthly naturalised data is available for all catchments. This data comes from the previous system specific hydrology studies plus the WR2012. The level of detail and data availability period however varies. For the smaller coastal rivers, some might be lumped into single quaternaries that results in a loss of ability to model seperately.	The data periods are typically over 80 years in length and suitable for the analysis required. A challenge that could be raised by stakeholders is that the hydrological records of the last 10 years are not likely to be included in existing hydrology, and this is a critical period for many portions of the study area with a serious drought occuring. Some catchments hydrology is being	No significant gaps other than the inclusion of the recent drought. Matters to be managed will be the following: • Adding catchments with different data periods into common models • Managing the timing of updated data availability from the hydrological studies of the reconciliation strategies vs timing of assessments needed by this classification study.	Have separate water resources assessment models for different catchments to allow differences in both hydrological data period, and scenarios of projected futures to be managed. An additional solution to manage the timing of updated hydrology data will be to work with the other teams conducting the reconciliation strategy, and build the EWRS to be used for the

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
		updated by separate studies by the DWS. The timing of these updates will need to be managed. The data from the previous 80 years prior to this drough is however, still valuable, but may be considered incomplete.		classification study into a common set of models to be used by both studies.
HAI output	Available for high confidence studies	Yes	Limited HAI results available	Do HAI for all selected intermediate sites
Water Resources Modelling				
Water Resource Planning Model (WRPM)	Available for larger systems, but not critical if a suitable Water Resource Yield Model (WRYM) model is available.	Would need to be used in a constant deveopment time slice mode, or latest data from the WRPM to be extracted and worked back into the WRYM.	Algoa WRPM is more advanced than the WRYM. A call to be made on whether to use the data and re-populate into the WRYM, or to use the WRPM directly in constant time slice mode. The decision to be taken in discussion with the Reconciliation staregy team.	WRPM models would likely only be used where a model is much more advanced than the WRYM models. The only location that this is likey to be a reality is for the Algoa WSS.
WRYM	WRYM available for all level 1 and 2 catchments (i.e. catchments were reconciliation staregies or drought operating	Data is suitable with modifications such as sub-division to include EWR sites where not at	No WRYM models developed for the smaller rivers (level 3 catchments)	Suitable WRYM models to be developed by this team, where required, based on the WR2012

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	rules have been conducted to date, or by current studies in time for classification analyses.	the boundary of a quaternary.		study schematics and hydrology available. The scale and lumping of the models will be based in a combination of IUAs, development scenario information, and practical model size.
Water demands (current and future)	Suitable current and future water demands are available for level 1 and 2 catchments (where reconciliation strategies and other previous studies have been conducted, or are being updated). Bulk water master plans and information in DWS geodatabase also available for most WSAs. WSDPs for the basic human needs portion (to be separate from the piped sources). The Validation and Verification study will	Existing water resources strategies and studies data suitable, particilarly where this data is already included in water resources models. A challenge with the bulk water master plans is that they are often overly ambitious to plan and budget for the worst case scenario, but do provide a possible upper envelope. Their resolution is also sometimes not aligned with existing water resource models.	The timeframes of the projections for the drought studies (some level 2 catchments) are typically only 5 years, and thus do not provide a long term perspective. Level 3 catchments water use data often outdated – not current (e.g. 2010) and projections are not likely to be available in a format that readily aligns with hydrological models.	Assess existing water demands in hydrological models, and compare with other souces of information from WSA's and DWS geodatabase, and Validation and Verification study. Hold a meeting with the DWS to discuss data and likely growth and changes in data. Acquire the WSDPs data.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	also be valueable for current / recent water use and land use data.			
Base hydrology	See natural hydrology which is intended to be used as the base hydrology across the study area.			
System configuration	Available for the WRYM and/or WRPM models for Amatole, Algoa and various smaller stand alone systems (All Towns studies). Also available for the WR2012 study as used in the WRSM2000 model	Suitable for managing and using models for a technical and communication tool.	The schematics may not align with the WSDPs and other sources of data. This is not a critical issue, but may result in the translation of the data from other data sources being more time consuming to integrate into the models.	May be valueable to overlap strategic water resources areas on schematics, if editable schematics can be obtained.
Reconciliation strategies	Available for Amatole, Algoa and various smaller stand alone systems (All Towns studies). Updates planned in the study area as well as possible new staregies for smaller towns / systems.	Developed for water resources studies so typically aligned.	Various smaller catchments and more rural areas not yet covered. Timing of new or updated strategies may be an issue to be managed.	Initial meeting held with the DWS and respective study teams of in tandem studies in the study area. Preliminary estimates of dates for new data provided and classification program and reconciliation strategy study programs being compared.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				A list of all the systems with existing or planned reconciliation strategies to be deveoped.
Scenario analysis				
Catchment scenarios	Similar to the water demand projections, but includes the proposed catchment developments such as dams and transfers. Impacts of demand side measures on water demand projections also important and to be provided from reconciliation strategies. Feedback from stakeholders on any plans by private sector not captured by DWS plans will also need to be considered.	Typically already built into models or at least aligned with water resources models. Water Service Development Plans (WSDPs) (embedded in Integrated Developmnet Planning (IDPs) and bulk master plans may also provide suitable indications of development aspriations, but translation into numbers and scenarios may require some discussion.	Available for catchments with reconciliation strategies and also the Water Availability Assessment Study (WAAS). However, development plans for other areas may be less catchment focused and more municipal or administrative boundary focused. There may be gaps for the more rural areas.	Using existing system specific development scenarios where available. Develop reaonable assumptions of projected catchment development based on IDPs, historical growth patterns, and through discusions with the DWS and stakeholders.

Table 4-4: Summary of open gauging weirs and data availability in the study area

Gauge[1]		Record Period		% Gap in Daily Data[3]
No.	River and Gauge Name	Start Date	End Date[2]	
K8H001	Kruis River @ Farm 508	2005/08/31	2014/06/24	1%
K8H002	Elands River @ Kwaai Brand For. Res	1961/07/11	2014/06/24	5%
K8H006	Groot River @ Rooiwal	1998/09/29	2014/06/24	0%
K8H005	Tsitsikama River @ Geelhoutboom	2005/06/20	2014/06/25	0%
K9H001	Krom River @ Kromme Riviers Poort	1948/09/01	2014/06/25	10%
K9H003	Krom River @ Elandsjagt	1983/07/28	2014/06/25	4%
L6H001	Heuningklip River @ Campherspoort	2004/12/07	2014/06/23	0%
L7H006	Groot River @ Grootrivierspoort	2005/06/20	2014/06/23	1%
L8H002	Haarlem Spruit @ Welgelegen	1970/07/09	2014/04/22	2%
L8H001	Wabooms River @ Diepkloof	2005/12/06	2014/05/15	3%
L8H005	Kouga River @ Stuurmanskraal	2005/03/15	2014/06/24	2%
M1H004	Elands River @ Wintcanton	1965/04/06	2014/06/24	12%
M1H012	Swartkops River @ Uitenhage	1994/11/28	2014/06/24	5%
N2H007	Sondags River @ De Draay	1978/05/24	2014/06/23	1%
N2H008	Riet River @ Groene Leegte	2004/11/09	2014/06/23	1%
N4H001	Sondags River @ Korhaanspoort	1914/12/01	2014/06/24	73%
N4H005	Coerney River @ Selborne	1987/05/19	2014/06/24	1%
P1H003	Boesmans River @ Donker Hoek	1957/02/21	2014/07/22	3%
P3H001	Kariega River @ Smithfield	1969/07/04	2014/05/20	1%
P4H001	Kowie River @ Bathurst	2005/02/23	2014/05/20	1%
Q1H012	Teebus River @ Jan Blaauws Kop	2000/02/04	2014/06/04	0%
Q1H020	Right Canal From Grassridge Dam @ Klipheuvel	1924/01/25	2014/07/22	8%
Q1H022	Left Outlet To Great Brak River @ Klipheuvel	1985/06/21	2014/07/22	76%
Q1H013	Little Brak River @ Zeeven Fontein	2006/02/16	2014/06/04	0%

Gauge[1]		Record Period		% Gap in Daily Data[3]
No.	River and Gauge Name	Start Date	End Date[2]	
Q2H002	Great-Fish River @ Zoutpansdrift	2003/08/28	2014/07/23	1%
Q3H005	Great-Fish River @ Rietfontyn	2004/12/09	2014/07/22	1%
Q4H013	Tarka River @ Bridge Farm	1980/07/24	2014/07/22	0%
Q5H007	Great Fish at Elandsdrift Dam	2012/01/25	2014/06/30	8%
Q6H003	Baviaans River @ Botmansgat	2005/04/18	2014/06/30	2%
Q7H005	Great Fish River @ Sout Vleij	2005/02/21	2014/05/19	3%
Q3H004	Pauls River @ Coutzenburg	1975/10/01	2014/07/23	2%
Q8H010	Little Fish River @ Grootvlakte	1999/12/01	2014/07/24	1%
Q8H008	Little Fish River @ Doorn Kraal	1979/08/07	2014/07/02	2%
Q8H006	Little Fish River @ Wellington-Grove	2008/09/09	2014/05/14	0%
Q9H012	Great Fish River @ Brandt Legte	2005/02/24	2014/05/21	1%
Q9H030	Koonap River @ Frisch Gewaagd	2004/06/07	2014/05/21	0%
Q9H002	Koonap River @ Adelaide	1928/10/01	2014/05/21	1%
Q9H018	Great Fish River @ Matomela's Location	1969/07/30	2014/07/23	10%
Q9H026	Kat River @ Weltevreden	1965/01/12	2014/05/22	0%
Q9H019	Balfour River @ Grey Kirk	2008/02/19	2014/05/22	1%
Q9H017	Blinkwater River @ Blinkwater	1965/06/26	2014/05/22	0%
Q9H029	Kat River @ Fort Beaufort	2009/12/03	2014/05/22	1%
R1H017	Keiskamma River @ Lower Mcqumeya	1987/11/19	2014/06/18	4%
R1H014	Tyume River @ Kwa Khayaletu	1953/06/24	2014/06/18	1%
R1H015	Keiskamma River @ Farm 7	1969/07/31	2014/06/17	3%
R2H001	Buffalo River @ Pirie Main For.Res.	1946/10/01	2014/06/20	0%
R2H008	Quencwe River @ Braunschweig	1947/06/01	2014/06/20	2%
R2H006	Mgqakwebe River @ Msenge Ridge	1948/07/05	2014/06/20	10%
R2H005	Buffalo River @ King Williams Town	1947/10/01	2014/06/20	21%

Gauge[1]		Record Period		% Gap in Daily Data[3]
No.	River and Gauge Name	Start Date	End Date[2]	
R2H009	Ngqokweni River @ Sheshegu	1947/06/01	2014/06/18	15%
R2H010	Buffalo River @ 135 K.W.T.Q	1950/07/01	2014/06/18	2%
R2H016	Zwelitsha Spruit @ Malakalaka	1988/03/22	2014/06/18	3%
R2H015	Yellowwoods River @ Fort Marray Uitspan	1988/03/21	2014/06/18	1%
R2H027	Buffalo River @ Mhlabati	1994/02/24	2014/06/20	2%
R2H029	Buffalo River @ Mdantsane	2001/10/25	2014/06/17	0%
R3H001	Gqunube River @ Outspan	1972/04/21	2014/06/23	0%
R3H003	Nahoon River @ Farm 305	1965/01/15	2014/06/17	0%
R3H008	Nahoon River at Abbotsford	2003/04/23	2014/06/27	12%
S1H004	White Kei River @ Cacadu	2003/05/15	2014/06/24	0%
S2H006	Doorn River @ Indwe	1970/12/07	2014/06/25	0%
S2H005	Indwe River @ Mutote Farm	1968/11/07	2014/06/25	4%
S3H006	Klaas Smits River @ Weltevreden	2005/03/02	2014/06/24	3%
S3H010	Klipplaat River @ Waterdown	1957/02/06	2014/06/19	0%
S3H012	Oskraal River @ Oxkraal Kamastone	1989/11/09	2014/06/19	0%
S3H004	Black-Kei River @ Cathcarts Gift	1964/04/17	2014/06/24	4%
S3H013	Swart Kei River at Hotfire	2003/09/25	2014/06/24	10%
S5H004	Tsomo River @ Famini Loc	1976/03/02	2014/07/23	44%
S5H002	Tsomo River @ Wyk Maduma	1999/05/12	2014/05/28	13%
S6H001	Kubusi River @ Stutterheim	1947/04/12	2014/05/12	5%
S6H004	Gubu River @ Farm 253	1971/09/22	2014/06/23	0%
S6H005	Kubisi River @ Wriggleswade	1989/01/10	2014/06/23	1%
S6H003	Toise River @ Forkroad	1964/08/27	2014/05/12	1%
S7H004	Great-Kei River @ Area 8\092092044Springs B	1999/01/05	2014/06/27	1%
S7H001	Gcuwa River @ Butterworth	1951/10/01	2014/06/26	29%

Gauge[1]		Record Period		% Gap in Daily Data[3]
No.	River and Gauge Name	Start Date	End Date[2]	
T1H001	Xuka River @ Caca 45	1999/09/21	2014/07/23	61%
T1H013	Mbashe at Gxwali Bomvu	2005/07/27	2014/05/27	2%
T1H011	Qumanco at Damane	2003/12/09	2014/05/30	0%
T1H014	Mbashe River at Rune	2006/12/14	2014/05/27	0%
T1H015	Mbashe at Rara 34	2006/03/23	2014/07/24	0%
T2H008	Mtata River @ Umtata	2002/05/14	2014/06/03	0%
T2H010	Cicira River at Roode Heuvel	2003/07/25	2014/04/25	4%
T6H004	Xura River @ Xura 27	1992/03/01	2014/06/24	3%
T6H001	Mntafufu River @ Ntafufu Loc. 35	1969/07/28	2014/06/23	25%
T7H001	Mngazi River @ Mgwenyana Loc. 22	1998/11/11	2014/06/23	17%

Notes:

(1) From DWS (2015);
(2) Status as assessed in 2014; and
(3) Based in statistics provided by DWS HYDSTRA database, if available.

4.2 **Wetlands**

A gap analysis was undertaken for wetlands based on a range of specific criteria (e.g. wetland typing) relevant to wetlands as well as based on existing reports/publication which deal with wetlands in each sub-catchment in the overall study area (see Table 3-1). The intensity of effort directed at all the criteria in Table 4-5 varies greatly across the sub-catchments, and appearing to be lowest in the Gamtoos, Sundays, Tsitsikamma, Mtata, Mbashe and Wild Coast areas. Similarly, the number of wetland reports is very unevenly distributed across the sub-catchments. The Kromme River catchment, although only occupying a very small proportion of the overall study area, has a conspicuously larger number of wetland reports than any other sub-catchments. This is followed by Gamtoos (concentrated primarily in the Baviaans River portion), Algoa and Bushmans, all with an intermediate number of reports, then by the Kei, Amathola and Wild Coast with a moderately low number, and lastly by the Sundays, Fish, Tsitsikamma, Mbashe and Mtata with a low number of reports, and therefore probably representing the most conspicuous gaps.

The gap analysis based on the information above is illustrated in Table 4-5.

Table 4-5: Evaluation of information available and identification of gaps for wetlands

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Wetland mapping, identification and delineation	NWM5, plus new datasets for localized areas, notably Amathole municipality.	Intensity of mapping effort across the overall study area is very patchy (and not systematically recorded) therefore requiring caution and interpretation when using the existing spatial data.	Gamtoos, Sundays, Tsitsikamma, Mtata, Mbashe and Wild Coast sub-catchments have thus far been identified as having a relatively low level of mapping effort, and for which wetlands have generally been under-mapped.	Collaboration with SANBI to extend the areas with heads-up mapping in Wild Coast and Tsitsikamma sub-catchments and hopefully other additional under-mapped areas.
Wetland typing	As above	As above, the intensity of effort directed towards identifying HGM type of wetlands across the overall area is generally very low, except in localized areas.	The sub-catchments identified above have very little field verification of the desktop identified HGM types.	Field-verification of HGM types in selected priority areas.
Wetland Categorisation (PES & EIS)	NFEPA: for all mapped wetlands, PES has been inferred based on landcover and the river PES WfWetlands Provincial Strategic planning: PES assessment based on WET-Health Level 1A	The resolution of both the NFEPA and WfWetlands assessments is low. Also, given the method used by NFEPA, which is based on the *maximum* impact inferred from (1) landcover in the wetland, (2) landcover in a localized buffer around the wetland, (3) land-cover in a more extensive buffer, and (4) the PES of any stream spatially connected with	The sub-catchments identified above have very little field verification of the desktop-assessed PES, which is a particularly important gap given the issues covered in *Suitability for use.*	Once refinement of the wetland layer and typing has been completed, the PES of individual wetlands will be assessed using WET-Health level 1, with strategically targeted field verification and applying an adjustment to account for historically disturbed areas now mapped largely as natural vegetation.

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
		the wetland, the wetland PES appears to be generally under-scored. In addition, NFEPA distinguishes only between natural and transformed land-cover and does not account for the greatly varying intensities of impact associated with different types of transformation. The WET-Health Level 1A assessments also need to be interpreted with caution, it seems especially in many arid areas in particular, where historically disturbed areas are now mapped largely as natural vegetation, and where PES inferred from the "natural vegetation" inadequately accounts for persistent impacts resulting from historical anthropogenic disturbance, thus leading to a general over-scoring of PES.		
Priority Wetland identification	Individual priority wetlands have been identified by NFEPA.	A key limitation affecting the usefulness of priority wetlands identified is that they do not	The sub-catchments identified for *Wetland mapping, identification and delineation*	Once refinement of the wetland layer and typing has been completed, and the PES re-

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
	Priority quinary catchments have been identified by WfWetlands.	account for the unmapped wetlands, which has particular relevance to the under-mapped areas, as noted above.	are likely to be where some key priority wetlands have been overlooked.	assessed, a multi-criterion prioritization will be undertaken, including a stakeholder workshop to assist in identifying overlooked priority wetlands.

4.3 Groundwater

Much of the groundwater information will be sourced from WR2012 and the local databases (i.e. WARMS) and associated reports. In addition, the regional officer responsible for groundwater monitoring will be requested to provide groundwater information on both quality and quantity. This information will further aid in the more detailed investigations required.

To further discuss the groundwater status in the catchment, stressed areas and hotspots, along with the integration with rivers, wetlands and estuaries (if applicable), a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members will be held in due course, which will add further information, data and value to this component. New sourced data in focused areas i.e. priority quaternary catchments where linkages occur between groundwater, wetlands and rivers will also be undertaken for this study.

The gap analysis based on the information assessment for the groundwater component is illustrated in Table 4-6 below.

Table 4-6: Evaluation of information available and identification of gaps for groundwater

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Groundwater data	DWS: NGA, WMS, WARMS	Yes	Municipal databases; WUA databases	Engage with local stakeholders, water user associations
Groundwater recharge	WR2012	Suitable for high-level investigations; not suitable for more detailed investigations	Local databases and reports	Engage with local stakeholders, water user associations Propose a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members Collect new data in focused areas (priority quaternary catchments / where linkages occur between groundwater, wetlands and rivers
Basic Human Needs	WR2012; Census 2011	Adequate	None	Linking with socio-economics team members to ensure the use of the same data
Groundwater quality	WR2012; WMS	Suitable for high-level investigations; not suitable for more detailed investigations	Municipal databases; WUA databases	Engage with local stakeholders, water user associations Propose a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members Collect new data in focused areas (priority quaternary

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				catchments / where linkages occur between groundwater, wetlands and rivers
Water level depths	WR2012; NGA	Suitable for high-level investigations; not suitable for more detailed investigations	Municipal databases; WUA databases	Engage with local stakeholders, water user associations Propose a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members Collect new data in focused areas (priority quaternary catchments / where linkages occur between groundwater, wetlands and rivers Cross-link with wetlands component
Contribution to baseflows	No, but this is related to groundwater level depths near streams, GDEs, wetlands etc.		Identify strategic sites for the setup of monitoring networks	Collect new data in focused areas (priority quaternary catchments / where linkages occur between groundwater, wetlands and rivers Cross-link with wetlands component
Groundwater use	WR2012; WARMS	Suitable for high-level investigations; not suitable for more detailed investigations	Municipal databases; WUA databases	Engage with specialists regarding the Gamtoos GW data for irrigation demands

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				(Goega, Krom, Gamtoos and Langkloof) For other areas, engage with local stakeholders, water user associations Propose a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members Collect new data in focused areas (priority quaternary catchments / where linkages occur between groundwater, wetlands and rivers
Stress index	WR2012	Suitable for high-level investigations and planning purposes	Revise if needed based on new data on recharge, baseflow and groundwater use	Collect new data in focused areas (priority quaternary catchments / where linkages occur between groundwater, wetlands and rivers
Hotspots	Some information from previous studies (ISP, reconciliation strategies, All Town studies)	Yes	Might not cover all areas in detail	Once refinement of the groundwater has been completed, a prioritisation will be undertaken, including a stakeholder workshop to assist in identifying overlooked GW hotspots and the integration with wetlands and other

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
				groundwater dependent/ driven systems.

4.4 Estuaries

The gap analysis for the estuaries were undertaken based on previous Reserve studies, other relevant estuarine studies and the results from the 2018 National Biodeversity Assessment. This 2018 assessment is the most comprehensive and was undertaken for all the estuaries in the country. The assessment classified estuaries according to the Biogeographical Region and ecosystem type. The threat status, the main impacts/ pressures, biodiversity (including if part of a MPA, RAMSAR site, etc.), present estuarine health/ condition or PES (overall and per metrics of hydrology, hydrodynamics, water quality, fish, etc.) and possible restoration/ mitigation measures were included in the evaluation of the estuaries.

It futher included a new class of estuary, namely microsystems. However, no additional information were provided for these microsystems. The gap analysis (see Table 4-7) is based on the 154 estuaries in the study area. If any of the 97 microsystems are included as a priority RU, the relevant data will have to be collected during the field surveys.

Table 4-7: Evaluation of information available and identification of gaps for estuaries

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
River inflow/base flows / floods hydrology	Some river gauging stations, and estuarine stations (DWS) Hydrology data and models from reconciliation strategies, All Town studies and WR2012	Yes	Limited observed datea	Use available observed data and modelled data from previous studies or this study.
Delineation	NBA 2018 – Spatial EFZ classification	Yes		
Water quality (abiotic drivers)	Harrison WQ, S. Taljaard,	Yes	Not available for all the estuaries	Collect additional data during field surveys
Biological data (Microalgae, Macrophytes, Invertebrates, Fish, Birds)	Adams *et al.,* 2016 – area coverage of macrophyte habitats Colloty *et al.,* 2001, Turpie 2004 and others Harrison, Turpie 2004, Marais 1996, Plumstead 1985-1990's, Whitfield (recent work), Angus Paterson, Underhill & Cooper, 1984 (most), Turpie 2004 CWAC (Birdlife SA – Nicky), Turpie	Yes	Some of the data is outdated or cover only some of the estuaries in the study area	Collect additional data during field surveys

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
EWRs (PES/EIS)	Reserve studies for ~20 estuaries. NBA, 2018 results and Ecoclassification , 2015	Yes	Not all estuaries covered and some results on desktop level	Collect data during field surveys for priority estuaries if no detail data is available.
Hydrodynamics data, mouth status and sediment processes	Key information required for estuarine assessments. SAEON aerial imagery available. Additional aerial photos along the Wild Coast available from B van der Waal. Estuarine Management Plans	Yes	Available for some estuaries	Collect data during field surveys for priority estuaries if no detail data is available and set up model.
Impacts on estuaries (pollution, developments within EFZ, etc.)	NBA, 2018 and 2015 Ecoclassification	Yes	Available for all the estuaries, might be based on desktop assessments.	Collect data during field surveys for priority estuaries to improve confidence.

4.5 Socio-economics and BHN

This section reports on the data required to undertake the socio-economic assessment and proposes alternative sources should the recommended data not be available. These data requirements are to fulfil each task in the socio-economic component of the project.

4.5.1 Task 1 Determination of Catchment Status-quo & Determination of IUAs

The data required to determine the status quo of the catchment and contribute to determining IUAs is summarised in Table 4-8 below and is predominantly spatial in nature and Stats SA census data. Stats SA Census data which is on a ward level was last done in 2011. To calculate recent population and BHN in the catchment, various data sources will be used to support the 2011 Stats SA census, such as Stats SA mid-year population, General Household Surveys (GHS) and DWS- National Water Services Knowledge System (NWSKS). Detailed agricultural data to be used will be obtained from Department of Rural Development and Land Reform. Any other relevant data sources that are available will be used.

Table 4-8: Recommended data requirements for describing the socio-economic status, key drivers and general spatial features across a catchment

Data Required	Possible Source	Data/ Information Availability	Suitability (confidence)	Other Sources
Latest Population densities	National Census data (Stats SA)	Yes (2011)	Low (data only available for 2011)	Municipal Non-Financial census; Household surveys, DWS (NWSKS)
Latest Land Use/ Cover	DEA (egis.environment.gov.za)	Yes (2018)	High	
Economic contributors	Stats SA/ GDP Publication	Yes (2019)	High	
Catchment boundaries	Department of Water and Sanitation (DWS)	Yes (2016)	High	
Towns and cities	DEA (egis.environment.gov.za)	Yes	High	
Satellite Imagery	Google Earth™	Yes	High	
Agriculture	Department of Rural Development and Land Reform (DRDLR)	Yes (2017)	High	

Data Required	Possible Source	Data/ Information Availability	Suitability (confidence)	Other Sources
Latest Protected areas	DEA (www.egis.environment.gov.za)	Yes (2021)	High	

4.5.2 *Task 2: Describe Communities and Their Wellbeing*

Indicators such as employment status, household income, access to water services and education level describe the social well-being of communities (Table 4-9). This data is mainly sourced from Stats SA census. The data is outdated and can lead to under estimation of the social index score. DWS-NWSKS develops similar data annually on SA level, with Census data as their base line. Human Health diseases is not available and will be investigated through literature review and consultation with Department of Health.

Table 4-9: Recommended indicators for describing the social wellbeing of IUAs

Data Required	Possible Source	Data/Information Availability	Suitability (confidence)	Other Sources/ Mitigation of Gap
Household Income	Stats SA (census)	Yes (2011)	Low	Municipal Non-financial census; General Household surveys and DWS (NWSKS)
Access to water services				
Education level				
Source of water per household				
Employment Status				
Human health diseases	Stats SA/ Department of Health	No	High	Consult Department of Health and conduct literature review

4.5.3 *Task 3: Describe the Use and Value of Water*

Development of physical and monetary accounts helps to assess the use and value of water in the catchment. The data required to develop monetary accounts is municipal financial census and IDP which is water sales by the municipality from different sectors (see Table 4-10 and Table 4-11). The data is available from Stats SA.

Data required to develop the physical account is typically sourced through documents such as reconciliation strategies. A solution is that monetary accounts will be used together with inputs from the greater classification process (i.e., hydrological and groundwater studies), to develop the physical account. The general approach is that the volume of water utilised will be determined by calculating monetary values with water tariff per sector in the catchment (Table 4-10 and Table 4-11).

Table 4-10: Data required to develop the physical water account

Data Required	Possible Source	Other sources
Source of water (surface and ground water) and users	DWS Catchment and All Town reconciliation strategies (i.e., 2011 & 2018 Algoa Water Supply Area, 2002 Fish to Tsitsikamma, 2002 Mzimvubu to Keiskamma) and input data sets from hydrological study and ground water.	Consultation with DWS on Validation and Validation studies in the catchment and Water use License Applications. WR2012 water use results.
Volume of water used in the electricity industry	Stats SA Electricity Large Sample Survey (LSS)	
Water supply by water boards in the country	Water boards annual reports	
Total mean annual runoff	Inputs from our hydrological component of the classification study	
System input volume per municipality	DWS (No drop system),	

Table 4-11: Data required to develop Monetary water account

Data required	Type of data
GHS	Qualitative information on service delivery
Census of Agriculture	Crop water use data at Magisterial District level
Large Sample Survey (LSS) – Electricity, gas and water supply	Water volumes used water purchases
LSS – Manufacturing	Water purchases
Supply and Use Tables	Monetary transitions for water use sectors defined in the supply use tables
Survey of Actual Capital Expenditure of Municipalities	No direct relevant information
Survey of Actual Capital Expenditure of National Government, Provincial Government and Extra-budgetary and Funds	No direct relevant information
Financial Census of Municipalities	Water purchases by municipalities Water sales by municipalities
Non-Financial Census of Municipalities	Number of consumer units served

4.5.4 Task 4: Develop an Inventory of Aquatic Ecosystem Services

Following on from Task 1, the purpose of this step is to identify the ecosystem services within the catchment at an IUA level and determine a broad idea of the demand of these services by communities and the economic sectors that utilize them (Table 4-12).

Table 4-12: Indicators required to develop aquatic ecosystem services

Data Required	Methodology	Data/Information Availability	Significance/ Confidence
Ecosystem Service Flow Data	Millennium Ecosystem Assessment: Ecosystems and Human Well-Being (MEA) The Economics of Ecosystems and Biodiversity for Water and Wetlands (TEEB)	Ecological infrastructure: • Land data from task 1 (i.e., rivers, groundwater dams, wetland, agriculture, vegetation) • Inputs from other specialist studies (i.e., wetlands, fish, water quality, estuaries, riparian vegetation, etc.) Beneficiaries: • BHN output data from task 2 on IUA level • Water resource users from task 3 on IUA level	High confidence in existing data

4.5.5 Task 5: Quasi Social Accounting matrix

The Social Accounting Matrix (SAM) is a well-established macro-economic modelling tool which may be restructured into a modelling tool through which the impact of water resource management scenarios can be evaluated. In this step, two Quasi Social Accounting matrices will be developed, one is national QSAM (quantifies the South African economy) and the other will be a Keiskamma and Fish-Tsitsikamma QSAM (to quantify the size of the Keiskamma and Fish-Tsitsikamma economy) (Table 4-13).

Table 4-13: Data required to develop Quasi Social Accounting matrices

Data Required	Possible Source	Data/Information Availability	Significance/ Confidence
National QSAM	Stats SA	Supply and Use Tables published in 2021 for year 2018. This is the latest published available data.	High confidence
Keiskamma and Fish-Tsitsikamma QSAM	The national QSAM. Province Stats SA data	This QSAM will be built from basis of national QSAM. Data from the socio-economic profiles, growth & development plans and spatial economic overviews of the district municipalities that fall within the catchment. Quarterly employment statistics information. These are published every quarter. Annual economic reports.	High confidence in existing data

Data Required	Possible Source	Data/Information Availability	Significance/ Confidence
		Census of Agriculture. Data available is from 2017 when full census was done.	

4.5.6 Task 6: Evaluate Scenarios

Key to this step is input from all relevant parallel work streams. The data inputs to this point are required for the evaluation of scenarios and therefore all gaps identified above will be relevant for this step.

The gap analysis based on the information assessment for the socio-economics and BHN components are illustrated in Table 4-14.

Table 4-14: Evaluation of information available and identification of gaps for socio-economics and BHN

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
BHN				
Population	Stats SA Census (2011) DWS – NWSKS (2021) Community survey (2016) Stats SA mid-year population (2020)	Yes	Census data outdated	Current estimates of population numbers available from mid-year population and DWS (NWSKS).
Household Income				
Access to water services				
Education level				
Source of water per household				
Employment level				
Ecological infrastructure				
Land cover	DEA (egis.environment.gov.za)	Yes (2018)	-	-
Protected areas	DEA (egis.environment.gov.za)	Yes (2021)	-	-
Satellite Imagery	Google Earth™	Yes	-	-
Agriculture	DRDLR (2017), V&V studies (2016)	Yes (2017)	-	-
Water resources (aquatics, wetlands, estuaries, groundwater)	DWS,SANBI, DEA, and input data from specialists	Yes	-	-

Criteria	Data available	Suitability for use	Gaps identified	Proposed solutions/mitigation to address gap
Source of water (surface and ground water) and users	DWS Catchment and All Town reconciliation strategies (i.e., 2011& 2018 Algoa Water Supply Area, 2002 Fish to Tsitsikamma, 2002 Mzimvubu to Keiskamma) and input data sets from hydrological study and ground water studies. WR2012 data and results.	Yes	-	-
Economics				
Census of Agriculture	Crop water use data at Magisterial District level	Yes	-	-
Large Sample Survey (LSS) – Electricity, gas and water supply	Stats SA- Water volumes used water purchases	Yes	-	-
LSS – Manufacturing	Stats SA- Water purchases	Yes	-	-
Supply and Use Tables	Stats SA- Monetary transitions for water use sectors defined in the supply use tables	Yes	-	-
National QSAM	Stats SA- Supply and Use Tables published in 2021 for year 2018. This is the latest published available data.	Yes	-	-

5. SUMMARY OF KEY GAPS

Based on (i) the assessment of information and review of data availability and (ii) a specialist workshop held on 11 January 2022, the identified gaps were discussed and refined and how these will be addressed during this study to ensure high confidence results for the Water Resource Classification, Reserve and RQOs in the study area. The key gaps that will impact on the confidence of the final results that won't be or only be partially addressed during this study are listed below in Table 5-1.

Table 5-1: Summary of key gaps

Criteria	Key gap	Interventions
Water Resource Modelling		
Models	System models for the Algoa system may be poorly performing and associated uncertainty due to hydrology/ Land Use/ system model/ operation of the model. This will need to be verified during the study with input from the current in tandem development of a reconciliation strategy study team.	This study may be a chance to address this issue through: • Potential consideration to reschedule aspects of this study to align with the Algoa study, if necessary. • Reconciliation and WAAS studies – collaboration with these study teams is vital. • Suggested that the DWS study leads have a co-ordination meeting to resolve and direct the respective studies to optimise the outputs.
Daily hydrology		
Gauged daily data	Limited gauging stations in some of the catchments and existing gauging stations might not be in close proximity of the EWR sites. Possible unreliable/poor quality of flow data due to lack of maintenance of gauges. Dam balances available at some of the larger dams, but data unreliable due to environmental factors namely rainfall/evaporation calculations.	Monitoring of long-term flow data falls outside the scope of this study. Will use where available and indicate confidence in results.
Water quality		
Current water quality data	Limited and poor data available for present state in some catchments.	Specialists/DWS coverage has quantity and quality data, with additional quality data from the

Criteria	Key gap	Interventions
		DWS Regional Office in East London. Rhodes University may have available water quality data. IRIS database – links to WWTW and how functional they are.
Wetlands		
Wetland identification	Gaps in the national wetland coverage for the study area	Combine all existing and relevant wetland shapefiles into a consolidated and updated wetland shapefile. Once refinement of the wetland layer and typing has been completed, and the PES re-assessed, a multi-criterion prioritization will be undertaken, including a stakeholder workshop to assist in identifying overlooked priority wetlands. Focus areas to be identified to ensure the cross-linkage between wetlands, groundwater and rivers.
Groundwater		
Groundwater information	Local databases (WARMS, etc.) and reports	Propose a technical task group meeting with DWS and key Project Steering Committee/ Water User Association members Collect new data in focus areas i.e. priority quaternary catchments where linkages occur between groundwater, wetlands and rivers.
Estuaries		

Criteria	Key gap	Interventions
Estuarine information	Detail data available for some estuaries. Some data outdated and recent assessments on desktop level.	Collect additional data for priority estuaries for assessment, determination of requirements and setting of RQOs.
Socio-economics		
Socio-economics and basic human needs	The census data may be outdated.	Water Services Knowledge System – access to basic services. Assess the livelihoods and what proportion of the population are dependent on NWA schedule 1 access to water.
Integration		
Integration between components	No existing information or processed data available for the integration of the various components. Some partial integration between components has been undertaken as part of previous studies.	A specific area will be selected where the integration of rivers, wetlands, groundwater and estuarine components will be undertaken. The SWSA will be taken into account for the selection of this area.

6. SUMMARY OF KEY RISKS AND MITIGATION MEASURES

The accessibility constraints to parts of the study area can prevent the site selection process. Permits to survey certain rivers might also be problematic.

The mitigion measure for this key risk is to ensure liaison with stakeholders (especially farmers through irrigation boards and/ or Water User Associations) and CapeNature and/or SANPark officials. This will be key to ensure contact details are available to arrange site access and permits before the surveys. The PSP will contact DWS for assistance and support in this regard.

7. INTEGRATION BETWEEN WATER RESOURCE COMPONENTS

The integration between the various water resources components will be considered and evaluated with the use of available data. Knowledge of these interactions will be essential in addressing some of the gaps identified in Chapter 5. Further integrations for this study will include:

- Using priority systems/ RUs for the integration between wetlands and groundwater, rivers and wetlands and rivers and estuaries or any of the components relevant for a specific selected area or RU. The selection of these systems will be guided by the SWSAs, specific impacts and the availability of detailed data to ensure meaningful integration;
- Current assessments will provide an opportunity to integrate geomorphology data and sediment with riparian vegetation and macroinvertebrate information; and
- Integrate data between diatoms results and water quality.

8. CONCLUSIONS

This report (Gap Analysis Report) forms part of Task 2 of the overall approach (see Figure 4-1) adopted for this study, with the purpose to identify the gaps relevant to the determination of the Water Resource Classes, the Reserve and the associated RQOs for the significant water resources in the Keiskamma, Fish to Tsitsikamma catchments. Furthermore, the gap analysis phase forms part of Step 1 as per the Integrated Framework of the Development of Procedures to Operationalise Resource Directed Measures (DWS, 2017).

Several studies have been undertaken for the water resources of the study area. However, a number of these studies (reconciliation strategies, water availability assessments) were focussed around the metropolitan areas of Algoa and Amathole. Information is available for the smaller towns in the catchment through the All Towns studies that were undertaken.

Some Reserves studies have been undertaken for the rivers and estuaries in the study area, although a large number of systems have limited ecological data available, and no requirements were specified. Most of these studies have also been undertaken more than 10 years ago, resulting in the information being outdated and possible changes to the methodologies used to determine the EWRs.

Information from these studies will be useful and will be used as a basis, to collect additional data during the surveys to ensure high confidence results in this study, especially for the priority RUs.

Based on the review and analysis of the available datasets, GIS layers, information from previous studies, the project team has a better understanding of the availability, accessibility and usefulness of the information and data sources. However, various gaps do exist, of which some of these will be addressed during the study, through the collection of additional data during the seasonal field surveys.

The available information from these various data sources and reports are applicable, and with additional surveys that are scheduled, will provide adequate information for the determination of the Water Resource Classes, the Reserve and setting of RQOs.

The major gaps that will not be addressed during this study, as long-term monitoring is required are:

- Lack of adequate gauging weirs in the study area and the consequent lack of long-term flow data, especially daily data that is invaluable for the setting of EWRs; and
- Recent water quality data to determine the present state is not available for some areas. However, data available from various other sources and studies, including from the DWS

Regional Office in East London, coupled with the planned surveys forming part of this study, will assist with mitigating this gap.

Accessibility to some of the water resource/ areas and to obtain permits for sampling may further be problematic, as experienced during previous studies in these catchments. To mitigate this and to ensure specific attention to contacting stakeholders/ farmers/ landowners before the surveys, to ensure accessibility to their properties and to liaise with the conservation groups to obtain the necessary permits for sampling.

Thus, the best available, sensible data and information sources will be used to meet the objectives of this study, with guidance from the DWS where specific project direction is required.

9. REFERENCES

Abt, S.R., Clary, W.P. and Thornton, C.I. 1994. Sediment deposition and entrapment in vegetated streambeds. J. Irrig. Drain. Engin. 120:1098–113.

Adeniji, A.O., Okoh, O.O., Okoh, A.I., 2019. Levels of Polycyclic Aromatic Hydrocarbons in the Water and Sediment of Buffalo River Estuary, South Africa and Their Health Risk Assessment. Arch Environ Contam Toxicol 76, 657–669. https://doi.org/10.1007/s00244-019-00617-w

Adeniji, A.O., Okoh, O.O., Okoh, A.I., 2017. Petroleum Hydrocarbon Fingerprints of Water and Sediment Samples of Buffalo River Estuary in the Eastern Cape Province, South Africa. Journal of Analytical Methods in Chemistry 2017, e2629365. https://doi.org/10.1155/2017/2629365

Awofolu, O.R., Mbolekwa, Z., Mtshemla, V., Fatoki, O.S., 2005. Levels of trace metals in water and sediment from Tyume River and its effects on an irrigated farmland. Water SA 31, 87–94. https://doi.org/10.4314/wsa.v31i1.5124

Beeson, C.E. and Doyle, P.F. 1995. Comparison of bank erosion and vegetated and nonvegetated channel bends. Water Res. Bull. 31:983–90.

Binning, K., Baird, D., 2001. Survey of heavy metals in the sediments of the Swartkops River Estuary, Port Elizabeth South Africa. Water SA 27, 461–466. https://doi.org/10.4314/wsa.v27i4.4958

Brosofske, K.D., Chen, J., Naiman, R.J. and Franklin, J.F. 1997. Effects of harvesting on microclimate from small streams to uplands in western Washington. Ecol. Appl.

Dallas, H.F. 2007. River Health Programme: South African Scoring System (SASS) Data Interpretation Guidelines, Group, (September), pp. 85. Provide full reference for report

de Haan V, 2015. The Effects of Erosion-control Structures and Gully Erosion on Groundwater Dynamics along the Kromrivier, Eastern Cape, South Africa. MSc thesis. Stockholm University, Stockholm, Sweden.

DeFerrari, C.M. and Naiman, R.J. 1994. A multiscale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington. J. Veg. Sci. 5:247–58.

Department of Water Affairs and Forestry. 2002. Fish to Tsitsikamma Water Management Area: Water Resources Situation Assessment – Main Report – Volume 2 of 2: Appendices. Report No. P15000/00.0101

Department of Water and Sanitation, South Africa, February 2017. Development of Procedures to Operationalise Resource Directed Measures. Main Report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report no RDM/WE/00/CON/ORDM/0117.

Department of Water and Sanitation, South Africa. October 2021. Determination of Water Resource Classes, Reserve and RQOs in the Keiskamma and Fish to Tsitsikamma catchment: Inception Report. Report No: WEM/WMA7/00/CON/RDM/0121

Dosskey, Michael, G., Vidon, P., Gurwick, N.P., Allan, C.J., Duval, T.P. and Lowrance, R. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. Journal of the American Water Resources Association (JAWRA) 46(2):261-277. DOI: 10.1111/j.1752-1688.2010.00419.

Dickens, C.W.S. and Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 rapid bioassessment method for rivers, African Journal of Aquatic Science, 27, pp. 1–10.

DWS. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

DWS. 2015. Network Inventory Volume 1: Main Report. Report prepared by AECOM SA (Pty) Ltd for the Department of Water and Sanitation (DWS), Chief Directorate: Water Information Management (WIM), April 2015, Pretoria, South Africa. WP10871.

Eco-Pulse Consulting, 2018a. Proposed Wild Coast SEZ, Eastern Cape. Wetland Habitat Impact Assessment Report. Unpublished report prepared by Eco-Pulse Environmental Consulting Services for WSP. Report No. EP341-02. Version 0.1 (DRAFT). 10th July 2018.

Eco-Pulse Consulting. 2018b. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase 1: Regional Prioritization Report. Unpublished report prepared for ICLEI - Local Governments for Sustainability – Africa.

Eco-Pulse Consulting. 2018c. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase2: Desktop wetland mapping and condition assessment for wetlands in the Mnquma Local Municipality. Unpublished report prepared for ICLEI - Local Governments for Sustainability – Africa.

Eco-Pulse Consulting. 2018d. Focussed Wetland Prioritization and rehabilitation Planning in Amathole District Municipality as part of the Local Action for Biodiversity: Wetlands South Africa ((LAB: Wetlands SA) Project: Phase 3: Prioritisation and Selection of Sites for Wetland Rehabilitation. Unpublished report prepared for ICLEI - Local Governments for Sustainability – Africa.

Ellery WN, 2020. The current status of the Ngciyo Wetland and the Ghio Wetland Nature Reserve. Unpublished report. Geography Department, Lucas Avenue, Rhodes University, Makhanda

Ellery S, 2018. The origin of bedrock depression wetlands in the southern Cape of South Africa: a changing perspective. MSc thesis, Rhodes University, Makhanda

Eichhoff J, in prep. Characterizing wetland features and occurrence near Hogsback, Eastern Cape: application of the genetic geomorphic classification system. Honours thesis, University of Stellenbosch, Stellenbosch.

Fatoki, O.S., Awofolu, R., 2003. Levels of Cd, Hg and Zn in some surface waters from the Eastern Cape Province, South Africa. Water SA 29, 375–380. https://doi.org/10.4314/wsa.v29i4.5042

Fatoki, O.S., Lujiza, N., Ogunfowokan, A.O., 2002. Trace metal pollution in Umtata River. Water SA 28, 183–190. https://doi.org/10.10520/EJC116012

Freeman A, 2020. Investigating wetland structure and origin in the context of landscape geomorphic history: A case study of the wetlands of Makhanda. Honours thesis, Rhodes University, Makhanda

Glenday J A, 2015. Modelling the Hydrologic Impacts of Vegetation and Channel Network Change for a Semi-arid, Mountainous, Meso-scale Catchment: the Baviaanskloof, South Africa. PhD thesis, University of California, Santa Barbara, USA.

Glenday J, Jumbi F, Tanner j, Smith C and Smith-Adao L. In prep. Connectivity and climate: monitoring surface and groundwater flows to valley-bottom wetlands in the Baviaanskloof and Kromme catchments, the eastern end of the Table Mountain Group.

Gluckman L, 2014. Gully erosion and deposition in the Featherstone Kloof wetland, a headwater wetland in the Eastern Cape, South Africa. Honours thesis. Rhodes University, Makhanda.

Griffiths, G.A. 1980. Stochastic estimation of bed load yield in pool-and-riffle mountain streams. Water Res. Bull. 16: 931–37.

Haigh EH, Illgner PW, Wilmot J, Buckle J, Kotze D, and Ellery W, 2009. The Wetland Rehabilitation Project in the Kromme River Wetlands, Eastern Cape. In: Kotze D and Ellery W (Eds.) WET-OutcomeEvaluate: An evaluation of the rehabilitation outcomes at six wetland sites in South Africa. WRC Report No TT 343/08. Water Research Commission, Pretoria.

Hansen, A.J. and di Castri, F. eds. 1992. Landscape Boundaries. New York: SpringerVerlag.

Holland, M.M., Risser ,P.G. and Naiman, R.J. eds. 1991. Ecotones. New York: Chapman & Hall.

Hubbard, R.K., Sheridan, J.M. and Marti, L.R. 1990. Dissolved and suspended solids transport from Coastal Plain watersheds. J. Environ. Qual. 19:413–20.

Huchzermeyer, N., 2017. A baseline survey of channel geomorphology with particular reference to the effects of sediment characteristics on ecosystem health in the Tsitsa River, Eastern Cape, South Africa. (Masters Thesis). Rhodes University, Grahamstown, Eastern Cape, South Africa.

Hugo CD, 2011. The influence of fire and plantation management on wetlands on the Tsitsikamma plateau. MSc thesis, Nelson Mandela Metropolitan University, Gqeberha.

Hupp, C.R., Osterkamp, W.R. and Howard, A.D. eds. 1995. Biogeomorphology, Terrestrial and Freshwater Systems. Amsterdam: Elsevier Sci.

Hupp, C.R. and Simon, A. 1986. Vegetation and bank-slope development. Proc. 4th Fed. Interagency Sedimentation Conf., March 24–27, 1986, Las Vegas, Nevada. Vol. II:583–592.

Illgner, PM, Haigh E H and Holland H, 2003. Identification, mapping and assessment of the present state of the wetlands in the Baviaanskloof River catchment. Institute for Water research (IWR), Rhodes University, Makhanda.

Lowrance, R., Sharpe, J.K. and Sheridan, J.M. 1986. Long-term sediment deposition in the riparian zone of a coastal plain watershed. J. Soil Water Conserv. 41:266– 71.

Job N, Roux DJ, Bezuidenhout H and Cole NS, 2020. A Multi-Scale, Participatory Approach to Developing a Protected Area Wetland Inventory in South Africa. Front. Environ. Sci. 8:49. doi: 10.3389/fenvs.2020.00049

Kleynhans, C.J. 1999. The development of a fish index to assess the biological integrity of South African rivers. Water SA 25(3):265-278.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08

Kotze D C, and Rivers-Moore N, 2021. A project to predict wetland occurrence and type in the Western Cape for improved mapping and management. Unpublished report submitted to South African Biodiversity Institute, Cape Town.

Lagesse J, 2017. Discontinous Gully Erosion as a Mechanism for Wetland Formation: a case study of the Kompanjiesdrif Basin, Kromrivier, Eastern Cape, South Africa. MSc Thesis. Rhodes University, Grahamstown.

Larson M R, 2019. Integrated health assessment and ecosystem service provision of two urban wetlands in Port Elizabeth, Eastern Cape (South Africa). MSc thesis. Nelson Mandela University, Gqeberha.

Le Roux, J.J., Morgenthal, T.L., Malherbe, J. and Pretorius, D.J. 2008. Water erosion prediction at a national scale for South Africa. Water SA. 34 (3): 305-314.

Lehner, B., Reidy Liermann, C., Revenga, C., Vorosmarty, C., Fekete, B., Crouzet, P., Doll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rodel, R., Sindorf, N., Wisser, D., 2011. Global Reservoir and Dam Database, Version 1 (GRanDv1): Dams, Revision 01.

Macfarlane DM, van Deventer R, Kotze D and Teixeira-Leite A, 2014. SANRAL N2 Wild Coast Toll Highway: Specialist Aquatic Assessment Report. Unpublished report prepared by Eco-Pulse Consulting for CCA Environmental.

McGregor, G., 1999. The geomorphological impacts of impoundments, with particular reference to tributary bar development on the Keiskamma River, Eastern Cape (MSc thesis). Rhodes University, Grahamstown, South Africa.

Malanson, G.P. 1993. Riparian Landscapes. Cambridge University Press.

McNamara S, 2018. The influence of landscape dis-connectivity on the structure and function of the Krom River, Eastern Cape, South Africa. MSc thesis, Rhodes University, Makhanda.

Melly BL, 2016 Factors influencing wetland distribution and structure, including ecosystem function of ephemeral wetlands, in Nelson Mandela Bay Municipality (NMBM), South Africa. PhD thesis, Nelson Mandela Metropolitan University, Gqeberha.

Melly BL, Schael DM, and Gama PT, 2017. Perched wetlands: An explanation to wetland formation in semi-arid areas. Journal of Arid Environments 141: 34-39.

Melly B L, Schael D M, Rivers-Moore N A, and Gama P T, 2016. Mapping ephemeral wetlands: manual digitisation and logistic regression modelling in Nelson Mandela Bay Municipality, South Africa. J. Environ. Manage. 25, 313–330. doi: 10.1007/s11273-016-9518-7.

Mtshali H, 2011. Wetland vegetation of coastal Pondoland. Honours thesis, University of the Free State, Qwaqwa Campus, Phuthaditjhaba.

Mucina, L. and Rutherford, M. 2006. The Vegetation of South Africa, Lesotho and Swaziland. Pretoria: Reprint 2011, Strelitzia 19, South African National Biodiversity Institute (SANBI).

Myers, T.J. and Swanson, S. 1992. Variation in stream stability with stream type and livestock bank damage in northern Nevada. Water Res. Bull. 28:743–54.

Naiman, R.J., D´ecamps, H. and Pollock, M. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl. 3:209–12.

Naiman, R.J and Décamps, H. (1997). The Ecology of Interfaces: Riparian Zones Annual Review of Ecology and Systematics. Vol. 28:621-658 (Volume publication date November 1997) https://doi.org/10.1146/annurev.ecolsys.28.1.621

Naiman, R.J., Fetherston, K.L., McKay, S. and Chen, J. 1997. Riparian forests. In River Ecology and Management: Lessons from the Pacific Coastal Region, ed. RJ Naiman, RE Bilby. New York: SpringerVerlag.

Nakamura, F. and Swanson, F.J. 1993. Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon. Earth Surf. Proc. Landforms 18:43–61.

Newman, B.K., Watling, R.J., 2007. Definition of baseline metal concentrations for assessing metal enrichment of sediment from the south-eastern Cape coastline of South Africa. Water SA 33. https://doi.org/10.4314/wsa.v33i5

Nsor AC, 2007. Plant Community Distribution and Diversity, and Threats to Vegetation of the Kromme River Peat Basins, Eastern Cape Province, South Africa. MSc thesis. Rhodes University, Makhanda.

Omar M Y, Le Roux PAL, van Tol JJ, 2014. Interactions between stream channel incision, soil water levels and soil morphology in a wetland in the Hogsback area, South Africa, South African Journal of Plant and Soil, DOI: 10.1080/02571862.2014.944593

Powell R, 2015. Recent degradation along the upper-middle reaches of the Baviaanskloof River floodplain: An examination of drivers of change and best rehabilitation practices. PhD thesis. Rhodes University, Makhanda.

Powell, R., 2016. Geomorphological connectivity and sensitivity examined in a recently degraded gravel-bed stream: implications for river-floodplain rehabilitation (PhD thesis). Rhodes University, Grahamstown, South Africa.

Pulley S, Lagesse J and Ellery W, 2016. The mineral magnetic signatures of fire in the Kromrivier wetland, South Africa. J Soils Sediments DOI 10.1007/s11368-016-1577-0

Pulley S, Ellery W N, Lagesse J V, Schlegel P K, McNamara S J, 2018. Gully erosion as a mechanism for wetland formation: An examination of two contrasting landscapes. Land Degrad Dev. 29:1756–1767.

Pollock, M.M., Naiman R.J. and Hanley T.A. 1997. An empirically based model for predicting plant diversity in forested and emergent wetlands. Ecology.

Rebelo A J, 2012. An ecological and hydrological evaluation of the effects of restoration on ecosystem services in the Kromme River system, South Africa. MSc thesis. University of Stellenbosch.

Rebelo A J, 2017. Ecosystem Services of Palmiet Wetlands: The Role of Ecosystem Composition and Function. PhD thesis. Department of Biology, University of Antwerp, Antwerp, and Conservation Ecology, Stellenbosch University, Stellenbosch.

Rebelo A J, Emsens W-J, Meire P, Esler K J, 2018. Quantification of water purification in South African palmiet wetlands. Water Science and Technology 78: 1199-1207

Rebelo AJ, Le Maitre DC, Esler KJ, and Cowling RM, 2015. Hydrological responses of a valley-bottom wetland to land-use/land-cover change in a South African catchment: Making a case for wetland restoration. Restoration Ecology, 23: 829–841.

Risser, P.G. 1995. The Status of the Science Examining Ecotones. BioScience Vol. 45, No. 5, pp. 318-325. Published By: Oxford University Press. https://doi.org/10.2307/1312492.

Rowntree, K.M. 2013. Module B: Geomorphology Driver Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 551/13.

Schael D M, Gama P T, and Melly B L, 2015. Ephemeral Wetlands of the Nelson Mandela Bay Metropolitan Area: Classification, Biodiversity and Management Implications. WRC Report No. 2181/1/15. Water Research Commission, Pretoria.

Schlegel, 2017. Spatial variation in modelled hydrodynamic characteristics associated with valley confinement in the Krom River wetland: implications for the initiation of erosion gullies. MSc thesis, Rhodes University, Makhanda

Scherman, P.A., Muller, W.J., Godon, A., Reynhardt, D, du Preez, L. and Chalmers, R. 2004. Eastern Cape River Health Programme. Technical Report: Buffalo River Monitoring (2002- 2003).

Scherman, P.A., Reynhardt, D., Cawe, S., Gordon, A., Weeks, D., Kinya, J., du Preez, L., Ntozakhe, T. and Myeko, N. 2006. Eastern Cape River Health Programme. Technical Report: Mthatha River Monitoring (2004- 2006).

Silbernagl R, 2014. Origin and Dynamics of the Featherstone Kloof Wetland (Eastern Cape, South Africa). Honours thesis. Rhodes University, Makhanda.

Sinchembe M and Ellery WN, 2010. Human impacts on hydrological health and the provision of ecosystem services: a case study of the eMthonjeni–Fairview Spring Wetland, Grahamstown, South Africa. African Journal of Aquatic Science 35: 227–239

Smith C, 2019. Determining the hydrological functioning of the palmiet wetlands in the Eastern and Western Cape of South Africa. MSc thesis, Rhodes University, Makhanda.

Smith-Adao LB, 2016. Links between valley confinement, landforms and vegetation distribution in a semi-arid valley floor environment, Baviaanskloof, South Africa. PhD Thesis, Rhodes University.

South African National Biodiversity Assessment. Technical Report. Volume 2a: South African Inventory of Inland Aquatic Ecosystems (SAIIAE). Version 3, final released on 3 October 2019. Council for Scientific and Industrial Research (CSIR) and South African National Biodiversity Institute (SANBI): Pretoria, South Africa. Report Number: CSIR report number CSIR/NRE/ECOS/IR/2018/0001/A; SANBI report number http://hdl.handle.net/20.500.12143/5847.

South African National Biodiversity Institute (SANBI). 2019. National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria. pp. 1–214.State of Rivers Report, 2017 – 2018. River Ecostatus Monitoring Programme State of Rivers Report 2017-2018. Report Number: N/0000/00/REMP/2019

Tanner JL, Smith C, Ellery W and Schlegel P, 2019. Palmiet wetland sustainability: a hydrological and geomorphological perspective on system functioning. WRC Report No. 2548/1/18. Water Research Commission, Pretoria.

Turpie et al., 2004. Contributions to information requirements for the implementation of resource directed measures for estuaries: Vol 1; Improving the biodiversity importance rating of South African estuaries.

Triska, F.J., Duff, J.H. and Avanzino, R.J. 1993a. The role of water exchange between a stream channel and its hyporheic zone in nitrogen cycling at the terrestrial aquatic interface. Hydrobiologia 251:167–84.

Triska, F.J., Duff, J.H. and Avanzino, R.J. 1993b. Patterns of hydrological exchange and nutrient transformation in the hyporheic zone of a gravel bottom stream: examining terrestrial-aquatic linkages. Freshwater Biol. 29:259–74.

Turpie JK, Clark B. 2007. Development of a conservation plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health and economic costs and benefits. Final Report. Anchor Environmental Consultants.

Tuswa A, 2016. Assessing heavy metal content in urban wetland macrophytes and sediments in NMBM. Honours thesis. Nelson Mandela Metropolitan University, Gqeberha.

Van der Waal, B., 2015. Sediment Connectivity in the Upper Thina Catchment, Eastern Cape, South Africa (PhD thesis). Rhodes University, Grahamstown, Eastern Cape, South Africa.

Van Niekerk, L. et al. (2015) 'Desktop Provisional Ecoclassification of the Temperate Estuaries of South Africa'. Report to the Water Research Commission by Council for Scientific and Industrial Research, p. 156.

Van Niekerk L, Adams JB, Lamberth SJ, MacKay CF, Taljaard S, Turpie JK, Weerts SP, Raimondo DC. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A. Pretoria: South African National Biodiversity Institute.

Van Niekerk L, Adams JB, James NC, Lamberth SJ, MacKay CF, Turpie JK, Rajkaran A, Weerts SP & Whitfield, AK. 2020: An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management, African Journal of Aquatic Science, 45:1-2, 199-216, DOI: 10.2989/16085914.2019.1685934

Wadeson, R.A., 1995. The development of the Hydraulic Biotope Concept within a Catchment Based Hierarchical Geomorphological Model (PhD thesis). Rhodes University, Grahamstown, South Africa.

Watling, R.J., Talbot, M.-F., Branch, E., Marsland, S., 1985. Metal surveys in South African esuaries IX. Buffalo River. Water S.A. 11, 61–64.

Watling, R.J., Watling, H., 1983. Metal surveys in South African estuaries VII Bushmans, Kariega, Kowie and Great Fish Rivers. Water S.A. 9, 66–70.

Watling, R.J., Watling, H., 1982. Metal surveys in South African Estuaries VI Sundays River. Water S.A. 8, 192–195.

Wallace C, 2014. An Examination of the Causes and Geomorphic Consequences of Erosion in Wetlands: A Case Study of the Fairview Spring Wetland, Grahamstown, South Africa. Honours thesis. Rhodes University, Makhanda.

Walters D, 2016. An evaluation of the ecological outcomes at the Wetland Management Area 01, Hogsback, Eastern Cape. Unpublished report submitted to Working for Wetlands, Pretoria.

Wilson MI, 2010. Geomorphic evolution and sedimentology of a blocked-valley wetland: the Ngciyo Wetland, Eastern Cape, South Africa. Honours thesis, Rhodes University, Makhanda

Weigelhofer, G. and Waringer, J.A. 1994. Allochthonous input of coarse particulate organic matter (CPOM) in a first to fourth order Austrian forest stream. Int. Rev. Ges. Hydrobiol. 79:461–71.

Whitfield and Bate, 2007. A Review of Information on Temporarily Open/Closed Estuaries in the Warm and Cool Temperate Biogeographic Regions of South Africa, with Particular Emphasis on the Influence of River Flow on These Systems

WRC. 2012. Water Resources of South Africa, 2012 Study (WR2012). WRC Project No. K5/2143/1

10. APPENDICES

Appendix A: Figures for the study area

Appendix A: Study area

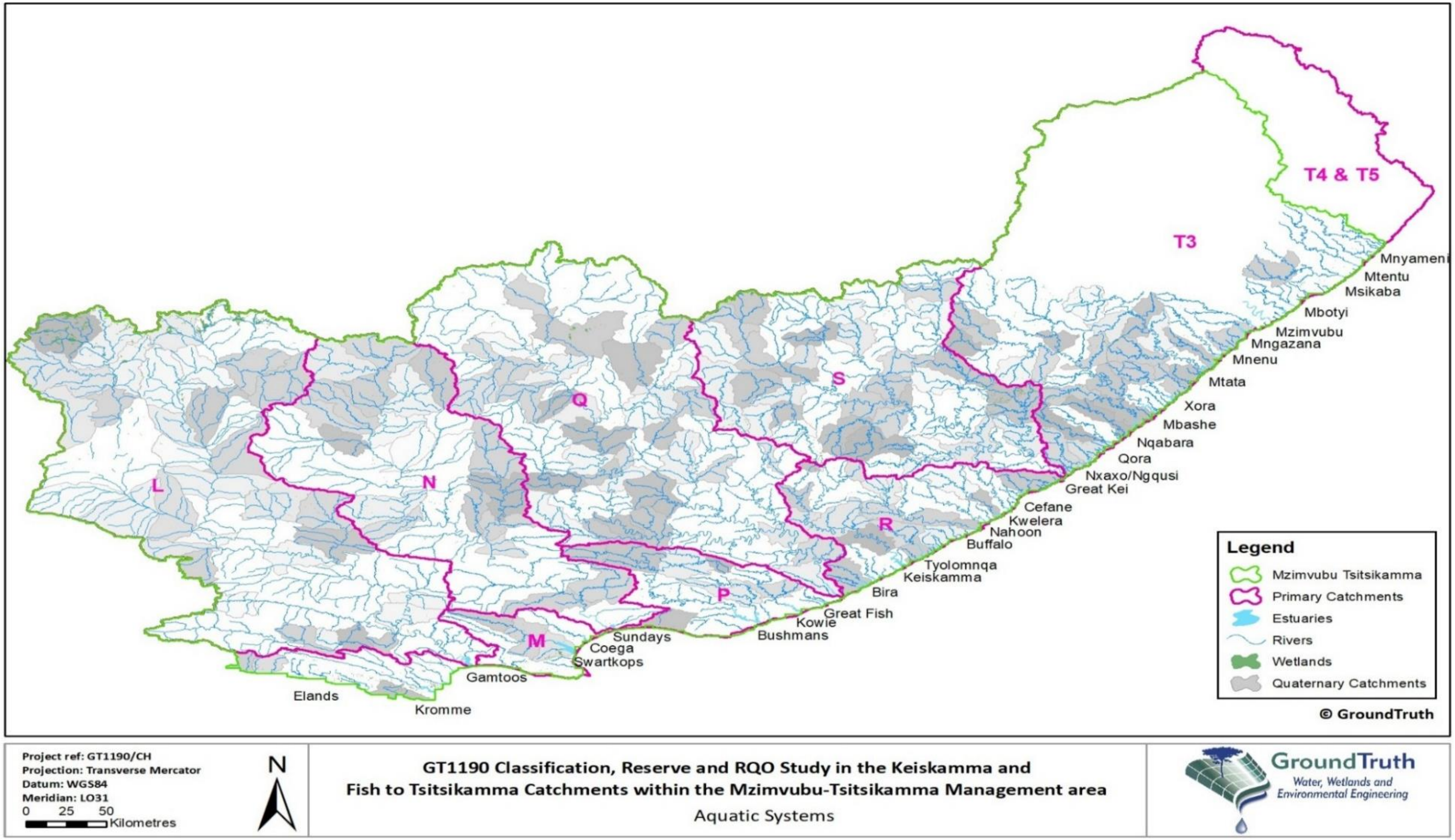

Figure 10-1: Study area of the Keiskamma, Fish to Tsitsikamma

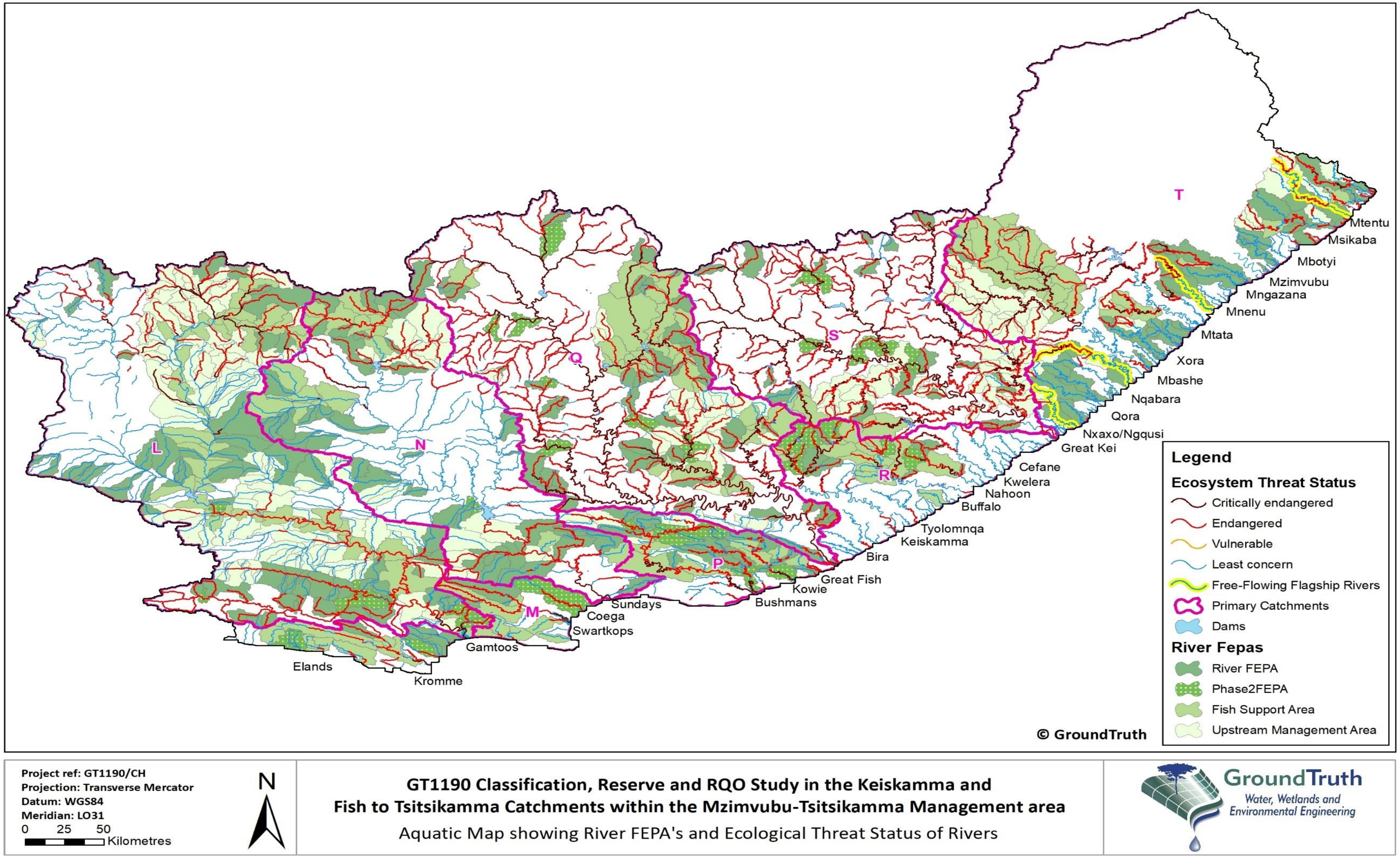

Figure 10-2: Ecosystem threat status (aquatics)

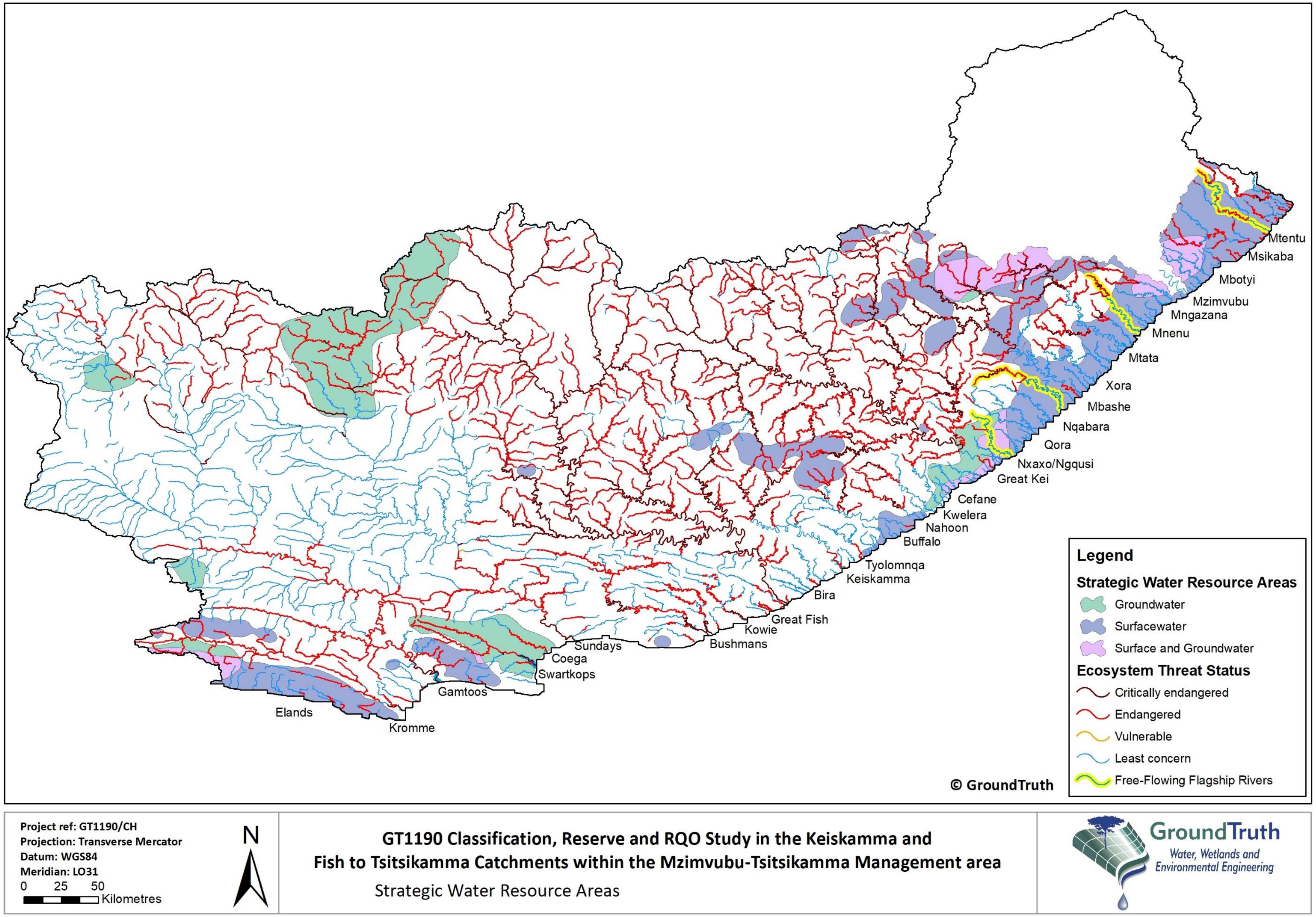

Figure 10-3: Strategic Water Source Areas within the study area

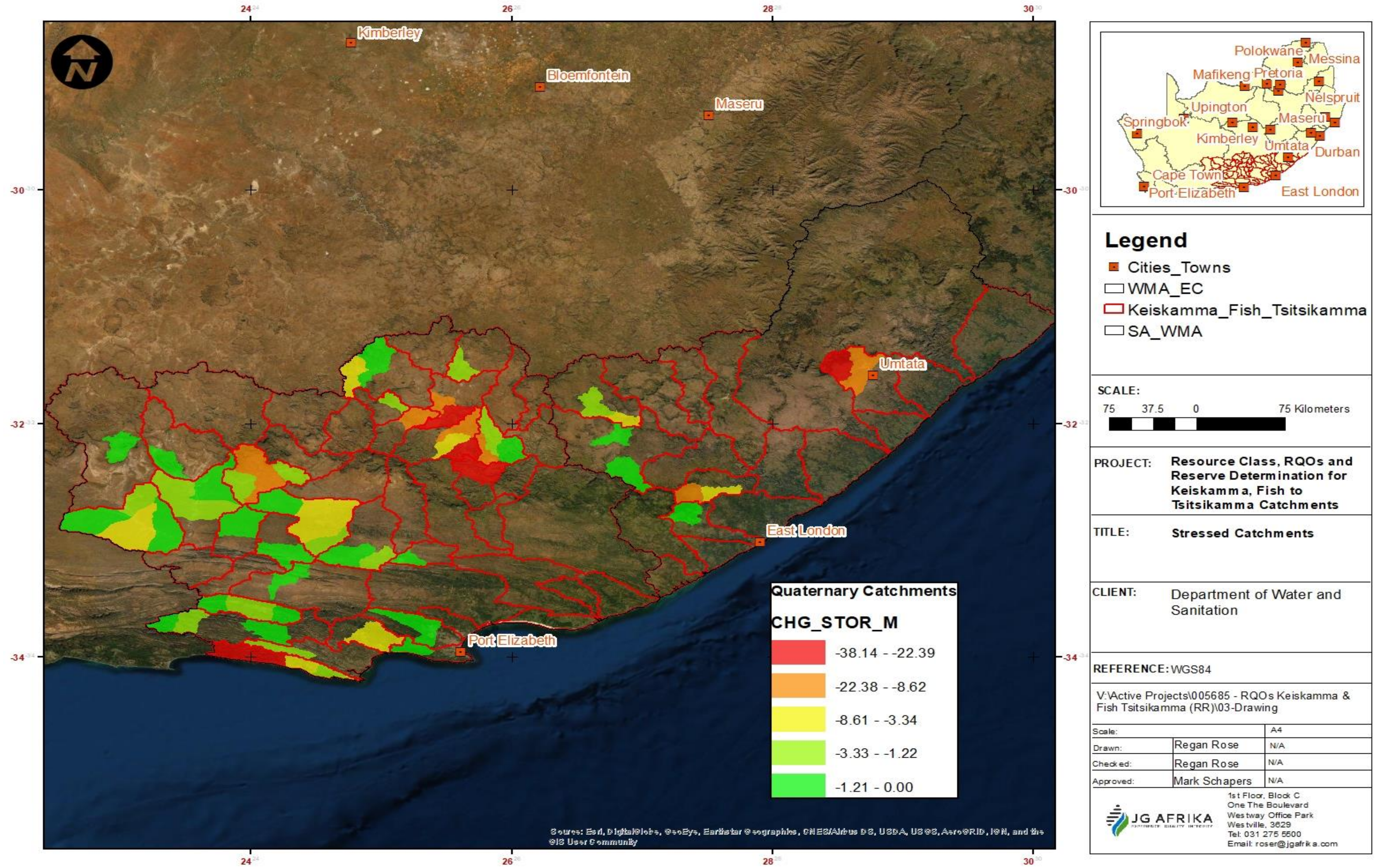

Figure 10-4: Groundwater stressed catchments (legend indicates “change in storage”: a negative change in storage value reflectsa negative change in storage or deficit in the catchment, thus stressed