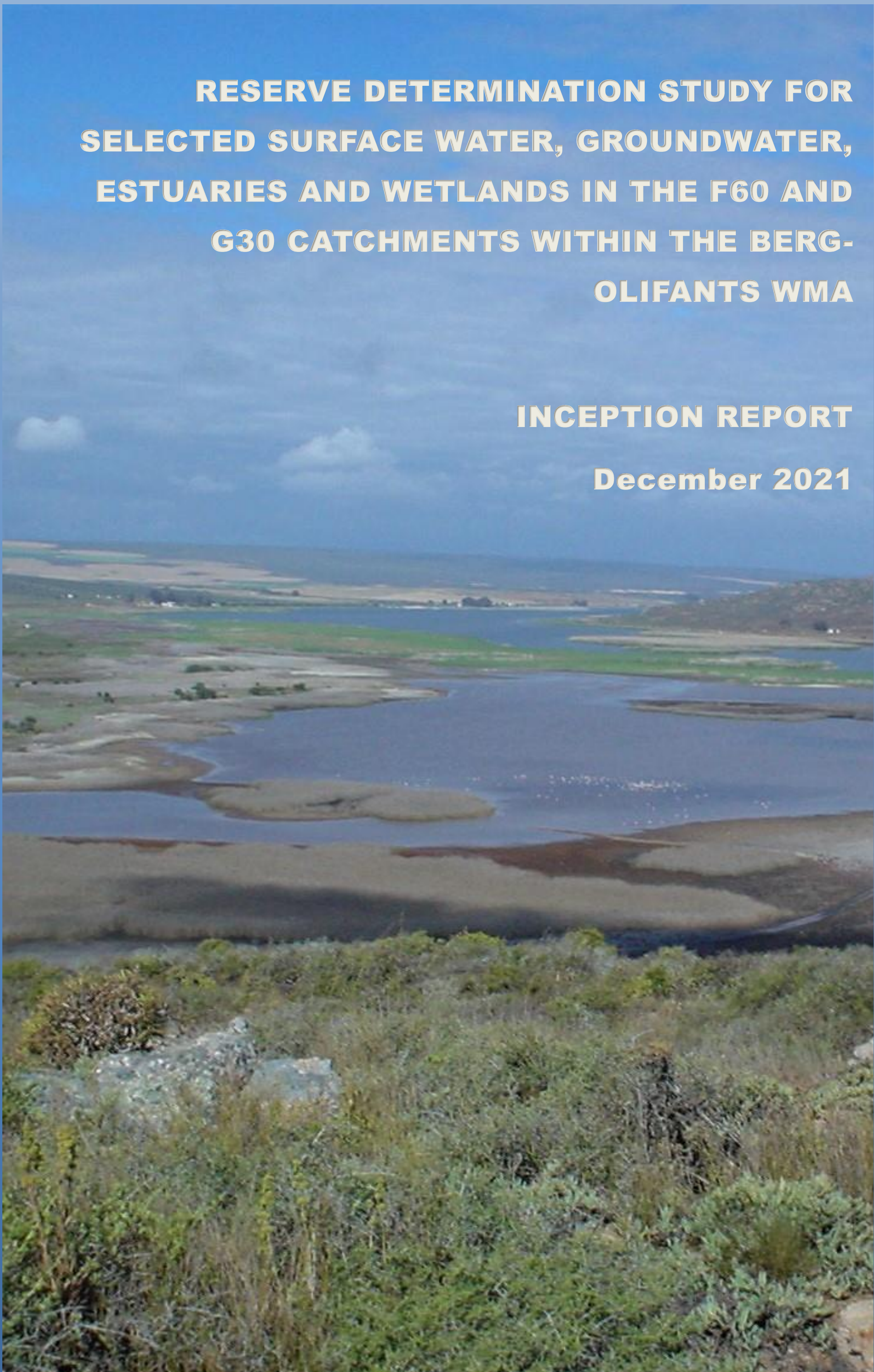


# RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA

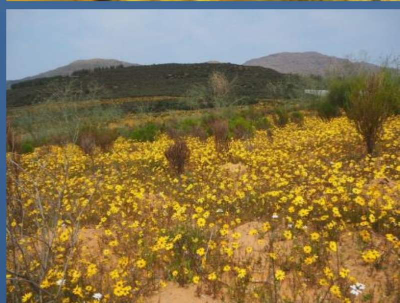
## INCEPTION REPORT

December 2021









Department of Water and Sanitation

Chief Directorate: Water Ecosystem Management

**DEPARTMENT: WATER AND SANITATION**

**CHIEF DIRECTORATE: WATER ECOSYSTEM MANAGEMENT**

**RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA**

**WP11340**

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**REPORT NUMBER: RDM/WMA09/00/CON/0121**

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APPROVED BY DEPARTMENT OF WATER AND SANITATION: DIRECTORATE RESERVE DETERMINATION

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DATE:

## DOCUMENT INDEX

***Reports as part of this project:***

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| BAS | Best Attainable State |
| BHN | Basic Human Needs |
| CSIR | Council for Scientific and Industrial Research |
| CMA | Catchment Management Agency |
| CWAC | Coordinated Waterbird Counts |
| DEA | Department of Environment Affairs |
| DEADP | Department of Environmental Affairs and Development Planning (Western Cape Government) |
| DFFE | Department of Forestry, Fisheries and the Environment |
| DRIFT | Downstream Response to Imposed Flow Transformation |
| D:RDM | Directorate: Resource Directed Measures |
| DWA | Department of Water Affairs |
| DWAF | Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation |
| EC | Electrical Conductivity |
| EcoSpecs | Ecological Specifications |
| EcoStatus | Ecological Status |
| EGSA | Ecosystem Goods, Services and Attributes |
| EIS | Ecological Importance and Sensitivity |
| EMP | Estuary Management Plan |
| EWR | Ecological Water Requirements |
| FRAI | Fish Response Assessment Index |
| GAI | Geomorphological Driver Assessment Index |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GRDM | Groundwater Resource Directed Measures |
| GRU | Groundwater Resource Unit |
| HDAI | Hydrological Driver Assessment Index |

| | |
|---|---|
| HGM | Hydrogeomorphic |
| HRU | Hydrological Resource Unit |
| ICMA | Integrated Coastal Management Act |
| IFR | Instream Flow Requirement |
| IHI | Index of Habitat Integrity |
| IUCN | International Union for Conservation of Nature |
| l/s | Litre per second |
| MAP | Mean Annual Precipitation |
| MAR | Mean Annual Runoff |
| MCM | Million Cubic Metres |
| MIRAI | Macro Invertebrate Response Assessment Index |
| mm/a | millimetre per annum (precipitation) |
| mS/m | milliSiemens per meter (measurement of the electrical conductivity of water) |
| MRU | Management Resource Unit |
| MSL | Mean Sea Level |
| NEMA | National Environmental Management Act |
| NFEPA | National Freshwater Ecosystem Priority Area |
| NMU | Nelson Mandela University |
| NWA | National Water Act |
| PAI | Physico-Chemical Assessment Index |
| PES | Present Ecological State |
| ppt | parts per thousand (measurement of salinity) |
| PMC | Project Management Committee |
| PSC | Project Steering Committee |
| RDM | Resource Directed Measures |
| REC | Recommended Ecological Category |
| REI | River Estuary Interface |
| REMP | River EcoStatus Monitoring Programme |

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|---|---|
| RHAM | Rapid Habitat Assessment Method |
| RQO | Resource Quality Objective |
| RU | Resource Units |
| RWQO | Resource Water Quality Objective |
| SANBI | South African National Biodiversity Institute |
| SPATSIM | Spatial and Time Series Modelling |
| TEC | Target Ecological Category |
| TMG | Table Mountain Group |
| TT | Task Team |
| VEGRAI | Vegetation Response Assessment Index |
| VEMF | Verlorenvlei Estuary Management Forum |
| V & V | Validation and Verification |
| VIGTT | Verlorenvlei Inter-Governmental task team |
| WARMS | Water Use Authorisation and Registration Management System |
| WRC | Water Research Commission |
| WMA | Water Management Area |
| WMS | Water Management System |
| WR2012 | Water Resources 2012 |

## GLOSSARY

| | |
|---|---|
| ABIOTIC | Without life, inanimate; physical environment like temperature, rainfall |
| AESTHETIC | The overall scenic attraction of the setting, including amongst other things; natural beauty of banks and waters, or any unusual natural phenomena; the appeal of wildlife and aquatic plants; desirable natural landscape for home sites on the shores etc. |
| ANISOTROPIC | Properties that vary according to the direction from which they are observed |
| ANTHROPOGENIC | Caused by human activity |
| AQUATIC | Relating to water |
| AQUIFER | Underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) |
| ATTENUATION | To make something weaker or have less effect. |
| BASEFLOW | That part of stream flow that is contributed by groundwater and discharged gradually into the channel. |
| BENTHIC | Organisms that inhabit the shallow, bottom habitat of water. |
| BIOTA | The living organisms occupying a place together, e.g. plants, animals, bacteria, etc in the aquatic biota, or terrestrial biota. |
| BIOMONITORING | Monitoring of living organisms, usually as indicators of habitat integrity |
| CALCAREOUS | Composed of, containing, or characteristic of calcium carbonate, calcium, or limestone |
| CATCHMENT | The area from which any rainfall will drain into the watercourse or watercourses, through surface or subsurface flow. |
| CONTAMINANT | A foreign agent that is present (e.g. in water, sediment) that may produce a physical or chemical change but may not cause adverse biological effect |
| DIFFUSE SOURCE | A general source (e.g. of pollution), the exact location of which is difficult to pinpoint. |

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| DISTURBANCE REGIME | The pattern of natural variability of physical and biological processes, incorporating the return time to a stable condition from extreme conditions. |
| ECOLOGICAL HEALTH | A descriptive non-specific term for the combination of all factors, biotic and abiotic, that make up a particular environment and its organisms |
| ECOREGIONS | Areas of similar ecological characteristics. |
| ECOSYSTEM | A community of animals, plants and bacteria with its physical and chemical environment. |
| EPHEMERAL | An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year |
| ENVIRONMENT | All of the external factors, conditions, and influences that affect the growth, development, and survival of organisms or a community. This includes climate, physical, chemical, and biological factors, nutrients, and social and cultural conditions. |
| EROSION | The wearing away and removal of materials of the earth's crust by natural means. Running water, waves, moving ice, and wind currents are examples of erosion. |
| ESTUARY | A partially or fully enclosed body of water that is open to the sea permanently or periodically, and within which the sea water can be diluted, to an extent that is measurable, with fresh water drained from land. |
| EUTROPHICATION | The process whereby high levels of nutrients result in the excessive growth of plants. |
| FLOW REGIME | Recorded or historical sequence of flows used to create a hydrological profile of the water resource. |
| GEOMORPHOLOGY | The branch of geology that deals with, amongst other things, the form of the earth and the changes that take place in the process of development of landforms. |
| GRADIENT | The degree of slope or incline. In the context of this course, it refers to the slope of a stream bed, or the vertical distance that water falls while travelling a horizontal distance downstream. |
| GYPSIFEROUS | Containing or yielding gypsum |
| HABITAT | The environment or place where a plant or animal is most likely to occur naturally. |

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| HYDRAULICS | Of, involving, moved by, or operated by a fluid, especially water, under pressure. |
| HYDROLOGY | The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere. |
| HYPERSALINE | An environment that has salinities greater than that of normal seawater |
| HYPORHEOS | water flowing over streambeds in lotic environments |
| IMPACTS | The measurable effect of one thing on another. |
| IMPOUNDMENT | To retain water artificially by means of a weir or dam. |
| INDICATOR SPECIES | A species that has been extensively studied to the point that the effect of environmental changes upon its distribution and lifecycle are well known, so that knowledge of its status provides information on the overall condition of the ecosystem, and of other species in that ecosystem. |
| INDIGENOUS | Living or growing naturally in a particular area, but not naturally confined only to that area or any resource consisting of: (a) any living or dead animal, plant or other organism of an indigenous species, (b) any derivative of such animal, plant or other organism; or (c) any genetic material of such animal, plant or other organism. |
| INDIGENOUS SPECIES | A species that occurs, or has historically occurred, naturally in a free state, in nature within a ecologically similar area, but excludes a species that has been introduced from another area or continent as a result of human activity |
| INTERGRANULAR AQUIFER | An aquifer in which groundwater flows in openings and void space between grains or weathered rock |
| INVERTEBRATE | Animal without a backbone |
| KARST AQUIFERS | Aquifers that occur within limestone geology, where the limestone (or other easily dissolved rock) has been partially dissolved so that some fractures are enlarged into passages that carry the groundwater flow |
| LEGISLATION | A law or a series of laws |
| MANDATE | The authority to do something, given to an organisation or government, by the people who support it. |

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| METASEDIMENTARY | A sedimentary rock that shows evidence of having been subjected to metamorphism |
| MODIFIED | Changed, altered. |
| NUTRIENTS | Elements required for life processes: nitrogen, phosphorus and potassium are probably the most important nutrients. |
| POINT SOURCE | A definable or precise location or source e.g., of pollution |
| POLICY | A plan of action, statement of ideals, etc. proposed by an organization, government, etc. |
| PRISTINE | Remaining in a pure or natural state. |
| PREDATION | A predator is an animal that kills and eats other animals. Predation is the capturing of prey as a means of maintaining life. |
| PRESENT ECOLOGICAL STATE | The current state or condition of a resource in terms of its various components, i.e. drivers (physico-chemical, geomorphology, and hydrology) and biological response (fish, riparian vegetation and aquatic invertebrates). The prequel to recommended ecological category |
| QUATERNARY CATCHMENT | A fourth order catchment in a hierarchical system in which the primary catchment is the major unit. |
| RIPARIAN | Of, on, or relating to the banks of a water course, including the physical structure and associated vegetation. The area of land adjacent to a stream or river that is influenced by stream-induced or related processes. |
| RIVER ESTUARY INTERFACE | That part of an estuary where river and estuarine waters mix, and where the vertically integrated salinity is usually less than 10 ppt |
| SEDIMENTATION | The act or process of depositing sediment. Sediment comprises fragments of inorganic or organic material that are carried and deposited by water. |
| SPECIES | A kind of animal, plant or other organism that does not normally interbreed with individuals of another kind, and includes any sub-species, cultivar, variety, geographic race, strain, hybrid or geographically separate population |
| STAKEHOLDER | May be (a) a person, an organ of state or a community or (b) an indigenous community |

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| TAXON | Biological category (e.g. species) or its name |
| TERTIARY CATCHMENT | A third order catchment in a hierarchal classification system in which a primary catchment is the major unit. |
| SUBSTRATE | The surface to which a plant or animal is attached or on which it grows. |
| SURFACE WATER | All water that is exposed to the atmosphere, e.g., rivers, reservoirs, ponds, the sea, etc. |
| VARIABILITY | The tendency to vary i.e. to change. |
| WATERCOURSE | "A natural channel or depression in which water flows regularly or intermittently" (definition in the NWA) |
| WATER QUALITY | The value or usefulness of water, determined by the combined effects of its physical attributes and its chemical constituents, and varying from user to user |
| WETLANDS | "Land which is transitional between terrestrial and aquatic systems where the water table is usually at, or near the surface or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support vegetation typically adapted to life in saturated soil" (definition in the NWA) |

# 1. INTRODUCTION

## 1.1 Background

Under the National Water Act (Act 36 of 1998) all water resources (rivers, wetlands, estuaries and groundwater) are an indivisible natural asset under the custodianship of the National government. **The only right to priority of use is that of the 'Reserve', consisting of a 'Basic Human Needs Reserve' and an 'Ecological Reserve'**. The Basic Human Needs Reserve ensures the water that is required by domestic users for drinking, food preparation and personal hygiene. The Ecological Reserve refers to "*the **quantity** and **quality** of water required … to protect aquatic ecosystems to secure ecologically sustainable development and use of the relevant water resource*" (NWA, Ch 1, para. 1. (xviii)). The quantity and quality of water which remains after the requirements of the Reserve have been met is considered to be the 'total allocatable resource', which may be distributed amongst competing water users guided by the objectives of social equity and economic efficiency.

As water becomes increasingly scarce or over allocated and utilised, the need to properly understand the Reserve requirements becomes ever more important to ensure the sustainable functioning of aquatic infrastructure and its ecosystems in the desired condition such that it can continue to provide valued ecological goods and services for future use. Determination of the Reserve requirements for already stressed water resources, requires a higher level of confidence in the Recommended Ecological Category (REC) to be determined at each Environmental Water Requirement (EWR) site.

The water resources of the Sandveld and greater West Coast are already under stress. The area is characterised by important aquatic and terrestrial ecosystems, while it is economically significant in terms of its agricultural activities and its towns, which have a high tourism value. The West Coast area relies on groundwater resources, as surface water flows are generally limited. Thus, the likelihood of competing water use is high, resulting in a critical need for integrated water resource management to achieve the sustainable and equitable use of these resources. Determining the Reserve for the significant water resources in the area, with a high level of confidence where it is possible, is the first step towards sustainable water resource management.

The Chief Directorate: Water Ecosystems Management of the Department of Water and Sanitation (DWS) has embarked on a preliminary Reserve determination study for the **G30** and **F60** catchments (**Figure 1**). These are the two remaining Tertiary Catchments of the Olifants-Doorn Water Management Area (WMA) that still require a higher level of confidence Reserve determination.

In recent years, the following studies and projects have provided information that has contributed to the knowledge and understanding particularly of the resource protection aspects within the study area, and will support the Reserve determination study:

- Sandveld Preliminary (Rapid) Reserve determinations. Langvlei, Jakkals and Verlorenvlei Rivers. Ground and Surface water, undertaken in 2003 for the Department of Water Affairs and Forestry (DWAF);
- Numerous monitoring and assessment reports on groundwater use in the Sandveld have been undertaken for both private organisations and government;
- Ongoing River Health surveys and the State of the River Report for the Olifants/Doring WMA in 2006, undertaken primarily by DWS;
- Freshwater biodiversity conservation plan for the Olifants-Doorn WMA, compiled by the CSIR for DWAF in 2006;
- Proposed Classes of Water Resources for the Catchments of the Olifants-Doorn, gazetted by the DWS in 2014;
- Integrated Water Resources Management Plan for the Sandveld, Olifants-Doorn Water Management Area, Western Cape, prepared for DWS Western Cape by GEOSS in 2008, and
- Development of Estuary Management Plans for the Verlorenvlei, Jakkalsvlei, Wadrift and Sout Estuaries for the Western Cape Government in 2019.

A lot of public attention is given to the Sandveld from the media, the public in general and relevant authorities. Agricultural expansion continues within the Sandveld and the long-term climate change modelling indicate that the area is going to become drier and hotter in the next 50 to 80 years (Western Cape Government, 2018). Municipal and agricultural requirements are slowly increasing and thus the pressure on water resources in the area are continually increasing with the associated impacts on groundwater-dependent and surface water ecosystems. It is thus crucial that the Reserve calculations are revisited and the water resources with the Sandveld catchments addressed holistically, with a clear understanding of the surface and groundwater interactions and interdependencies being well researched and documented.

The recent drought conditions that were experienced in the Western Cape in 2017/2018 has added to the need of users to attempt to secure longer-term sustainable access to the water resources. The low water levels of the Verlorevlei estuary and its associated wetland areas added to the concerns of the long-term management and biodiversity of the area. The Verlorevlei was designated as a Wetland of International Importance (Ramsar Site) on 28 June 1991 under the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat. In addition, peat wetlands have been identified to occur in the area that are associated with the Verlorevlei that provide important ecological services but are under severe threat and require urgent protection.

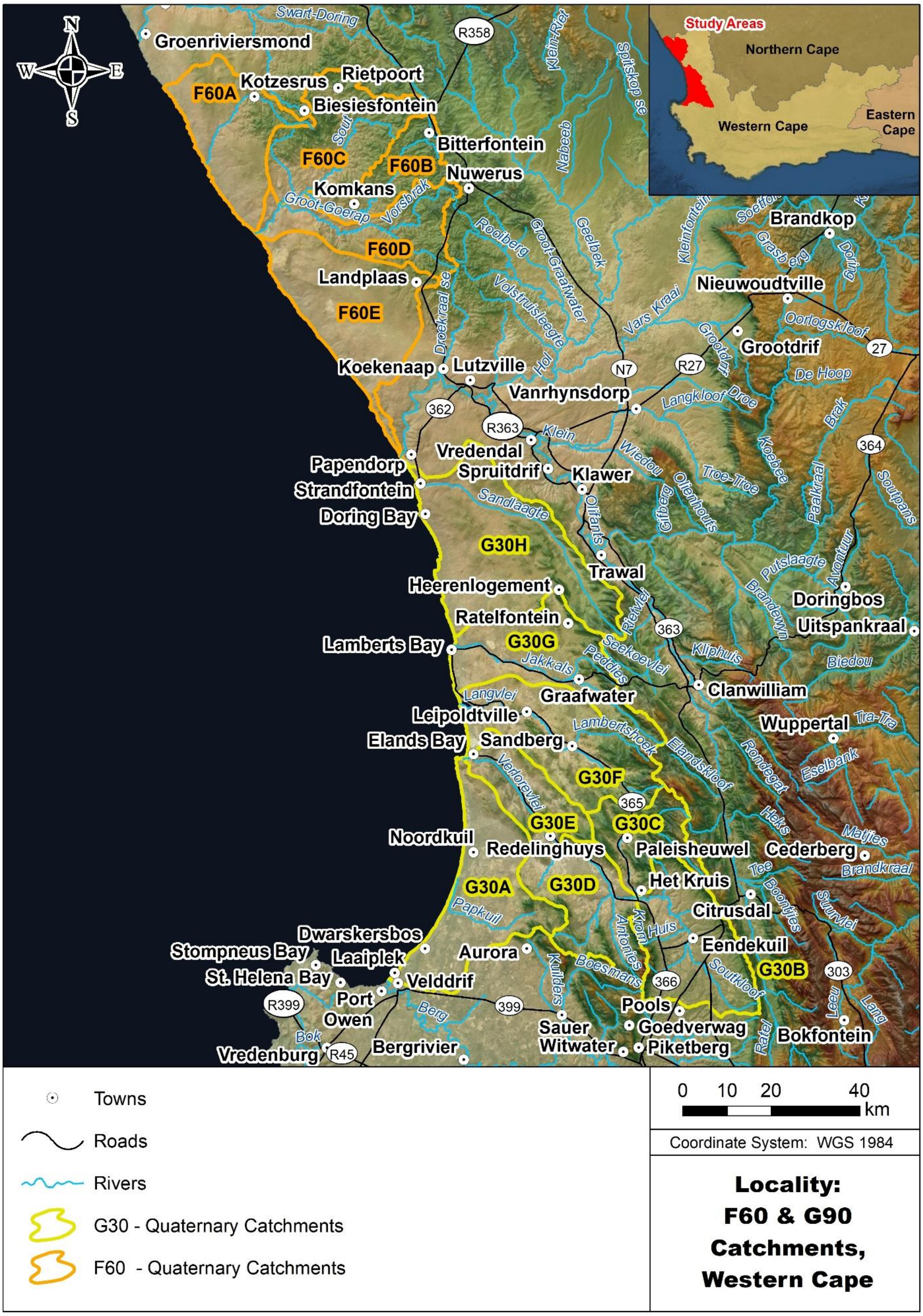


**Figure 1:** Map of the study area with the location of the G30 and F60 Catchments and main aquatic features shown

## 1.2 Objectives

The aim of this study is as outlined and detailed in the Terms of Reference presented in the Request for Bid WP11340 for the Reserve Determination Study for Selected Surface Water, Groundwater, Estuaries and Wetlands in the F60 and G30 Catchments within the Berg-Olifants Water Management Area (WMA 9), dated 2 October 2020. First and foremost, the Scope of Services called for assistance in the identification of gaps in previous Reserve Determination Studies and to determine the Reserve at a high level of confidence to yield results that could be gazetted and provide legal protection specifications.

The following objectives are listed:

1. Determination of the water quantity and quality for the protection of **rivers** at various Ecological Water Requirement (EWR) sites;
2. Determination of the water quantity and quality for the protection of priority **wetlands**, pans and lakes;
3. Determination of the water quantity and quality of **estuarine** freshwater requirements for the protection of various identified estuaries;
4. Determination of the **groundwater** quantity and quality requirements for the protection of groundwater resources; and
5. Determination of the quantity and quality of water required for the provision of **Basic Human Needs**.

# 2. DESCRIPTION OF THE STUDY AREA

## 2.1 Catchments and Rivers

The study area comprises two Tertiary Catchments:

- The **G30** Tertiary Catchment (Sandveld) comprises the seasonal Papkuil, Verlorenvlei, Langvlei, Jakkals and Sandlaagte rivers located to the south of the Olifants River Estuary (**Figure 2**); and
- The **F60** Tertiary Catchment lies immediately north of the Olifants River Estuary and comprises the Groot-Goerap/Sout and Brak Rivers (**Figure 3**).

The Sandveld consists of the coastal plain along the west coast of South Africa bordered by the Olifants River catchment in the north and east, the Berg River catchment in the south and the Atlantic Ocean coastline in the west. The area comprises mainly of the three parallel seasonal river systems, namely Jakkals, Langvlei and Verlorenvlei. The catchments drain westwards through the Sandveld and consist of a combination of rivers, pans and wetland/vlei systems.

The **Ramsar designated Verlorenvlei** wetland system is the best known of these systems. The Ramsar treaty falls under the aegis of the United Nations and the International Union for the Conservation of Nature (IUCN) and member nations - of which South Africa is one and thus has acceded to the Ramsar treaty with its clearly defined responsibility of actively conserving the unique wetland and the biological diversity that it supports.

The Groot Goerap/Sout and Brak River Catchments to the north of the Sandveld are in the even more arid Knersvlakte region that comprises low, undulating hills with isolated patches of white quartz stone and saline soils. Due to the poorly developed soils and the low agricultural potential of the area, only a small percentage of the area is cultivated and that is mostly to the southeast portion of the catchment.

Rainfall within this area occurs mostly in the winter months, being very low along the coast where it is as low as 100 mm/a. The highest annual rainfall recorded in the broader area is in the upper Bergvallei where the mean annual rainfall exceeds 400 mm/a. As one moves northwards the rainfall drops. Evaporation potential for the area is high (1,200 mm/a to 1,600 mm/a) and is more than the highest rainfall in the area. This low rainfall means that **surface water and rivers are very limited and are ranked as significant water resources that require high levels of protection**.

This rainfall distribution in the study area also implies that most of the flow in the rivers, as well as the groundwater recharge areas, occur in the high-lying mountainous areas with very little rainfall and runoff occurring on the low lying, coastal plains. Most of the G30 Catchment as well as the higher lying areas of the F60 Catchments lie within Strategic Water Source Areas for Groundwater (West Coast, Sandveld, Strandfontein and Kamieskroon).

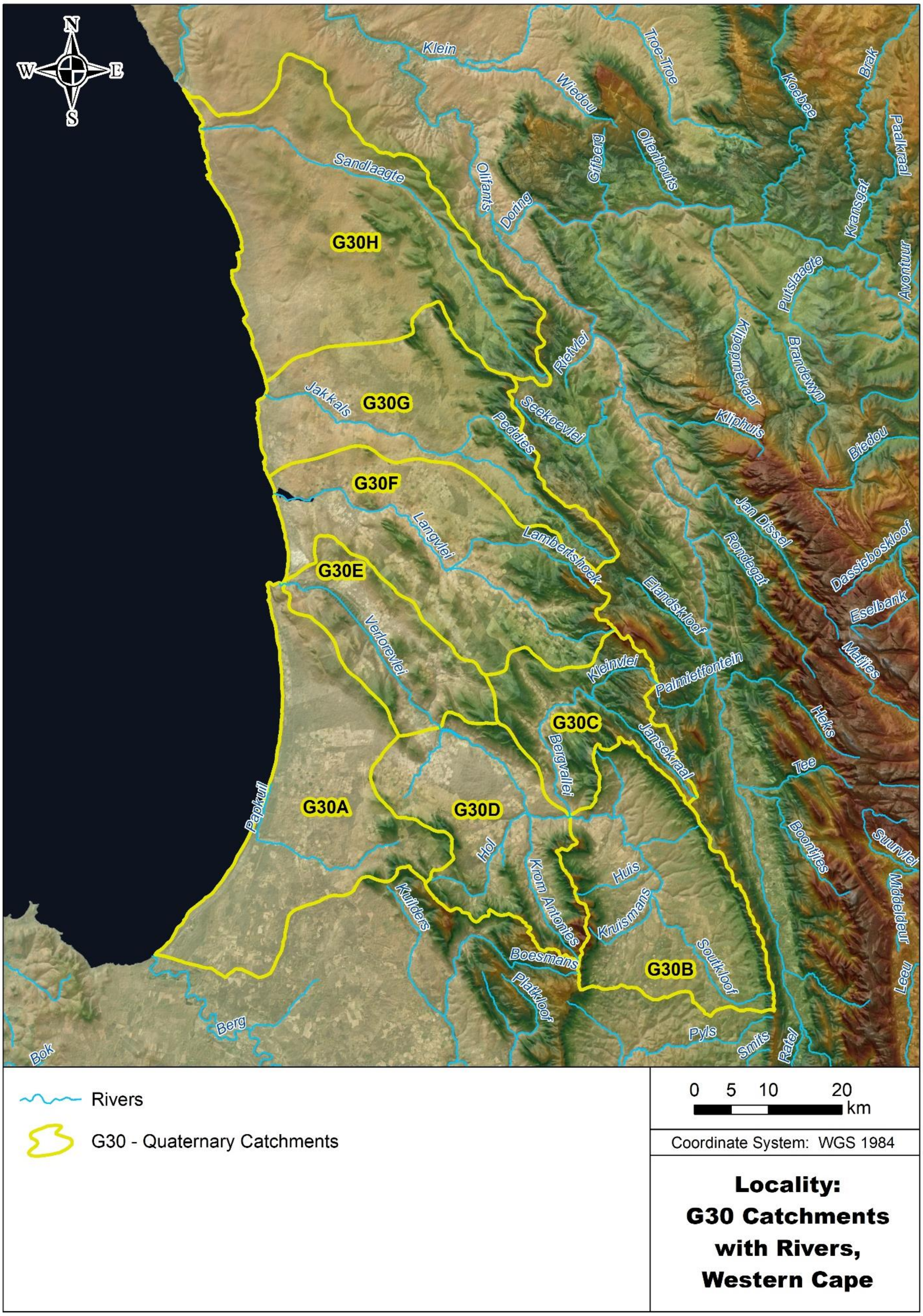


**Figure 2:** Map of the G30 Catchments with the associated rivers indicated

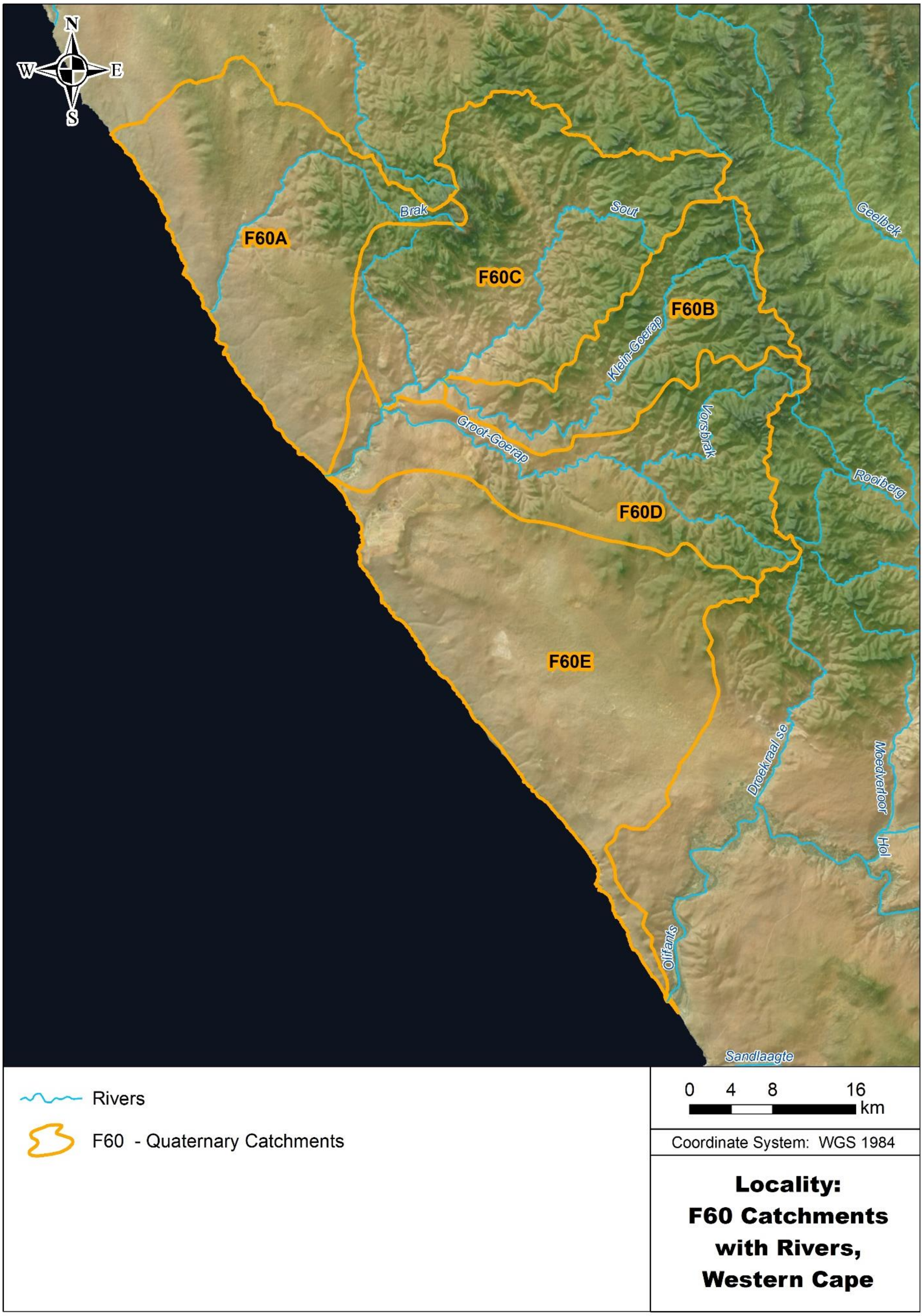


**Figure 3:** Map of the F60 Catchments with the associated rivers indicated

In terms of hydrology, the **Verlorenvlei River System is the most significant of the rivers** in the study area and is the only one that contains perennially flowing rivers while the remaining river systems are all mostly non-perennial. As this system is the greatest water resource in the study area it has the most significant associated ecosystems but also has the largest use and most disturbances. The rainfall/runoff modelling done thus far for the Verlorenvlei has suggested that less frequent high discharge events are responsible for supporting the vlei (lake) (Watson *et al*., 2019, 2018). This is apparent when considering the high daily water level fluctuation of the lake, where the average inflow does not meet the surface water evaporation rate.

The potential threat of Verlorevlei dependence on low frequency high flow events is that climate change impacts are likely to be more significant than anthropogenic water use although the impedance or diversion of water to larger dams in the catchment can have a significant impact on the high flow events (Watson, *et al*, 2019). While this work is still ongoing and the final verdict has to be made, the overall size of the small farm holding dams is significant and the impacts of dam diversions can be postulated from the adjacent highly modified Berg River Catchment.

**Water abstraction from surface and groundwater have significantly modified flow of the aquatic ecosystems, particularly reducing low flows in summer.** Modified flows have reduced, amongst others, the habitat integrity and consequently the goods and services provided by these ecosystems. Land use in the area consists largely of livestock farming (sheep and goats), with small areas being used for dryland farming. Intensive irrigation of citrus and potatoes is undertaken in the south. Urban and rural areas are small, with the main towns being Redelinghuys, Elands Bay, Eendekuil, Leipoldtville, Graafwater, Lamberts Bay, Strandfontein and Bitterfontein (See **Figure 2** and **Figure 3**).

The anticipated impact of global climate change for the area is that more extreme precipitation events will occur, and temperatures will increase, with a resulting increase in veld fires and a change in the water availability in areas where water is exploited. The increase in drying up and burning of significant wetlands in the study area are already an impact of concern.

## 2.2 Wetlands

The seasonal Langvlei, Jakkals and Verlorenvlei are extensive longitudinal wetlands in the study area with localised and weak riverine components. While short sections of morphologically distinct river channels exist (e.g., Upper Kruis, Bergvallei, Krom Antonies Rivers and the headwaters of the Langvlei tributaries – the Alexandershoek and Lambertshoek – See **Figure 4**) the dominant characteristic of these systems, as well as others in the adjacent catchments, is that of bank-to-bank corridors of reeds. In the case of the upper Jakkals River, the aquatic ecosystem is comprised of a series of temporary vleis and meadows, with a poorly defined central channel.

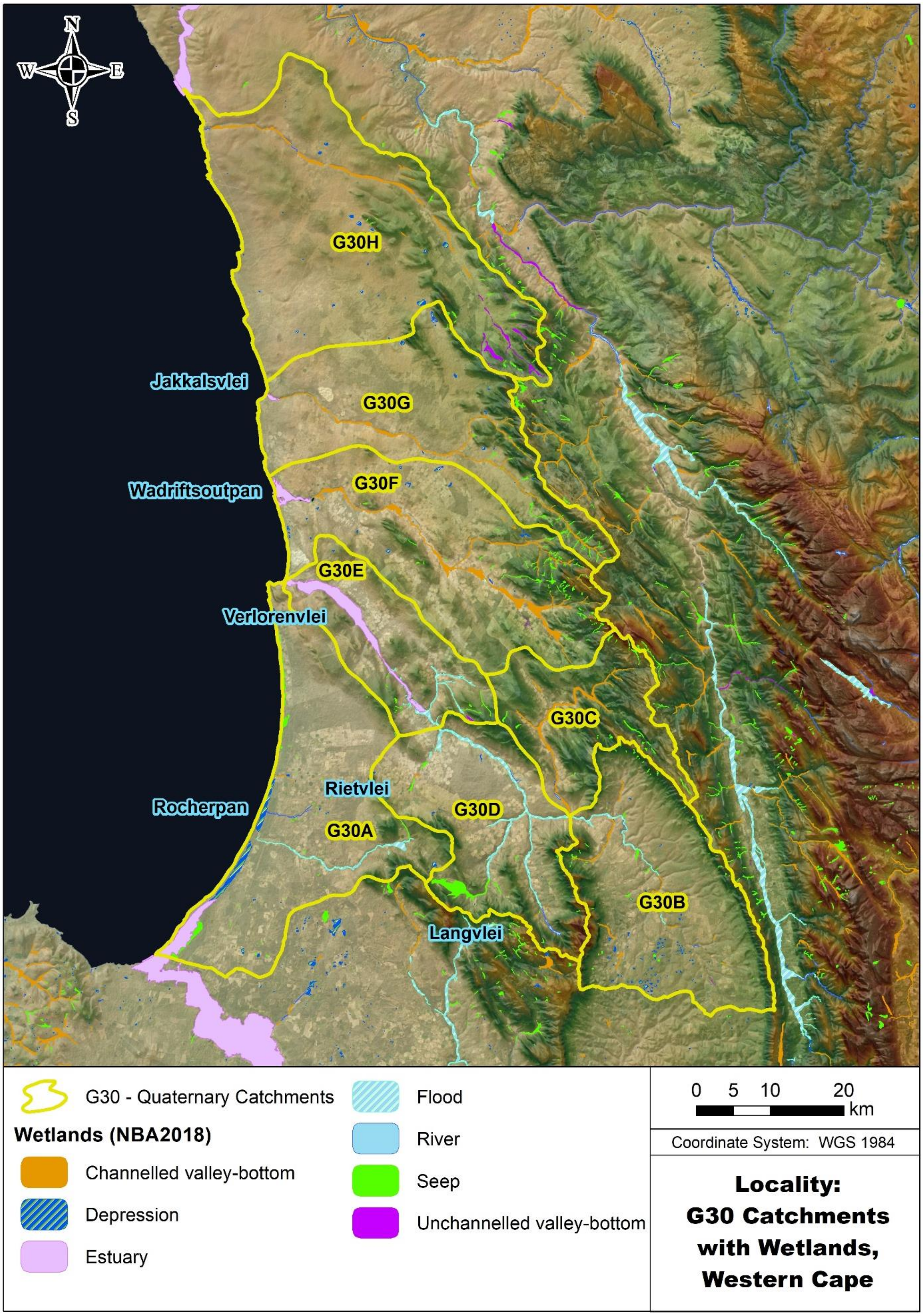


**Figure 4:** National Wetland Map of the various wetland types that occur in the G30 Catchments


**Figure 5:** National Wetland Map of the various wetland types that occur in the F60 Catchments

Important secondary characteristics are the presence of multiple freshwater springs or 'eyes', occurring along the length of all three systems (Figure 4). Lateral intrusions of brackish to saline water also occur. Distinct variations in water quality and plant species occur throughout each of the three systems. In essence, these systems exist as a series of wetlands, connected by surface channels in places, but mostly by flow through the **hyporheos** (water flowing over streambeds in lotic environments). It should be noted that, for purposes of the current study, the Verlorenvlei system has been treated as an Estuary (see the following section) and not as an inland wetland, although cognizance has been taken of the reality that portions of the system are not subject to significant saline intrusion or tidal fluctuations.

The maps in **Figures 4 and 5** show the wetlands (and their categorisation into different hydrogeomorphic types) that have been delineated on a desktop basis, within Secondary Catchments F60 and G30, respectively, on the National Wetland Map (Version 5) (NWM5) that was used in the wetland component of the 2018 National Biodiversity Assessment (Van Deventer et al., 2019). SANBI has done work subsequent to the NWM5 that includes work on depression wetlands and could add to the description of wetlands in the two catchments.

While the seasonal Langvlei, Jakkals and Verlorenvlei longitudinal wetlands are the main wetlands of note in the study area, other relatively large wetland areas comprise of:

- Rocherpan near the Berg River Estuary;
- Valley bottom wetland habitats associated with the Papkuil River in G30A; and
- Several pans in the upper Verlorenvlei Catchment (See **Figure 4**).

These wetland areas occur within an arid landscape that has been significantly modified by agriculture provide valuable habitat for birdlife as well as amphibians. The **Verlorenvlei wetland, a proclaimed Ramsar site**, is regarded as one of the ten most important wetlands for wading birds in the southwestern Cape and is a particularly important feeding area for the white pelican. In summer, in the adjacent Wadrift Pan when the water level recedes, the shallow mudflats support several bird species, such as lesser and greater flamingo, Cape shoveler, shelduck, black oystercatcher, avocet and chestnut-banded plover.

In addition to the more prominent and known wetlands discussed above, there are numerous smaller and lesser-known wetlands of various types in the study area.

## 2.3 Estuaries

### *2.3.1. Verlorenvlei*

The Verlorenvlei Estuary, shown in **Figure 6**, is a large estuarine lake system. The estuary is an "Important estuary from a biodiversity perspective" (Turpie and Clark 2007, Van Niekerk *et al*. 2012). Verlorenvlei is a proclaimed Ramsar site (No. 525) and the vlei itself is owned by the state.

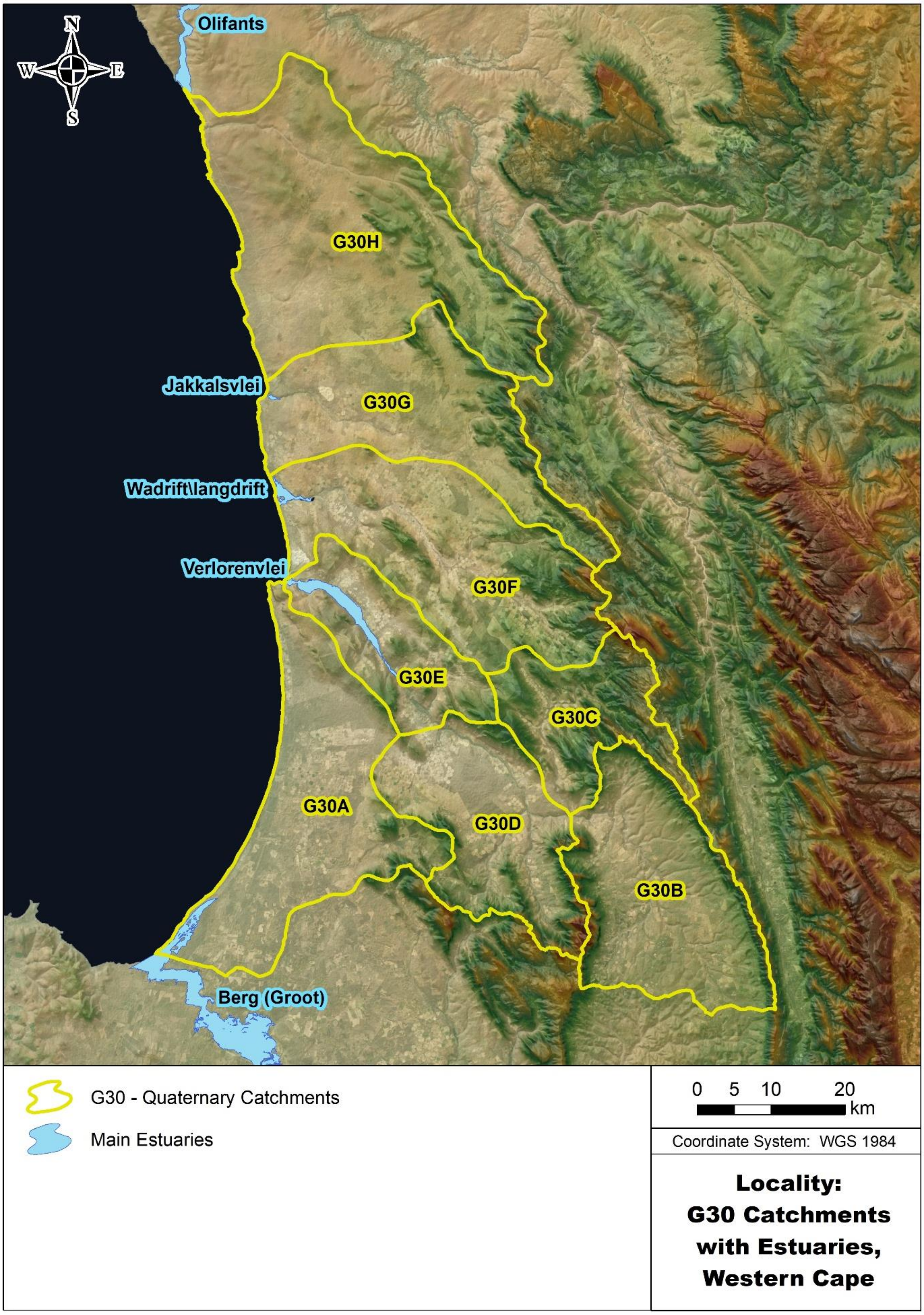


**Figure 6:** Map of the estuaries that occur in the G30 Catchment

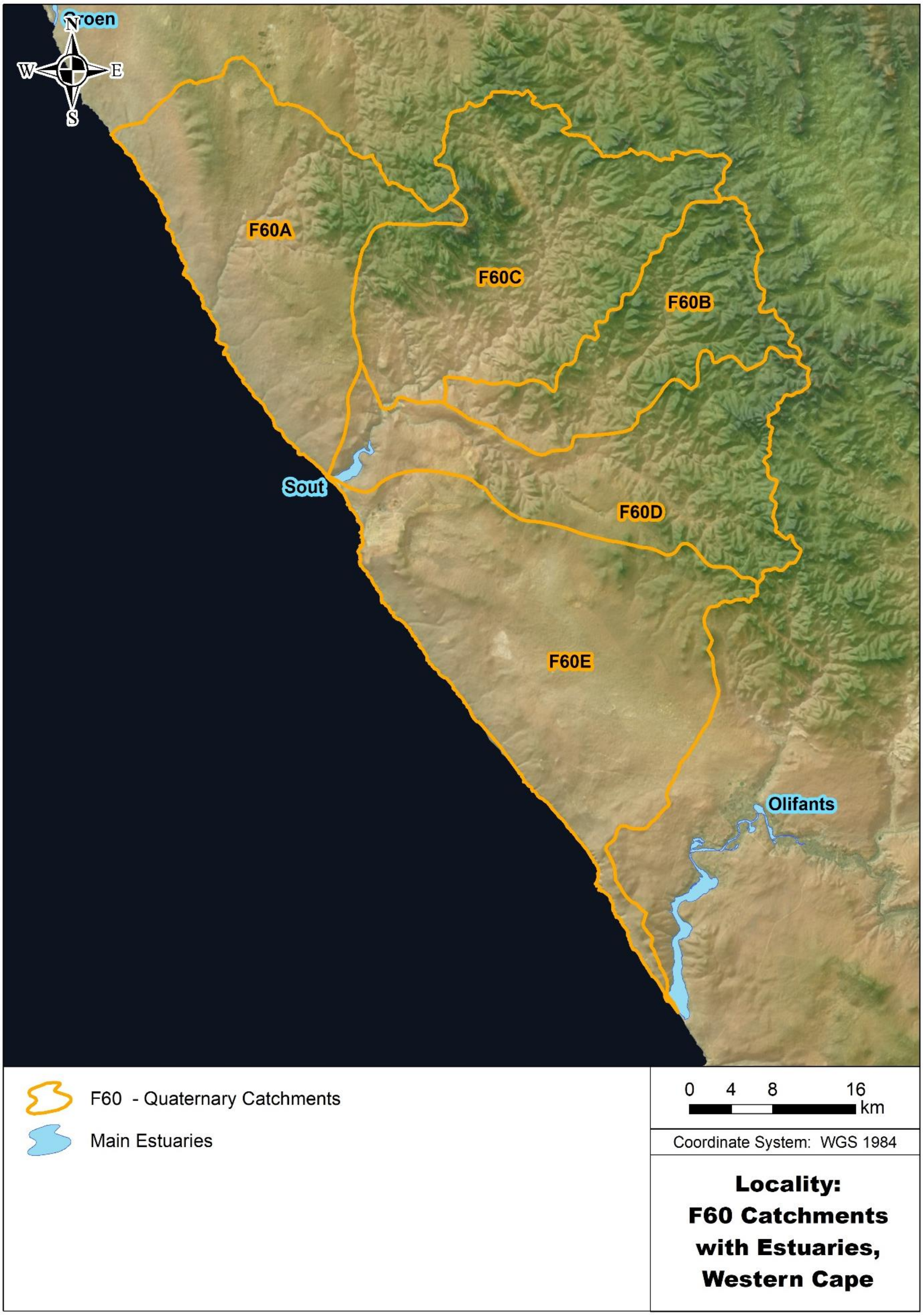


**Figure 7:** Map of the estuaries that occur in the F60 Catchment

The Verlorenvlei estuary does not have any statutory protection, however, it is included in the subset of estuaries identified as requiring protection to conserve South Africa's estuarine biodiversity estate in the National Estuary Biodiversity Plan (Van Niekerk *et al*. 2012). The wetlands of the Verlorenvlei system are between 1 and 5 m above mean sea level. Its catchment is 1 900 $km^2$ and the surface area of the main water body is estimated to be 1 630 ha. The average depth of the open water area of the lake is between 2 and 3 metres with a maximum depth of 5 metres (Robertson 1980). A small estuarine channel about 2.6 km long connects the lake to the sea.

The Verlorenvlei Estuary is naturally a nearly permanently closed. It only breaches to the sea during periods of high inflow. During the closed phase and under high inflow conditions, water backs up, flooding into the wetlands downstream of Redelinghuys, inundating grazing land and prompting requests for premature breaching of Verlorenvlei. The resulting lower water levels, together with nutrient enrichment, causes eutrophication in the form of phytoplankton algal blooms (green or brown water column), excessive reed growth around the edges and/or submerged macrophyte growth. Phytoplankton algal blooms deplete oxygen and stress fish, while reed growth at the low water bridge increase risk of flooding.

In 2003 a preliminary Reserve determination study was conducted on Verlorenvlei as part of the larger Sandveld Reserve Project (DWAF 2003). This study provided a very cursory estimate of the present health of the vlei. The study found Verlorenvlei to be moderately modified (Category C). A number of the assumptions made in the assessment did not appear to reflect the true state of affairs, e.g., **the reduction in seasonal inflows was estimated to be 60% and the total recharge abstracted was about 90%, but the frequency of natural opening only changed by 20% to the time**. This seems to be far too conservative an assumption based on volumetric analysis of a **Natural Mean Annual Runoff (MAR) of 100 X $10^6$ $m^3$**.

Based on the natural MAR, open mouth conditions, should have been much more frequent and for longer periods under the reference conditions. Changes in water levels and mouth conditions drive most of the other physical and ecological features of the system, such as nutrient cycling, salinity, micro-algal blooms, growth of emergent and submerged vegetation, invertebrate and fish recruitment from the sea, nursery function, and bird abundance. Therefore, most of the components evaluated as part of the Sandveld study would show a further reduction in health if the scores for the mouth state were adjusted.

To assist in the development of an Estuary Management Plan (EMP) (individual EMPs are required by the National Environmental Management: Integrated Coastal Management Act (Act No. 24 of 2008), as amended) for the Verlorenvlei (CSIR 2009) a provisional rapid level Reserve assessment was conducted following the Estuarine Resource Directed Measures (RDM) methodology developed for determining the Ecological Water Requirements of an estuary (DWAF 2008). Verlorenvlei was determined to be in a "Moderately to largely modified state", i.e., Category C/D, based on the 2009 assessment. The degradation of the system's health is largely attributed to:

- Significant reduction in the freshwater inflow (ground- and surface water) to the system;
- A decrease in open mouth conditions (i.e., frequency and duration);
- Increase in the nutrient and sediment load to the system and a reduction in the channel and open water habitats;
- Increased coverage by reeds and sedges; and
- Changes in the species composition and abundance of fish as well as birdlife in the system.

As the Verlorenvlei is a Ramsar site it should be managed to achieve a much better condition, but it is highly unlikely that the flow reduction to the system can be alleviated easily and as this is the major driver for change in the system it was felt that the Best Attainable State is a moderately modified system (i.e., Category C). It is very important that this provisional health rating of Verlorenvlei be confirmed by an Intermediate or Comprehensive level Estuarine Reserve (Ecological water requirement) study to determine its Estuarine Recommended Ecological Category with a confidence that would allow for decisive management actions. **A high confidence reserve determination would also allow for stricter licensing and more adaptive management approach from the relevant authorities regarding the necessary intervention required to increase the health of the system. An updated hydrological assessment of the combined impact of abstraction on surface and groundwater resources is urgently needed to address the further decline in condition.**

### *2.3.2. Wadrift*

The Wadrift Estuary is situated on the west coast, south of the town of Lamberts Bay (**Figure 6**). With very heavy rainfall the estuary used to breach the sandbar/berm and connect to the sea. Historically flow from the Langvlei River during the winter rainfall months fills the estuary causing it to become fairly fresh. During the summer months as the estuary would then dry and the freshwater level recedes, making the estuary more saline at the mouth and exposing shallow mudflats, ideal for supporting a variety of bird species (River Health Programme, 2006).

The Estuary is a relatively small estuarine system (open water area 65 ha in 2009) and is of "Low to average biodiversity importance" (The default rating for systems not rated by Turpie and Clark 2007). **The Wadrift Estuary is known as an important site for its rich bird diversity**. Wadrift does not have any statutory protection and is not included in the subset of estuaries identified as requiring protection to conserve South Africa estuarine biodiversity estate in the National Estuary Biodiversity Plan (Turpie *et al*. 2012).

The Saldanha-Sishen railway line crosses the estuary about 600 metres upstream of the mouth. A study done in 1976 stated The Wadrift Estuary is generally disconnected from the sea by a sandbar/berm and only breaches with intensely heavy rainfall and that the position of the railway bridge does minimum damage to the estuary. They noted that it is far enough from the sandbar/berm to not interfere with its integrity. In the case of it being breached, the study claimed that there were sufficient culverts to allow normal emptying of the estuary. The water level in the estuary is not very high and therefore the causeway will interfere with the mixing processes of water. This could result in the water becoming more saline at the mouth. These conclusions were probably drawn with the best intentions, but it is now considered that the construction of the railway line and the adjacent causeway with the limited number of culverts with a too high floor level had a negative impact on open mouth conditions. This would be further enhanced by the reduction in flow reaching the estuary.

The causeway across the estuary at the mouth of the system was identified by the CSIR as possibly impacting the ability of the estuary to breach. Under the current conditions, floods are often unable to breach the sandbar at the mouth, which will not allow for the estuary to scour out, reduce nutrient levels in the sediments and help to prevent eutrophication of the sediments (to which it would appear vulnerable) and allow estuarine and marine species to migrate between the two habitats. This would have some effect on water quality and all the estuarine associated biota (algae, invertebrates, fish, birds etc.) as well as on the goods and services the estuary possibly provides (recreational, scenic, and fisheries value etc.). Lamberts Bay receives much of its water supply via groundwater extraction at the Wadrift Wetland (River Health Programme, 2006). Extensive groundwater abstraction which started in the late 1970s has not only reduced the flow to the estuary but has exposed surrounding wetlands which supported peatland vegetation. The Berg River redfin has then subsequently disappeared from the system.

The Wadrift Estuary was rated as Largely modified to Highly degraded (Category D/E in the Department of Water and Sanitation rating system) (van Niekerk *et al*. 2015). The estuary is negatively impacted by the following:

- A reduction in groundwater and surface inflow (especially the lack of summer baseflows);
- Increased nutrient load from the catchment;
- Increased mouth closure and reduced connectivity with the sea and within the artificial separated water bodies; and
- The Saldanha-Sishen railway crossing.

Recommended health status is a Category D (Largely Modified) as the system is of low to average importance and not a conservation priority (van Niekerk *et al*. 2015). This rating will be confirmed in the study.

### *2.3.3. Jakkalsvlei*

The Jakkalsvlei Estuary is a small estuarine system situated on the west coast north of the town of Lamberts Bay (**Figure 6**) within the cool temperate biogeographic region of South Africa. The system's open water area is between 3 and 10 ha since the removal of the causeway near the mouth. The estuary does not have any statutory protection and is not included in the subset of estuaries identified as requiring protection to conserve South Africa estuarine biodiversity estate in the National Estuary Biodiversity Plan (Turpie *et al*. 2012). The estuary is of "Low to average biodiversity importance" (The default rating for the system is not rated by Turpie and Clark 2007).

The Jakkalsvlei Estuary was rated as Largely modified (Category D in the Department of Water and Sanitation rating system) (van Niekerk *et al*. 2015). The estuary is negatively impacted by the following:

- A reduction in river inflow (especially the lack of summer baseflows);
- Increased nutrient load from the catchment; and
- Increased mouth closure causing inundation of supratidal areas and decrease recruitment from the marine environment.

The recommended health status of the Jakkalsvlei Estuary is a Category D (Largely Modified) as the system is of low to average importance and not a conservation priority. This rating will be confirmed in the study.

Historical aerial imagery shows that the Jakkalsvlei was a temporarily open/closed estuary with intermittent connection to the sea. During high wave action, natural processes would lead to marine sediments forming a sandbar/berm across the channel mouth, closing the connection to the sea, thus giving time for the main water body, to fill with water at times. Under natural conditions, with sufficient river flow during winter months the sandbar/berm would breach, and the water would drain, allowing marine water and biota to enter the estuary. Even a small continuous low flow is deemed to be sufficient to keep the estuary mouth open, because of the very small surface area (3 – 10 ha) of the estuary before 1970 and again after 2007.

Data on mouth conditions for the present situation are unfortunately not available, but the simulated inflow data indicates that open mouth conditions are probably strongly reduced because of the (almost) zero flows now occurring between October and April. Normally open mouth conditions during this period are important for ecological processes such as migration of juvenile fish and invertebrates and the germination of saltmarsh vegetation.

### *2.3.4. Sout Estuary*

**The hypersaline Sout River Estuary (Figure 7) is classified as an Arid Predominantly Closed System as the feeding river is ephemeral and thus the estuary is nearly always closed to the sea. The estuary is a highly transformed system due to the presence of a salt works which occupies much of the system. Road infrastructure, channel diversions and infilling have severely modified the estuarine functional zone and reduced connectivity to the associated aquatic ecosystem, as well as the transformation and degradation of the intertidal and supratidal areas. In general, the Sout River estuary is not acknowledged as a functional estuary or a noteworthy ecosystem.**

Limited water quality information exists for the estuary which remains in a hypersaline state, with recorded salinity ranging between 38 and 101 ppt. Extreme salinities may be a combination of natural evaporation in combination with seawater/groundwater pumping associated with the salt works. Nutrients levels are elevated in the lower reaches of the estuary and are correlated with lower dissolved oxygen concentrations as a result of organic loading, while turbidity levels are slightly elevated in the middle reaches, associated with feeding activity by flamingos.

The ecological health of the Sout River estuary is in an E Category (seriously modified). However, the functional importance of the Sout River estuary was deemed relatively high as it contributes to a very rare and limited “wetland habitat type” for estuarine and coastal birds along the dry Namaqualand Coast. As the Sout River estuary is currently below ecological functional levels, the Recommended Ecological Condition defined by the Department of Water and Sanitation (DWS) was a category D.

## 2.4 Groundwater

Groundwater in the G30 (Sandveld) Catchments plays an essential role in environmental functioning, it enables extensive agricultural activity and is the sole source of freshwater for most of the towns and settlements within the catchments. Only the towns at the northern tips of the catchments (Strandfontein and Doringbaai in Figure 7) can obtain additional sources through the Olifants River canal system. The surface water flows in the study area are essentially non-perennial and in the dry and hot summer months, the river systems stop flowing. **All the aquatic ecosystems within the study area are largely groundwater driven or dependent on groundwater** (GEOSS, 2005).

Distinct variations in water quality and plant species occur through the study area. Although surface water plays a significant role in the study area particularly for the aquatic ecosystems, groundwater plays a more significant role in sustaining these systems. **The main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg and Piketberg Mountain ranges** (GEOSS, 2019). These mountains are made up of the Table Mountain Group (TMG) formations, located in some instances outside the study area.

The TMG geological units are largely anisotropic and do not display uniform aquifer characteristics. Equally; The sandy plains are covered in thick layers of course sand with high infiltration rates. The little if any run-off during a rainfall event let me believe that significant portion of the precipitation (80%?) percolates into the soil. With the relative low water holding capacity of the sandy soils and the fibrous root systems of the veld type, it is likely that more than 6,44mm/a (3% of MAP) contributes to sub-terrain aquifers.

The infiltration, transmissivity and storage of groundwater is therefore controlled primarily by the abundance of faults, fractures, fissures and joints. The abundance of fractures, as well as the generally high rainfall of the mountainous areas, means that groundwater recharge is favourable. The increase in groundwater abstraction in the mountainous areas has significantly decreased surface run-off. Needs to be further investigated.

The TMG formations unconformably overlie the older Malmesbury metasedimentary formations. This formation Malmesbury Group represents the basement rocks in the study area, and together with the TMG, form the secondary rock aquifer that underlies the Quaternary sand deposits that extend along the western coast of South Africa.

These zones of alluvium are generally parallel to the larger rivers, in this case, the Verlorenvlei. The sandy overburden is generally underlain by unconsolidated to semi-consolidated sand, clay and sometimes beach gravels. The Quaternary age deposits were identified by Vandoolaeghe (1982) as the optimum source of groundwater. The properties of the Quaternary deposits vary significantly. Suitable areas for groundwater abstraction have been located (areas with deep paleo-channels). The sand deposits constitute the primary aquifer. Large regional NW – SE trending faults occur in the study area that acts as conduits and may be related to the recharge of high yielding primary aquifer areas.

The catchments thus contain both fractured and intergranular areas (**Figure 8**) (DWAF 2005). The average yield ranges from very low (0.5 L/s) to high yielding (> 5 L/s), with identified paleochannels producing boreholes of a yield higher than 25 L/s. Groundwater quality (**Figure 9**) is described as being good across the G30 catchments (DWAF 2005). This needs to be checked with more recent water quality data. Reports exist of deteriorating water quality in the Sandberg area. Fewer monitoring boreholes exist in the upper reaches of the catchments.

Areas, where Malmesbury Group formations form the main aquifer, can be identified as yielding groundwater of poor quality. Groundwater abstracted from the intergranular aquifer is generally of good quality and usually depends on whether the sand deposits are underlain by sandstone of shale deposits, with shale deposits producing poorer groundwater.

As mentioned, groundwater forms the only source of freshwater for the vast majority of the human settlements located within these catchments. Groundwater abstraction for agricultural irrigation use is the main groundwater use in the area. The Sandveld has over time transitioned from integrated livestock and rainfed crop production systems to irrigated vegetable production systems within the last 30 years. Although still an important potato producing area, the crops have diversified to include the production of other irrigated vegetables and in recent years, citrus. These crops are labour intensive and have contributed to the economic growth of the towns in the catchments. The growth of town and agricultural water uses has placed an increase in the groundwater demand for the area, and thus stress on the water resources.

Monitoring data is available in the form of water level readings from DWS, individual farms and the Potato SA monitoring project (GEOSS, 2019). Data reflecting the actual use for agricultural purposes is lacking. The distribution of these monitoring boreholes is towards the coast. **Much development has occurred in the last 20 years that the Validation and Verification (V & V) process has not accounted for. This gap in data has been highlighted recently when across the G30 catchments the V&V process was finalised and showed that the majority of the farmers are using more groundwater than what has been calculated during the V & V.**

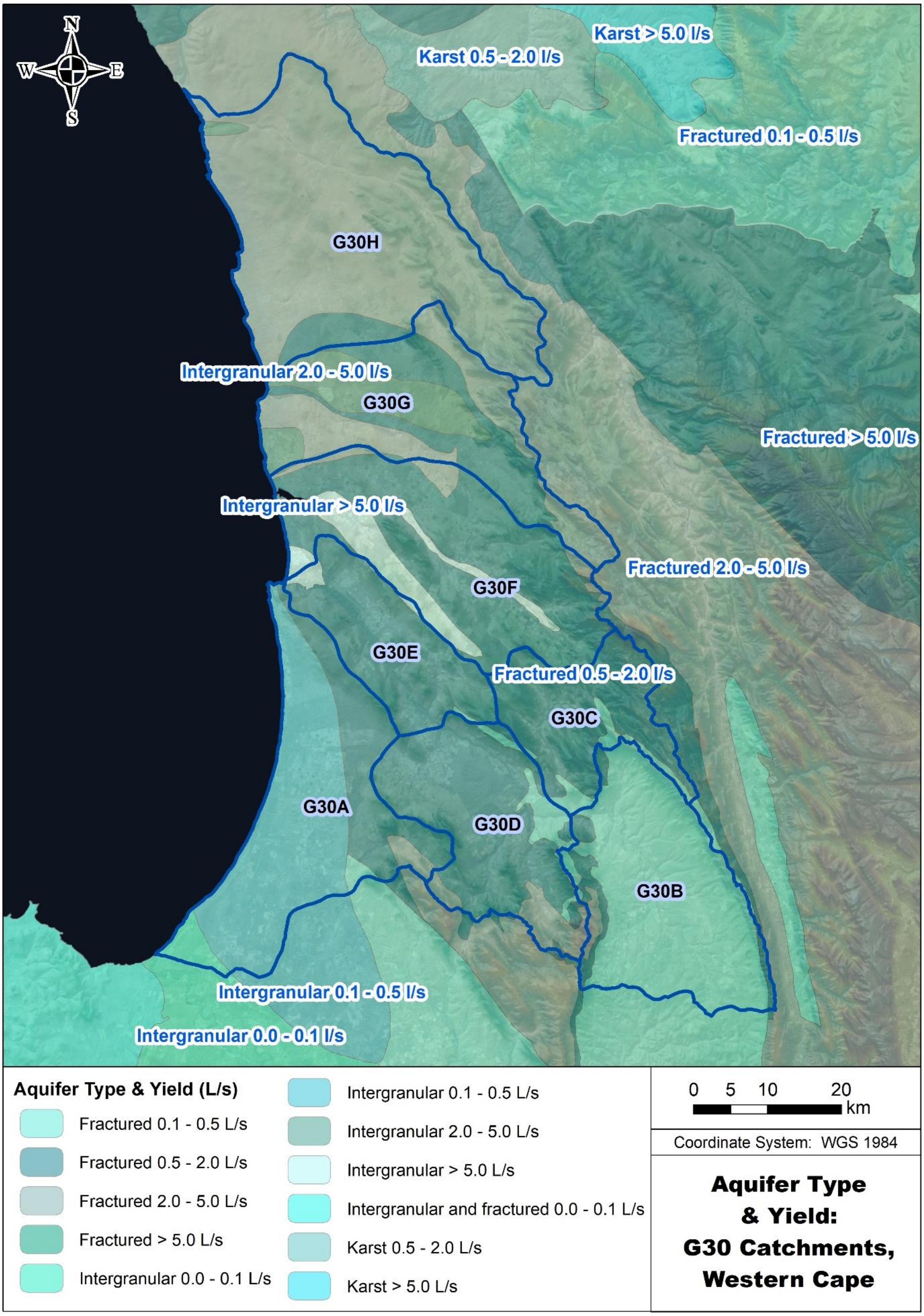


**Figure 8:** Regional aquifer yield for the G30 Catchments from the 1:1 000 000 scale groundwater map (DWAF, 2005)

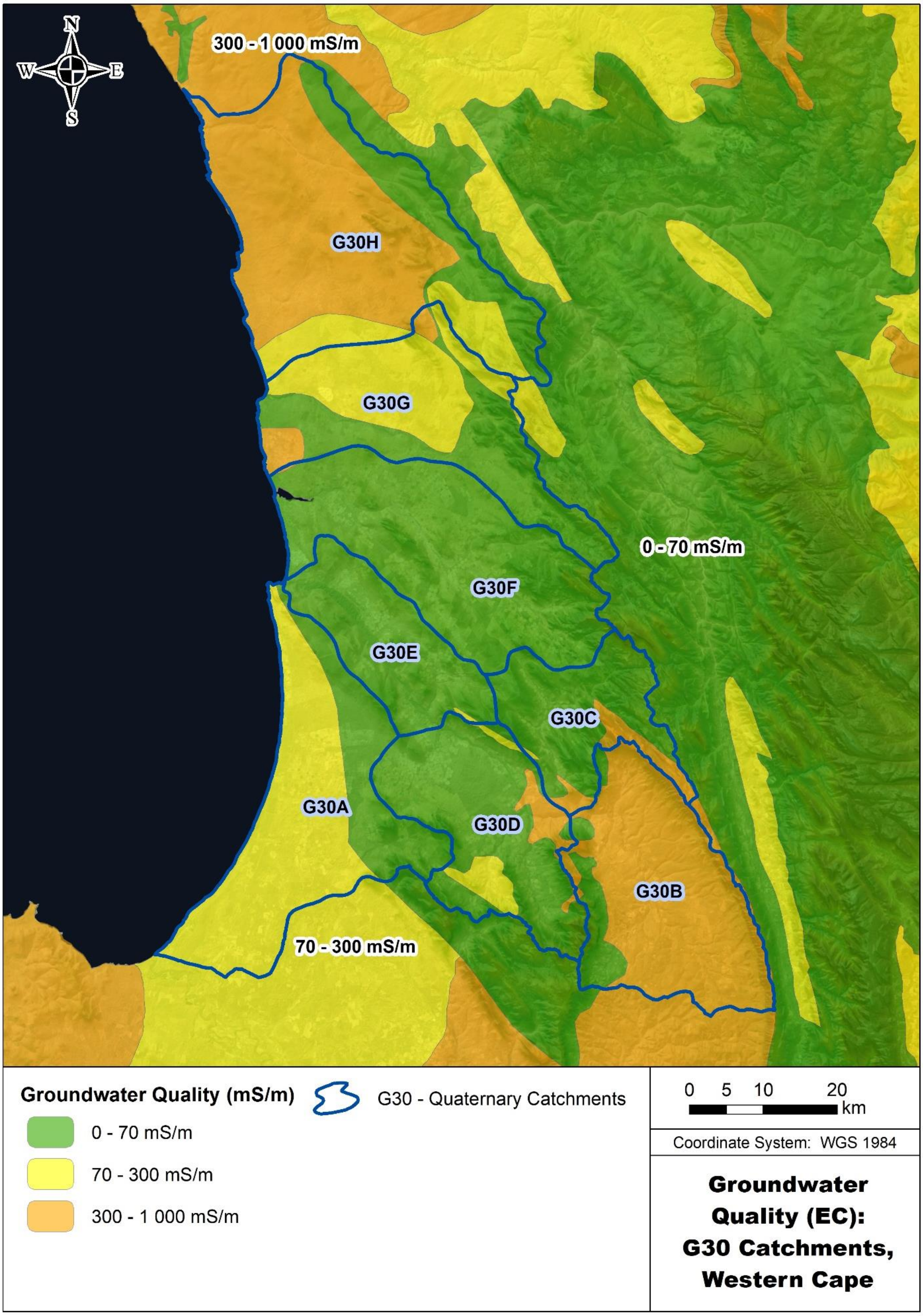


**Figure 9:** Regional groundwater quality (EC in mS/m) from (DWAF, 2005), for the G30 Catchments

More up to date figures on what is actually being abstracted for irrigation use across the catchments will need to be sourced. The Western Cape Regional Office have indicated that they are in the process of finalizing the V & V outcomes and will assist with providing data for this study. A map with information of the farmers that have applied for V&V and the detailed infrared process undertaken to quantify water usage during the qualifying period exists. The towns in the area do measure their water use and this will add valuable data on the amount needed for the towns.

The **F60 catchments** are overall drier and groundwater availability is much lower than in the **G30 catchments**. Furthermore, the geological setting of the area is more complex. Quaternary deposits are still present toward the coast but include calcareous and gypsiferous units as well as thick calcrete beds within the deposits. These sediments are underlain by igneous formations that form part of the Bushmanland and Richtersfeld Sub-province, that in turn falls under the Namaqua Metamorphic Province.

For the F60 area, various gneiss and granite formations from the Spektakel, Kamiesberg and Little Namaqua Suites, underlay the quaternary sand deposits towards the coast and outcrops towards the east of the catchments. The area contains minerals of economic value and multiple mines can be found within the F60 catchments, especially along the coast in the form of heavy mineral sand mines.

Groundwater is the only reliable source of freshwater in the area and all the human settlements are completely reliant on groundwater and rainwater collection. Farms are mainly livestock focussed and are reliant on the groundwater for domestic use as well as for human and animal consumption. A few farms abstract enough water to irrigate, although abstraction of groundwater for irrigation is low. This is mainly due to the lack of good quality groundwater.

The regional expected yields are very low (0.1 - 0.5 L/s) (**Figure 10**). The area has been classified as containing both intergranular and fractured aquifers (DWAF 2005). Higher yielding boreholes have been found at the most southern point of the F60 catchments, along the coast where calcareous and gypsiferous layers within the quaternary deposits create karst aquifers with an average yield potential of 0.5 – 2 L/s.

Groundwater quality across the catchments is generally categorised as being poor, with EC values of over 1000 mS/m expected across the different quaternary catchments within the F60 cluster (**Figure 11**) (DWAF 2005). Towns like Bitterfontein and Rietpoort rely on water treatment facilities to get their groundwater within the parameters acceptable for human consumption.

With the number of mines increasing across the catchment, local interested parties have raised concern regarding the increased demand being placed on a very scarce natural resource. **Limited active groundwater level and quality monitoring is taking place across the F60 area and available data will not reflect actual use across the catchments but could provide an indication of pre-mine conditions, although it should be noted that available data is spaced far and wide with large data gaps.**

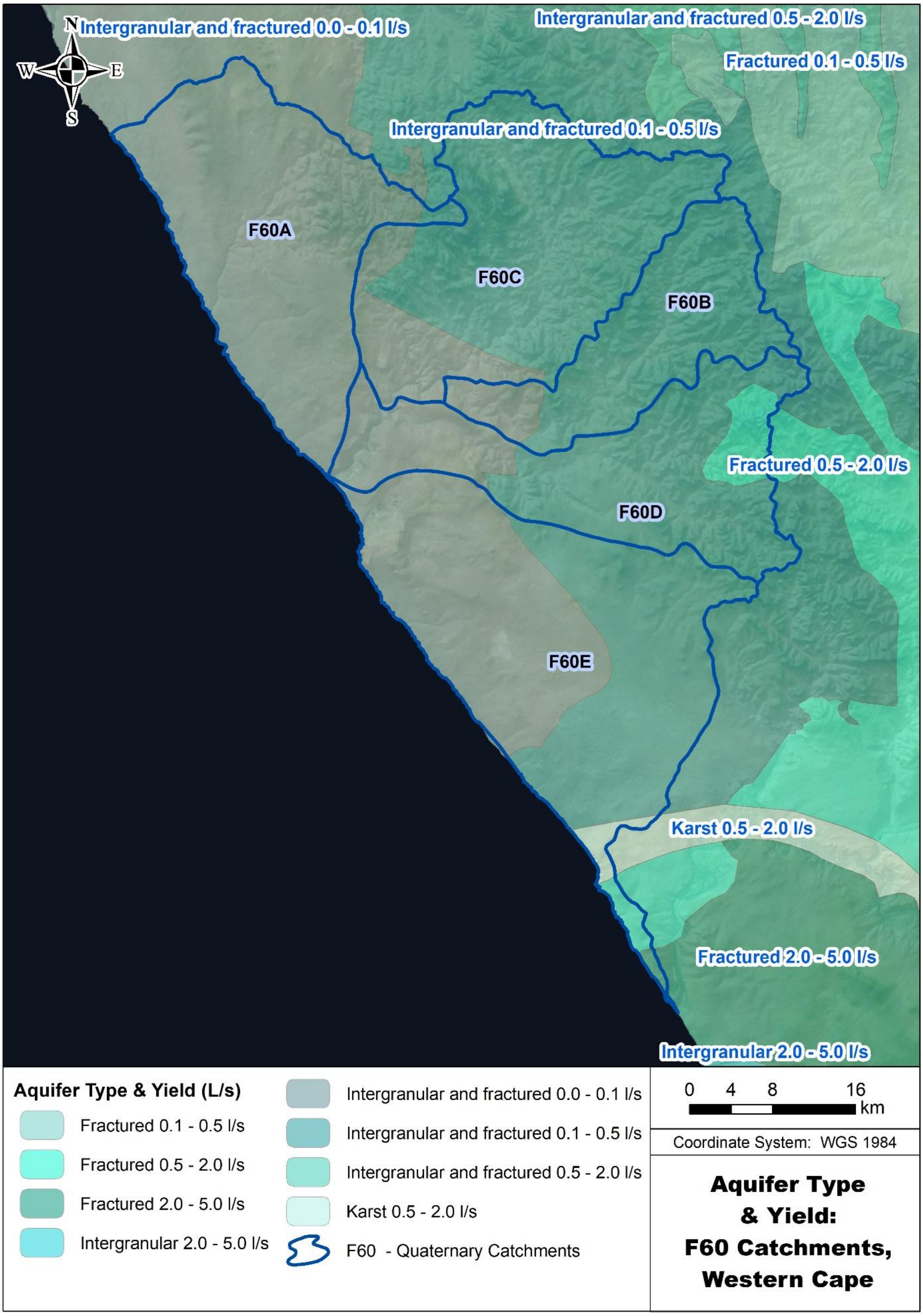


**Figure 10:** Regional aquifer yield for the F60 Catchments from the 1:1 000 000 scale groundwater map (DWAF, 2005)

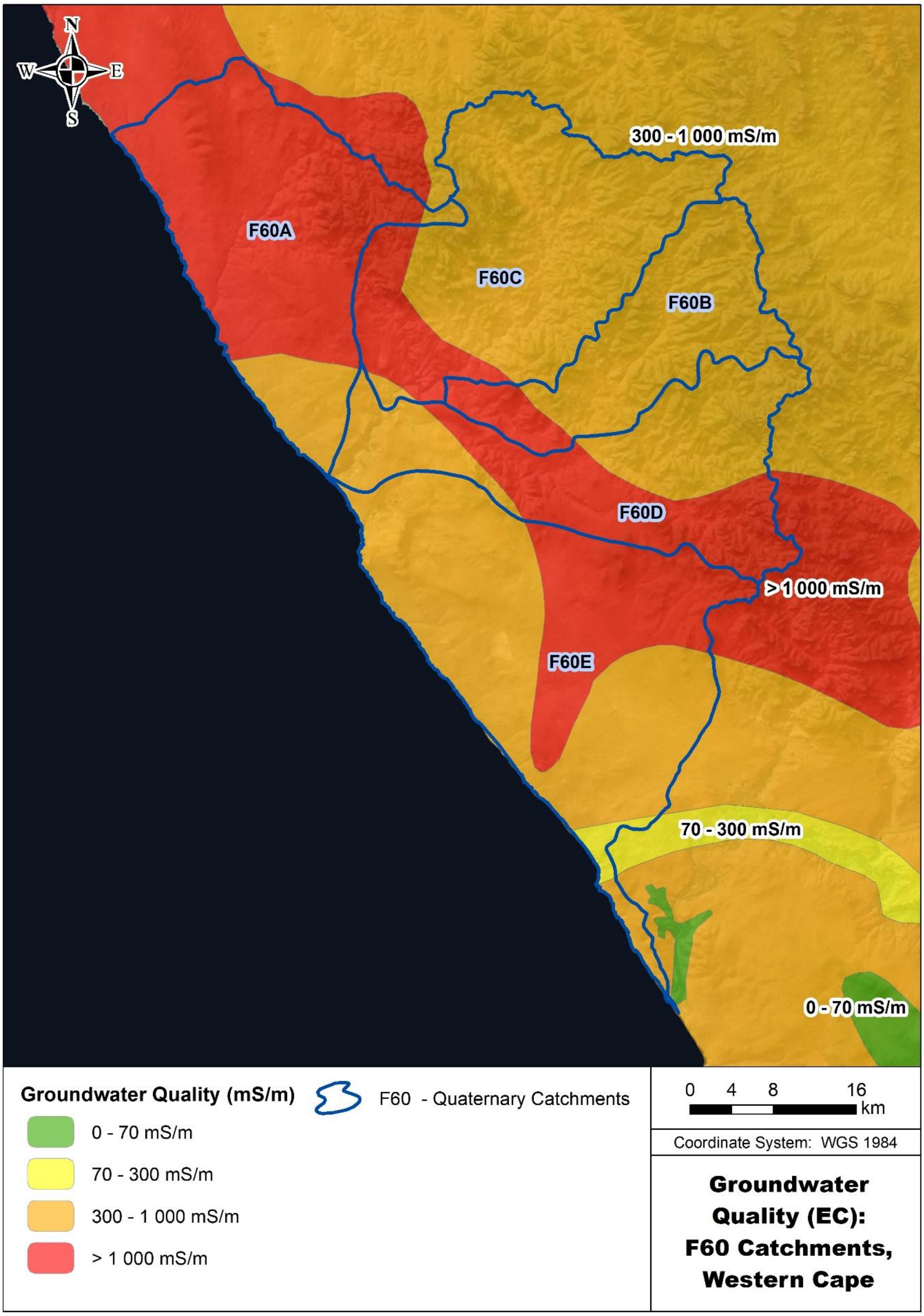


**Figure 11:** Regional groundwater quality (EC in mS/m) from (DWAF, 2005), for the F60 Catchments

## 2.5 Groundwater/Surface Water Interaction

There is seasonal interaction between surface water and groundwater, although river flows in the hot dry summer months become negligible. Based on an assessment of groundwater levels (in the summer months) a number of comments can be made.. For the **Jakkals River** catchment (G30G), in the area around Graafwater to 8 km downstream from Graafwater, there is **no contribution from groundwater to surface water flow** and the river system is a losing system (recharging groundwater) (GEOSS, 2005). The only gaining section on the Jakkalsvlei River is situated midway between Graafwater and Lamberts Bay. In the Langvlei, the gaining reaches within the catchment are short.

For the Verlorenvlei, the gaining sections are thought to be of significant length, with the longest gaining reach being downstream of the confluence of the Hol, Krom Antonies and Kruismans Rivers. At Redelinghuys and at the headwaters of Verlorenvlei, there are also stretches of gaining river. The Kruismans Tributary is regarded as the largest tributary and is mainly derived by surface runoff (Watson *et al*., 2019). Thus far, the Bergvallei Tributary is regarded as the largest groundwater flow contributor using the J2000 rainfall/runoff model, with strontium isotope ratios confirming this (Sigidi, 2017). The Krom Antonies Tributary is regarded as the largest, in terms of area-weighted flow contribution, with the TMG playing a critical role in terms of baseflow. While the Hol Tributary is saline (Watson *et al*., 2020a), but it is significant in that baseflow is more sustained, due to the dominance of slow groundwater flow from the Malmesbury shale aquifer.

**The recharge in Verlorenvlei is mainly generated in the TMG aquifer, which is a secondary porosity aquifer system and water is held in the fracture network. The recharge rates into the TMG aquifer have been estimated to be 37.6 to 50 mm/year using the Chloride Mass Balance** (CMB)(Watson *et al*., 2020a) and agree with bulk rainfall/runoff modelling estimates (Watson *et al*., 2018). Isotope data has been used to understand dominant groundwater flow paths and was instrumental in identifying groundwater mixing relationships between the upper, middle and lower Krom Antonies sub-basin (Watson *et al*., 2020a). Furthermore, the use of isotope dating techniques conducted for the catchment essentially shows three distinct aquifer systems which are mixed before reaching the Verlorenvlei itself (Miller *et al*., submitted scientific paper for publication). These mixing relationships suggest and show the connection between the TMG and primary alluvial aquifer as well as the connection between the TMG and Malmesbury shale aquifer.

The connection between the Malmesbury and alluvial aquifer is not clear, but these two systems must interact as pumping data shows that water can move between the alluvial and Malmesbury aquifer, although this is an interpretation of a single observation borehole, which could have multiple sourced water (Watson *et al*., 2020a). In terms of the dating outputs, the results show that the TMG and the alluvial aquifer is actively recharged, comprised of young water (34-57 years) with the Malmesbury aquifer being mainly comprised of very old groundwater but has not yet been successfully isolated due to mixing.

Getting a better idea of the composition of the Malmesbury aquifer is a critical part to understand this aquifers flow contribution, therefore identifying a borehole that shows limited mixing is important in constraining this. While this has already been done in the Berg River (Harilall, 2020), a more in-depth selection is required for Verlorenvlei.

## 2.6 Aquatic Biota in the Study Area

### *2.6.1. Freshwater Fish*

The study area is a water-scarce region that comprises largely non-perennial and ephemeral river systems. The area thus has a depauperate native freshwater fish ichthyofauna, comprising three recognised fish species, namely the Endangered Verlorenvlei redfin *Pseudobarbus Verlorenvlei*, Data Deficient Cape Galaxias *Galaxias zebratus* and the Data Deficient Cape kurper *Sandelia capensis*. However, ongoing genetic and morphological studies indicate a richer fish fauna, with the International Union for Conservation of Nature (IUCN) recognizing a distinct and Endangered Galaxias lineage from the Verlorenvlei River system. The Verlorenvlei catchment is especially important for freshwater fish conservation at a provincial and national level, as it contains two endemic taxa and both are listed as Endangered.

The rivers of the area also contain non-native fishes, including fish non-native to South Africa (e.g. carp *Cyprinus carpio*, largemouth black bass *Micropterus salmoides*) and non-native to the Western Cape (banded tilapia *Tilapia sparrmani*, Mozambique tilapia *Oreochromis mossambicus*). These fishes were introduced to farm dams in the region and Verlorenvlei for angling purposes more than 50 years ago, as the area only has small native fishes of no angling value.

The nature of the river systems in the area makes them especially sensitive to anthropogenic impacts and climate change which predicts a drier and hotter climate. The area is a winter rainfall area, so rivers flow in winter and early spring. By summer, rivers have stopped flowing and remnant pools remain, which are fed by groundwater and are often teeming with fishes (including large numbers of juveniles) because this is the only habitat available. The extremely hot and windy conditions in summer, combined with the possible unsustainable land use impacts (e.g., excessive water abstraction, including groundwater, river bulldozing, fertilizers entering instream areas) place huge pressures on water availability (e.g., pool depth) and the water quality in remnant pools for the survival of the fish species.

Significantly, the region has already seen the disappearance of a redfin population from the Langvlei River due to unsustainable agricultural impacts, especially excessive water abstraction from this small and highly sensitive water resource. The native fishes should be regarded as excellent indicators of the health of aquatic ecosystems in the region.

The challenge for the region going forward is to promote environmental suitable land use through wise and responsible allocation and use of water resources, to ensure that its unique aquatic biodiversity is preserved for future generations. The study provides a perfect opportunity for landowners, community and scholars to become more knowledgeable about their area.

### 2.6.2. Macroinvertebrates

The macroinvertebrate surveys have primarily been conducted in the Verlorevlei, Langvlei and Jakkals River systems by the DWS as part of the River Health Programme (now the River EcoStatus Monitoring Programme) from about 2005.As expected, the sites in the Mountain Stream Zone and Foothills zones contains macroinvertebrate communities that comprise mostly of more sensitive taxa. Downstream of these zones, there is a steady decline in the integrity of the macroinvertebrate communities occurs that is due to a decrease in the proportion of sensitive taxa and an increase in the proportion of tolerant and air-breathing taxa. These results have remained quite similar for the past 15 years that monitoring has been done on the rivers, only with seasonal variation, decreasing in late summer and being highest in spring.

### 2.6.3. Amphibians

As for the freshwater fishes, the relative dryness of the region results in a low amphibian species richness. A total of eleven frog species are known from or expected to occur in this area, with eight being reliant on the annual inundation of **wetland habitats**.

The amphibians of the study area can be roughly grouped into two guilds, i.e. terrestrial and aquatic lifestyles. The terrestrial guild can be further subdivided according to wetland types that these frogs are specifically associated with, as has been indicated in Table 1 below.

**Table 1: List of amphibian species known or likely to occur in the study area, with their respective IUCN conservation status and ecological guild category**

| Species | Common name | IUCN status | Guild |
|---|---|---|---|
| *Breviceps gibbosus* | Cape Rain Frog | **Near Threatened** | Terrestrial |
| *Breviceps namaquensis* | Namaqua Rain Frog | Least Concern | Terrestrial |
| *Breviceps rosei* | Sand Rain Frog | Least Concern | Terrestrial |
| *Sclerophrys capensis* | Raucous Toad | Least Concern | Endoreic, Riverine, Lacustrine, Palustine |
| *Vandijkophrynus angusticeps* | Cape Sand Toad | Least Concern | Endoreic, Riverine, Palustine |
| *Vandijkophrynus gariepensis* | Karoo Toad | Least Concern | Endoreic, Riverine, Palustine |

| | | | |
|---|---|---|---|
| *Xenopus laevis* | Common Platanna | Least Concern | Endoreic, Riverine, Lacustrine, Palustine |
| *Amietia fuscigula* | Cape River Frog | Least Concern | Endoreic, Riverine, Lacustrine, Palustine |
| *Cacosternum capense* | Cape Caco | **Near Threatened** | Endoreic, Palustine |
| *Strongylopus grayii* | Clicking Stream Frog | Least Concern | Endoreic, Riverine, Palustine |
| *Tomopterna delalandii* | Cape Sand Frog | Least Concern | Endoreic, Riverine, Lacustrine, Palustine |

### *2.6.4. Avifauna*

Verlorevlei and the adjacent Wadrift Pan provide important habitat for birdlife. Key bird species that depend on the two waterbodies are wading birds that utilise the shallow open waters, the rare *Pelecanus onocrotalus* that feed within the waters and large numbers of flamingos (*Phoenicopterus ruber roseus* and *P. minor*) that occur during dry periods. Breeding birds include *Tachybaptus ruficollis, Podiceps cristatus, Phalacrocorax carbo, P. capensis, Anhinga melanogaster, Bubulcus ibis, Platalea alba, Alopochen aegyptiacus, Tadorna cana, Anas capensis, A. smithii, Fulica cristata, Haematopus moquini, Vanellus armatus, V. coronatus, Charadrius pecuarius, Gallinago nigripennis* and *Sterna bergii*. The site is an important moulting area for *Alopochen aegytiacus, Anas undulata* and *A. smithii.* (rsis.ramsar.org).

## 2.7 Socio-Economic Aspects

In 1995, approximately 26 400 people lived in the Sandveld, with the majority of the population living in urban and peri-urban areas. The population outside of these towns is very low. It is unlikely that the population dynamics of the area have changed significantly. On the Knersvlakte to the north of the Olifants River, the population is even more sparse. The average population growth rate for the area is very low (about 0.5%).

Apart from fishing and eco-tourism around the coastal resort towns, potato farming primarily under centre-pivot irrigation systems is the economic mainstay of the coastal plain. Typically, the farms within the Sandveld area are large and the labour requirements are low for the farming activities carried out in the area. To a far lesser extent wheat, mealies, vegetables, rooibos and citrus are cultivated and there is some farming with livestock.

The west coast of South Africa is also well-known for minerals such as gypsum, tungsten, limestone and granite, with large areas of the area, particularly in the F60 catchment being mined.

There is a migration of people from rural areas to urban areas, resulting in higher growth rates in the towns, which vary between 1% and 4%. Population figures and growth rates for the major towns are provided in the table below.

**Table 2: Population figures for the towns in the study area**

| Town | Catchment | Population (2011) |
|---|---|---|
| Elandsbaai | G30E | 1525 |
| Redelinghuys | | 574 |
| Leipoldtville | G30F | 298 |
| Lambert's Bay | G30G | 6120 |
| Graafwater | | 2261 |
| Strandfontein | G30H | 431 |
| Doringbaai | | 1260 |
| Bitterfontein | F60B | 986 |

More recent population statistics from 2016, indicate that the population has increased by 5.8% in Matzikama Municipality, 6.4% in the Cederberg Municipality and 9% in the Bergrivier Municipality. Most of the population is within the age groups 15 to 34 years (about 34.5%) and 35 to 64 years (about 33%) and within the Coloured population group (about 78%).

## 2.8. Key Management Challenges

Some of the management challenges and areas of concern that have been raised for the area that need to be taken cognizance of in the Reserve study recommendations include:

1. There has been a steady increase in a diversity of agricultural activities, particularly within the catchments of the tributaries to the Verlorenvlei;
2. There is a shortage of long-term flow gauging stations in the study area:
3. The flow gauging weir at Het Kruis needs to be replaced;
4. G3H005 in the Hol River at Wittewater Papkuilsvlei (1978 to 1990) has very limited value as no rating table exists for the gauging station
5. G3H002 in the Verlorenvlei at Redelinghuys (1970 to 1972) has only a short data record
6. Level recorder within the Verlorenvlei G3R001 (Active from 1994) is some distance from the mount but cannot show when the estuary mouth is open to the sea.
7. Level recorder at Wadrift G3R002 (Active from 1999) has remained outside of the inundated area of the pan and as such does not provide a record of water levels in the pan.
8. The Western Cape Region has a monitoring programme in the Sandveld, which includes Verlorevlei. This data will be utilised for this study.
9. An approach that considers the water balance of the Verlorenvlei System in particular needs to be taken – such an approach should be supported by a numerical groundwater/surface water model.
10. The legal status of groundwater and surface water use needs to be assessed – a Verification and Validation process has been undertaken for the area that needs to be considered in the assessment of the implementation of the Reserve;
11. The use of boreholes close to spring/wetlands should be identified. The drying out of wetland habitats creates a huge risk of fires occurring in important wetland areas such as Verlorenvlei that may result in complete loss of peat wetland habitat such has already taken place at Wadrift.

12. There is an international obligation to conserve Verlorevlei, with its Ramsar status.
13. Develop buffer/sensitive areas that would be considered S21 c & i water use activities for S21 a - groundwater abstraction activities in close proximity to rivers, due to groundwater surface water interaction.
14. Integration of DWS monitoring data into the regional Sandveld groundwater database should be undertaken to improve the understanding of the groundwater resource.
15. There is a need to control invasive *Phragmites* reed growth in Verlorenvlei.
16. Removal of invasive plants such as *Eucalyptus* trees, *Acacia saligna*, *Acacia Cyclops*, and *Populus* × *canescens*.

# 3. LITERATURE, DATA AND INFORMATION

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## 3.2 Data and Information Gaps

### *3.2.1. Hydrology*

The hydrology developed for the WR2012 will serve as the basis for the hydrological analysis. The WR2012 configurations will be refined and disaggregated where necessary to suitably represent the conceptual understanding of the contributing sub-catchments and points of interest. The WR2012 hydrology covers the period 1920 to 2009. It will be necessary to obtain rainfall data from SAWS to extend the hydrological datasets to the 2019 hydrological year for approximately nine active rainfall stations in the area. There are no active flow gauging stations in the study area. Historical observed flows are available on the Kruismans River at Tweekuilen (DWS flow gauge G3H001 – See **Figure 11**) for the period 1971 to 2005.

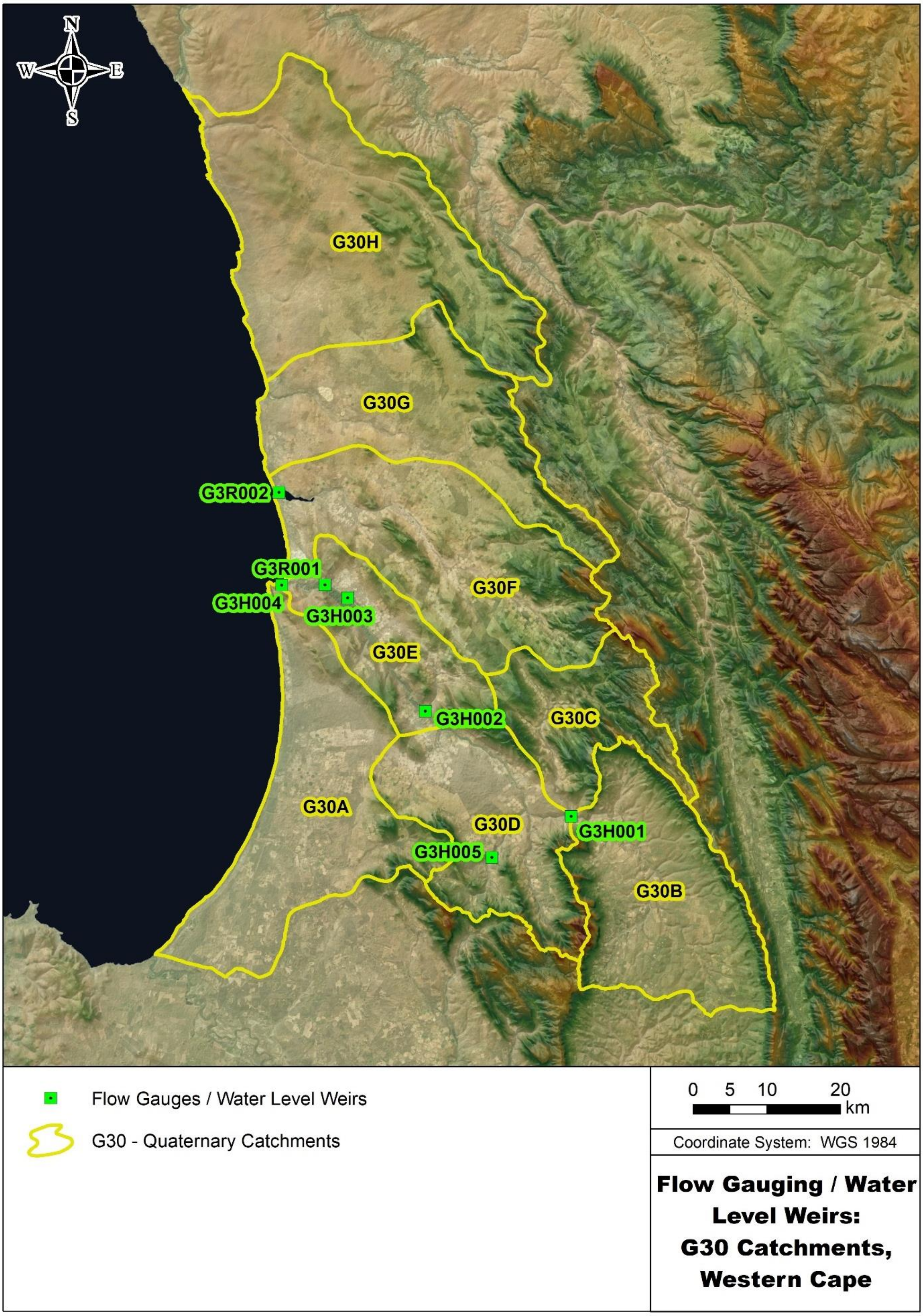



**Figure 12.** Map of surface water flow monitoring sites

An assessment of the data quality of this flow gauge will be made and relevant representative periods of observed flows will be used to validate the simulated flows. The validation of flows will be supported by expert knowledge and conceptual understanding of the surface water in the catchments.

DWS has access to the Mzansi Amanzi (Water South Africa) product by Geoterra Image (https://geoterraimage.com/mzanzi-amanzi/) which may assist with understanding the hydroperiodicity of the systems in the area, and in particular the wetlands. Data will be obtained from DWS: Spatial and Land Use Management.

### 3.2.2. Geohydrology

Lack of data across the F60 sub-catchments can impact the level of certainty of the calculated Reserve. For the G30 sub-catchments, the lack of baseflow monitoring data and the widespread undocumented groundwater abstraction could provide additional complexity. For both catchment clusters, there is a significant lack of information of reference “pre-groundwater development” conditions.

### 3.2.3. Sedimentology and Geomorphology

The main aspects with regards to the required sedimentation studies relate to sediment yields from the catchments and potential changes in sediment loads. These changes due to the construction of instream dams; channel modifications and changes to the composition of bed and bank materials.

The most important documents that are of relevance are:

- The Sediment Yield Map of Southern Africa (Rooseboom *et al*. 1992);
- As there is little data available regarding sediment yields that have been measured within the study area as a whole, there is a great deal of uncertainty regarding sediment yields and loads across the catchments; and
- The channel shape as well as the characteristics of bed and bank materials varies greatly along the rivers in the study area. Sampling sites, as well as sampling procedures, will therefore have to be selected with care.

### 3.2.4. Water quality

Water quality monitoring data is available on the DWS Water Management System (WMS). From an initial examination of the spatial distribution of water quality sampling points in the study area, it appears as if there was a good distribution of points that could be used to describe the spatial changes in water quality in the western portion of the study area with less monitoring data to the east of the study area. A more detailed assessment of the water quality data associated with each monitoring point also reveals that these points were mostly associated with once-off water quality surveys and that the only monitoring points in the G30 tertiary catchment where there is a longer data record, are at the Kruis River Tweekuilen/Eendekuil and the Hol River Wittewater Papkuilsvlei DWS gauging sites, referred to as G3H001 and G3H005 respectively. **Figure 12** shows the water quality sampling sites within the G30 catchment and the number of samples taken at these sites.

At the G3H001 sampling site, some 374 samples were collected from 1970 to 2017, while 102 samples were collected at G3H005 between 1978 and 2017. The Regional Office have indicated that more recent data is available but is not yet captured on the WMS. The project team will liaise with the regional office to ensure the full set of water quality data available for the area is included in the study.

Sampling frequency started at monthly intervals but was later reduced to *ad hoc* sample collection. The historical data record at both sampling stations will therefore be examined for seasonal changes to determine if there are differences in water quality between the wet and dry seasons. There are no long-term water quality monitoring data available in the F60 tertiary catchment.

In summary, although there is a large number of water quality monitoring points registered on the DWS database for parts of the study area, these were mostly associated with once-off surveys or routine sampling that was terminated in the early 1980s. The survey data will thus be used to examine “snap shots” of spatial changes in water quality to better understand how water quality changed along the length of the surveyed rivers. This will add to the knowledge base of water quality behaviour in the catchments.

**Surface water quality monitoring is limited, largely due to the lack of flow in the rivers for most of the year. This is even more so the case in the F60 tertiary catchment. For this reason, water quality data for groundwater and in particular springs in the study area will also be assessed.**

### *3.2.5. Freshwater biota*

*Aquatic Vegetation:* Surveys of riparian and instream vegetation have been undertaken as part of the 2003 Reserve Determination for the Jakkals, Langvlei and Verlorenvlei Rivers by Coastec. Assessments of the riparian vegetation of the above rivers were also undertaken at six sites as part of the River Eco-status Monitoring Programme and in particular informed the Olifants/Doring and Sandveld Rivers: State of Rivers Report, dated 2006. These assessments were before the development of the VEGRAI. No eco-status assessments of the riparian vegetation of the rivers within the F60 Catchments have been undertaken. Additional surveys will be carried out as part of this study.

*Macroinvertebrates:* SASS5 assessments of macroinvertebrates at six sites in the Jakkals, Langvlei and Verlorenvlei Rivers was undertaken from 2004 until recently, as part of the River Eco-status Monitoring Programme. The assessments informed the Olifants/Doring and Sandveld Rivers: State of Rivers Report, dated 2006. The state of river assessments was undertaken before the development of the MIRAI. Additional surveys will be carried out as part of this study.

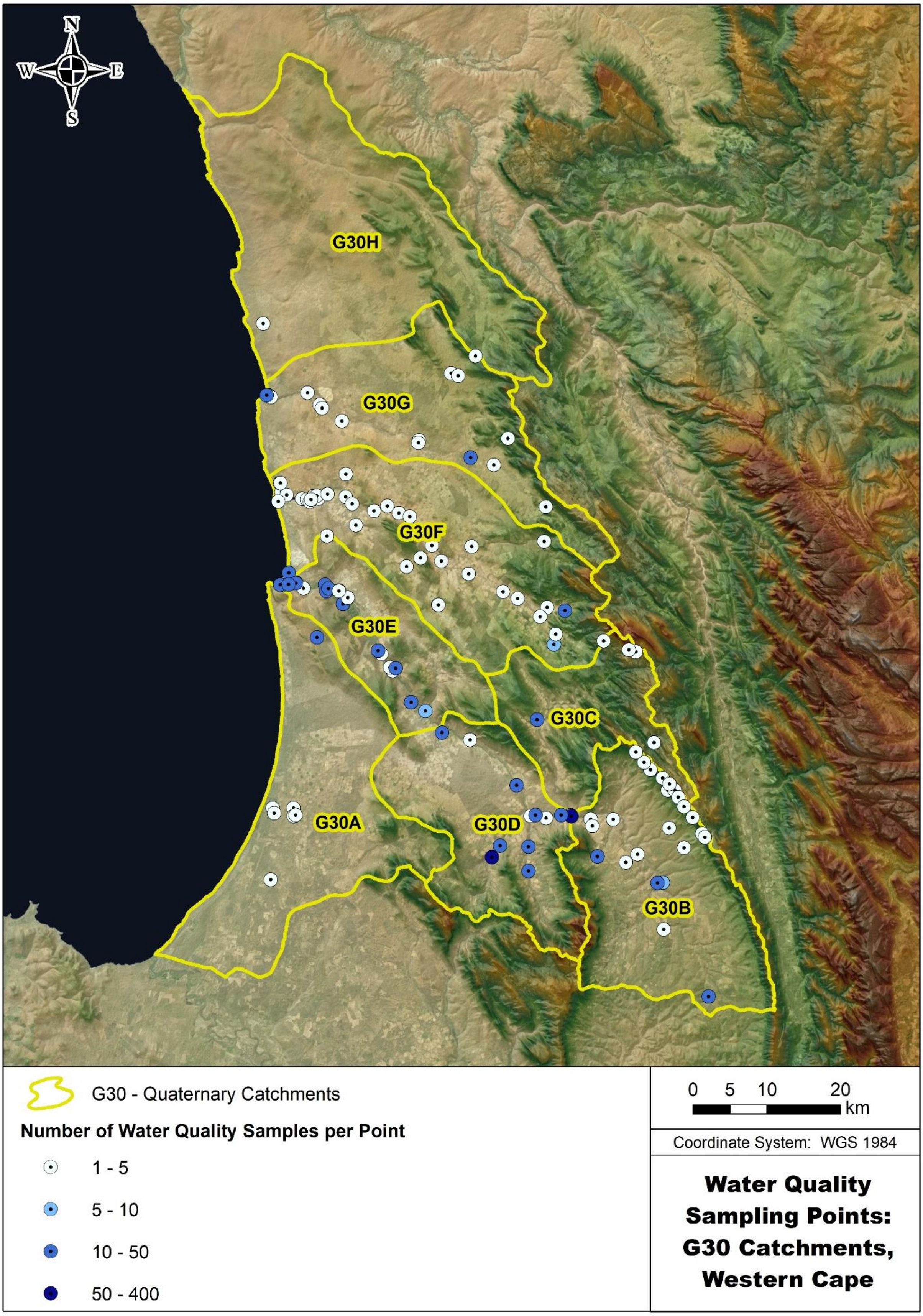



**Figure 13:** Map showing the location of groundwater quality sampling points and the associated number of samples collected at the site

*Fish:* The Verlorenvlei River System has had several fish surveys (most recent in 2015), but the other systems have been poorly surveyed because they are small and have little fish diversity. Additional surveys will be carried out as part of this study.

*Amphibians:* Some data exists for the area. As the study area is a relatively dry region it has a low amphibian species richness. A total of 11 frog species are known from or expected to occur in this area. Additional surveys will be carried out as part of this study.

#### *3.2.6. Wetlands*

Data gaps exist that are specific to wetlands, for example, wetlands in the area have been delineated on a desktop scale and high-resolution delineations are not available. Data on the PES and EIS of wetlands is also lacking.

#### *3.2.7. Estuarine*

*Hydrology and Hydrodynamics:* The level recorder at Verlorenvlei G3R001 (Active from 1994) does not show when the estuary mouth is open to the sea, thus making it very hard to calibrate a water balance model for Verlorenvlei. This will result in a low to medium confidence level EWR study for the estuaries.

*Water Quality:* Very little historical information is available on the water quality of Verlorenvlei, Wadrift, Jakkalsvlei or the Sout Estuary. Some data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS 2017a). This will result in low to medium confidence level EWR studies for the estuaries.

*Microalgae:* No historical information is available on microalgae of Verlorenvlei, Wadrift or Jakkalsvlei. Some microalgae data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017. This will result in low confidence level EWR studies for most of these systems.

*Macrophytes:* No recent macrophyte maps are available for Verlorenvlei, Wadrift or Jakkalsvlei. The Sout Estuary was visited in 2016 as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS 2017a). New macrophyte maps will be prepared as part of this study.

*Invertebrates:* Verily little historical information is available on microalgae of Verlorenvlei, Wadrift or Jakkalsvlei. Some data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS 2017). This will result in low to medium confidence level EWR studies on most of these systems.

*Fish:* Some fish data are available on Verlorenvlei and Jakkalsvlei. Little fish data are available on Wadrift, while the Sout Estuary is hypersaline and does not support fish (DWS 2017a). This will result in low to medium-high confidence level EWR studies on most of these systems.

*Birds:* Some data is available on birds of Verlorenvlei, Wadrift, Jakkalsdrift and the Sout Estuary (e.g., CWAC counts, historical EIAs and DWS 2017a). However, most of these data sets are not time-series and may thus result in low to medium confidence level EWR studies depending on data availability.

# 4. OVERVIEW OF METHODOLOGY AND APPROACH

A Reserve determination study endeavours to provide information at the highest level of confidence possible within the defined time, data availability and financial constraints of the project. These constraints dictate the spatial and temporal extent to which data can be collected and inform the understanding of aquatic ecosystem responses to flow volume and pattern changes. Within such a study, with a one- or two-year data collection period, a picture of the conditions in the ecosystems at the time of the study is formed that may provide greater confidence that the conditions at the time of the study (i.e. PES of the water resource at the EWR site) are accurately recorded and represented. This is of utmost importance is order to set a management condition for the system (REC or BAS) that would remain at the PES or would improve. The data collected will however not indicate the ecological condition or responses at another time under different conditions, i.e. drier or wetter periods.

The Terms of Reference called for a high confidence reserve determination process. However, a lack of data for the water resources in the study area is likely to result in the generic requirements recommended for a Comprehensive Ecological Reserve determination not being met and thus the level of confidence in the assessment may be lower than comprehensive. Clear recommendations with regards to future monitoring of the water resources must be included in the outcomes of this study to rectify this shortcoming.

The river, wetland, estuarine and groundwater component of the Reserve determinations will use the latest RDM recommended methodologies. While the standard methodologies for the determination of the Basic Human Needs and ecological Reserve would be followed in the study. Recognition of the need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers in the G30 and F60 Tertiary Catchment is proposed to be undertaken. This adapted approach is deemed to be necessary to address the following:

- Most of the surface water features within the study area are non-perennial with a hydrological regime that has a high variability in flow both spatially and temporally. This hydrological variability results in a highly unpredictable surface water flow. Surface water ecosystems in these systems are often confined to isolated pools that eventually dry up. The aquatic biota associated with these habitats comprises of hardy species with low diversity, although both the habitat and biota may be of high ecological importance;
- The estuaries within the area comprise mostly of coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems. As a result, they tend to be hypersaline;
- Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) thus needs to take place. A modelling approach is proposed to address this aspect that is discussed in further detail under Section 4.1.4 of this report; and
- The sequencing and interaction between the tasks and disciplines on this project is critical. The products from the groundwater specialists will provide improved understanding of the surface water ecosystems and the delineation of the river reaches and wetland regions Enough time must be set aside to allow for integration. The wetlands component will especially need to provide inputs to and rely on inputs from the Rivers and Groundwater

specialists. Once the priority wetlands have been determined, a key step will be to interact with the specialists to obtain assistance in determining EWRs. The River specialists would also need to have input into the wetland priorities chosen.

The revised generic procedure is provided in **Figure 14** (DWAF, 2008) that shows the process for the determination of the Ecological Water Requirement in the context of the larger Resource Directed Measures process, with possible links to issues such as the stakeholder process, classification, implementation and operation, indicated as suggested ways to integrate the Reserve determination process.

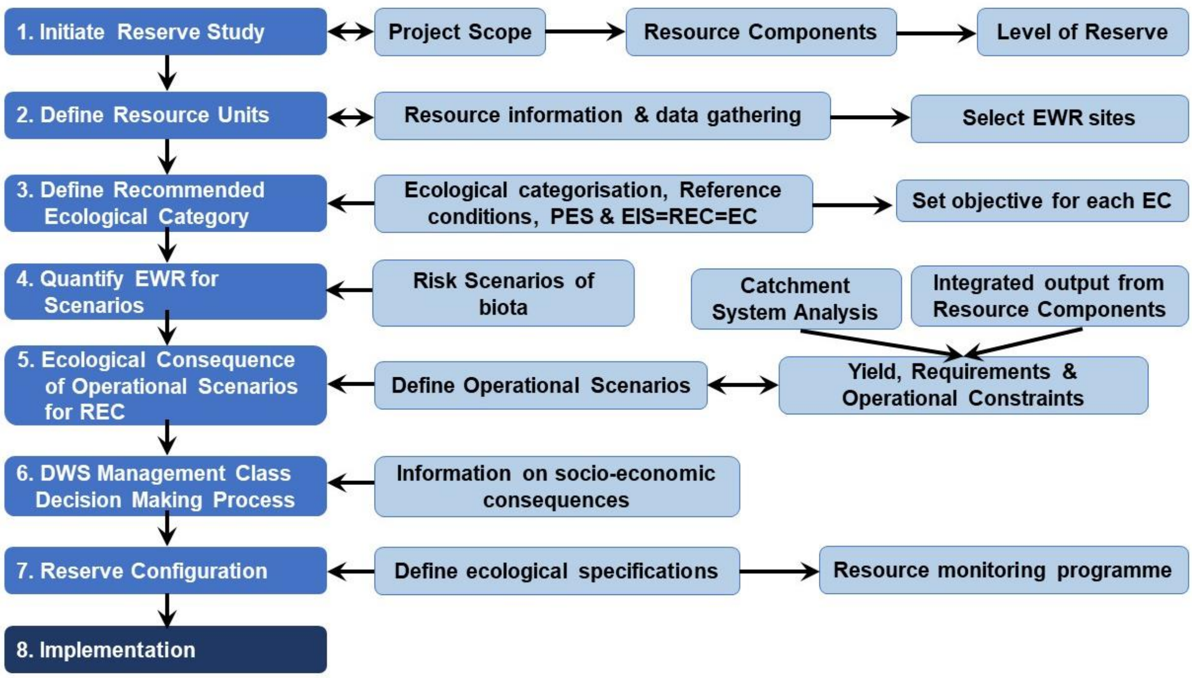



**Figure 14:** The Reserve Determination Process (adapted from DWAF, 2008)

## 4.1 Proposed Approach for the Reserve Determination for Rivers and Wetlands

The riverine quantity Reserve determinations are proposed to be undertaken at an intermediate level for the Verlorenvlei, Langvlei and Jakkals Rivers and at a rapid level for the other rivers in the study area. The wetlands Reserve determinations will be at a rapid level. Because the wetlands within the study area are often closely linked to both the rivers and the estuaries, much integration of specialist work will need to take place. Where possible EWRs for wetlands will be determined, but where this is not possible ecological specifications will be determined.

Specialists proposed to participate in the Reserve determination of the rivers and wetlands within the study area comprised of the following: hydrologist, geohydrologist, hydraulic modeller, water quality specialist, geomorphologist, botanist, freshwater ecologist; herpetofauna, fish and water birds.

A summary of the main activities associated with the Reserve determination is provided below. The proposed methods for determining the Reserve in non-perennial systems will also be considered for the dry ephemeral watercourses in the area. It is envisaged that approximately five river Reserve sites would be selected that can be extrapolated to the remainder of the study area. Rapid Reserve determinations would be undertaken for all the delineated resource units. Higher confidence wetland Reserve determinations would need to be considered in conjunction with the identified river and estuarine Reserve sites. Rapid Reserve determinations will be undertaken for the other significant wetland areas identified.

### *4.1.1. Delineate Resource Units and Selection of Reserve sites*

A series of initial assessments will be made of all river reaches within the study area to guide the choice of representative sites for the rivers and wetlands in the area. For rivers, existing or easily acquired data will be used to define longitudinal zones that differ in terms of channel morphology, water chemistry and temperature; and biological zones for fish, invertebrates and riparian vegetation. The DWS 2014 PES and EIS database will be utilised in the desktop assessment as well as data from the previous assessments. Based on these results, representative sites will be chosen, and the length of the river that each represents delineated.

Within wetland areas specifically, the hydrological drivers (rainfall, surface flow, interflow and/or geological groundwater) and landscape setting will be utilised to define the wetland type. The wetland type/s being assessed may be one or more of the main hydrogeomorphic wetland types (after Ollis *et al.,* 2013) – viz. Floodplain Wetland; Channeled Valley Bottom; Unchanneled Valley Bottom; Seep; Depression; or Wetland Flat. Representative sites and the associated wetland units will then be selected that are representative of the various wetland types within the study area, taking into account regional setting and hydroperiod in addition to hydrogeomorphic type. Peat wetlands, as wetlands of high importance and sensitivity will, in particular, be considered in this initial assessment process.

Sites will be sought with the highest proportion of natural features, as these provide good clues to flow-ecosystem relationships. Compromises will need to be made, as the number and location of study sites may be restricted by budgets and/or time constraints, access to the site, reliability of hydrology and hydraulics that can be generated at the site and the diversity and reliability of ecological cues that are present. **Explanations of the proposed approach to the selection of riverine and wetland EWR sites, respectively, are provided in the following sub-sections.**

### *4.1.2. Section of Riverine EWR sites*

The budget makes provision for seven (7) EWR sites, located throughout the study area, but with the emphasis on the Verlorenvlei River System. The intention is that, where appropriate, data obtained at these sites will be used to calibrate the Desktop model for extrapolation of the results to other hydrological nodes (river reaches) in the study area.

The results of the resource delineation task notwithstanding, we suggest that the EWR sites should be sought on the following river reaches:

- Lower Bergvallei/Kruismans and Lower Krom Antonies and Lower Verlorenvlei River in the Verlorenvlei River System;
- Lower Langvlei River, upstream of Wadrift Wetland and Pan;
- Lower Jakkals River, upstream of Jakkalsvlei;
- Lower Papkuils River; and
- Lower Groot Goerap River, upstream of the Sout Estuary.

The selection of sites for water quantity may not be the same as the selection of sites for water quality as the former are usually chosen relative to major tributary junctions, abstraction points etc, while the latter is usually chosen relative to sources of contamination and data sources. The water quantity sites will be selected at locations where the river is as close to natural as possible and represent a homogeneous section of the river. Where there are major tributaries, a EWR site will be selected upstream of the tributary and downstream on the mainstem. This may mean that the choice and number of EWR sites may not be the same for water quality and water quantity. The water quality sites will as far as possible be aligned with existing water quality monitoring sites of the DWS.

Seven EWR sites have been budgeted for, but the zoning of the river and the choice and number of sites is subject to discussion.

#### *4.1.3. Selection of Wetland EWR sites*

The identification of priority wetlands as potential EWR sites within the study area will be carried out by following the standardised approach recommended by DWS (2016), which entails completion of the following steps:

1. Identify the spatial distribution and extent of wetlands.
2. Identify wetland types based on primary HGM type and vegetation group (or Bioregion).
3. Determine PES and EIS of wetland RUs (on a desktop basis).
4. Identify wetland priorities based on ecological status (which includes condition, importance and sensitivity). Peat wetlands will automatically have a high protection status as a scarce habitat type.
5. Refine wetland priorities by considering other factors, particularly current and expected resource demand and risk of degradation.

The first step will involve the desktop-based mapping of wetlands in the study area. Datasets that will be considered for this mapping exercise will include NFEPA (Nel et al., 2011), the National Wetland Map used for NBA-2018 (Van Deventer *et al*., 2019) and the wetland layer/s of the Western Cape Biodiversity Spatial Plan (Pool-Stanvliet *et al*., 2017) as well as interpretation of available imagery of the study area to improve the mapping of wetlands in the study area. The National Peatland Database (Grundling *et al*., 2018) will also be consulted to determine where potential peatland wetlands are located within the study area. Where it is decided not to include certain wetlands as a priority, reasons will be given.

Wetland types will be assigned based on HGM type (to be determined during the desktop-based mapping exercise) and an appropriate regional grouping to be determined by the Project Team. Possibilities to be considered for regional grouping include vegetation groups (after Mucina & Rutherford, 2006), bioregions (after Rutherford *et al*., 2006) and aquatic ecoregions (after Kleynhans *et al*., 2005), amongst others.

An attempt will be made to model the PES and EIS of the wetlands in the study area on a desktop basis using Version 2 of WET-Health Macfarlane *et al*., 2020) and WET-EcoServices (Kotze *et al*., 2020), if sufficiently accurate land-use and other data can be obtained. Potential land-use data sources include available National Land Cover datasets (from 2014 and 2018), regional land cover datasets (if available), digitisation from 1:50 000 scale topographical maps (following the recommendations of Reinecke et al., 2018), and interpretation of available imagery. Spatial datasets that are of potential relevance to the determination of Wetland EIS will be identified and used for the desktop-based assignment of EIS categories, such as the national map of Strategic Water Source Areas (Nel *et al*., 2013). The Regional office will also be contacted for any additional wetland monitoring taking place in the area.

A map and list of priority wetlands will be generated by applying a set of agreed-upon criteria that will be derived from the criteria used in the following studies, amongst others:

- City of Cape Town's prioritisation of wetlands for conservation (Snaddon & Day, 2009);
- Working for Wetlands strategic planning and prioritisation undertaken for each province (e.g. Gresse, 2017);
- Prioritisation of Resource Units undertaken for the determination of Water Resources Classes and associated Resource Quality Objectives in the Berg Catchment (DWS, 2018a), the Breede-Gouritz WMA (DWS, 2018b) and the Olifants-Doorn WMA (DWA, 2013);
- Application of prioritisation methods in previous studies such as the Upper Vaal Reserve Determination (DWS, 2014); and
- The procedures developed to determine RQOs for wetlands (Bredin *et al*., 2019), which include steps to identify priority wetlands.

A table of the selected wetland sites will be compiled that details how the priority sites were derived based on the criteria selected for the prioritisation process.

Once an initial list of priority wetlands has been generated through this strategic desktop-based exercise, expert stakeholders with knowledge of the study area will be consulted to refine the list before the final selection of Wetland EWR sites.

#### *4.1.4. Hydrological Modelling*

This task involves a review of water resources information and data including all previous studies. From a hydrological perspective, a review of available water resources planning studies, including the availability of the latest water resources models and an evaluation of their applicability, will be undertaken.

An inventory of current water resources models (catchment hydrology rainfall-runoff models, water resource system models, groundwater models, estuary models, etc.) will be compiled and evaluated in terms of their applicability to the Study. Our current understanding is that the WR2012 version of the Pitman Model is the latest available configured model for the study area which are commonly used in Reserve determination studies. There are no active flow gauging stations in the study area.

The latest Water Resources of South Africa study (WR2012) produced long-term simulated monthly stream flows for all quaternary catchments in South Africa. The Pitman Model configurations for the **G30 and F60 catchment** will be sourced from that database. The availability of any more recent study data will be determined during the information assessment task. A gap analysis, relating to data availability and information required to update and configure the hydrological model will be compiled and recommendations will be made.

It is proposed that the WR2012 hydrology for the G30 and F60 catchments be extended from 2009 to 2019 hydrological year to include the 2015/2016 drought period which will be critical in providing up to date estimates of water availability in the catchment. To extend the hydrology, it will be necessary to source South African Weather Services (SAWS) rainfall station data for approximately 9 stations that are still active in and around the study area. This data will need to be obtained from SAWS with the co-operation and support of DWS and DFFE. The rainfall data will be sourced, screened and patched and formatted as required for input to the Pitman model.

Current land use data will be sourced from available datasets, including Cape Farm Mapper and DWS SLIM for an updated the dams layer in this catchment. The irrigation water requirements have recently been estimated using the 2017/2018 crop census for the Western Cape as part of the “Western Cape Integrated Drought and Water Response Plan” study currently being undertaken for the Western Cape Provincial Government. It is proposed that these estimates will be incorporated into the updated configuration of the Pitman model for tertiary catchments G30 and F60.

The WR2012 configurations will be refined and extrapolated to the delineated resource units and EWR nodes in the catchment for which actual observations and data collection is not being collected. It is envisaged that the refined WR2012 dataset will be configured in SPATSIM to better accommodate the application of the conceptual understanding of groundwater and surface water interaction. The latest Reserve Determination Model is also built-in to SPATSIM and this will facilitate the extrapolation process of the Reserve to the study area. The output of the Pitman model will be a monthly time series of natural and current-day runoff at the outlet of each quaternary and the EWR nodes in the required format for input to the Desktop Reserve Model.

**There is a strong surface water-groundwater interaction in these catchments; therefore, it will be important to work closely with the groundwater specialists to gain a deeper understanding of the connections and impacts of groundwater use on surface water availability and to incorporate these in the model configurations where applicable.**

Part of the hydrologist's task is to undertake an analysis of the present flow regime of the river, and of how and when that has changed from the past. The result of the analysis is a summary of the ranges of low flows within each chosen season, and the average number per annum of high-flow events. Flow duration curves (FDCs) derived from the low-flow data sets indicate the variability of the low flows and how often any discharge is met or exceeded.

The simplest way to assess the quantities of water flowing into, through and out of a river and the associated implications thereof is to use a Water Balance model – to balance the wetland inflows, outflows and losses from the system. Section 4.4. and Figure 15 provide further detail on the linkages between models and data used to inform the groundwater-surface interaction understanding.

Specific tasks are:

- Obtain rainfall station data per station per year to extend the existing WRMF dataset from 2009 to 2019 - thus 9 years need to be obtained for approximately 9 stations (probably less);
- Review of water resources information and data gathered primarily from the DWS regional office;
- Review all previous studies incl. Water resource planning, Reserve determination, water quality, socio-economic, augmentation and reconciliation strategies;
- List all available water resource models and evaluate their applicability;
- Undertake gap analysis and compile recommendations;
- Previous Reserve determination studies;
- Source SAWS rainfall data + patching/screening / formatting;
- Source and update hydrology (extend/calibrate);
- Groundwater – Surface Water interaction;
- Delineate to river hydrological nodes; and
- Generate natural and current-day sequences for input to reserve desktop.

### *4.1.5. Hydraulic Modelling*

Conversion of the hydrological statistics is then necessary to provide information on local hydraulic conditions which allows the various specialists to understand why certain aquatic habitats and species occur where they do. The Hydraulics specialist will undertake cross-section surveys and develop stage-discharge rating curves for identified sites in the study area in collaboration with the ecological specialists. The rating curves will be developed by application of the HEC-RAS hydraulic modelling software. An allowance has been made for the survey of five sites including two site visits by two team members, data processing, modelling and reporting.

Graphics of each cross-section will be provided, that show the extent of each vertical zone of riparian vegetation, as well as any other features of interest, such as riffles, secondary channels, sand, or aquatic vegetation. These graphics, together with the hydraulic modelling outputs of velocities and depths will be provided to the specialists to develop an understanding of the links between flow and the features or species of interest.

#### 4.1.6. Water Quality Reserve Recommendations

During the Reserve determination for each EWR site, water quality is divided into three components physical, chemical and biological and will be assessed accordingly. The values of each water quality variable in the un-impacted state or Reference Condition will be derived. These values will be compared to the current water quality (PES) to assess the level of water quality-related modification. These values will also be compared to those required for the Recommended Ecological Reserve Category and the Water Quality Objectives that have been recommended. Mitigation measures, monitoring and management recommendations for the implementation of the water quality objectives will be given.

The Physico-chemical Driver Assessment Index (PAI) model (DWAF, 2008, DWS, 2016) will be utilized where applicable in line with the use of the other assessment indices (HAI, GAI, FRAI, MIRAI and VEGRAI).

The lack of water quality data makes it challenging to determine reference conditions and even more challenging is the fact that both G30 and F60 tertiary catchment have non-perennial rivers linked to wetlands and estuaries with definite wet and dry rainfall seasons with and without interaction with the groundwater and springs in the study areas. Reference conditions will have to be determined by following the non-perennial river methodology as described in Seaman *et al,* 2010, in which the catchment and not only the EWR site is included in the evaluation of the reference condition.

The fact that the rivers are fed from different water resources (groundwater, surface water runoff and springs) does not enable one to confidently extrapolate water quality characteristics from one site to the next. Close cooperation between the specialists from the wetlands, groundwater and rivers is required to understand the flow interaction between the different water resources, as each of the resources can have a different chemical footprint depending on its origin (Seaman *et al*., 2010).

The selection of EWR sites for water quality may not be the same as the selection of sites for water quantity but the water quality EWR sites should correspond to the EWR sites chosen for fish, invertebrates and riverine vegetation and will take into account the existing water quality monitoring sites.

#### 4.1.7. Aquatic Specialist Assessments and EcoClassification Process

Field assessments will be undertaken to determine the Present Ecological state (PES) and Ecological Importance and Sensitivity (EIS) of the rivers and wetlands at each EWR site, as well as to collect critical data to quantify ecological water requirements for the river reach or wetland unit. Field assessments, particularly within this study area will need to be undertaken during the wet winter season or in the early spring when there would be flow in these aquatic features and the timing would be optimal for the collection of biotic data such as vegetation identification as the primary cue for identifying water requirements.

The fish assessment will require the identification of sufficient survey sites on the river systems within the study area that contain suitable fish habitats, to document the present-day fish diversity and population health. These should focus, where possible, on existing sampling sites used by CapeNature and other agencies. Such sites should be surveyed in early summer (November / December) and in early autumn (March). GoPro Video footage and seine and fyke nets will be used for sampling purposes. Where possible, electrofishing would also be undertaken to assist in the fish assessment.

For the amphibians, surveying is best undertaken during the winter/spring months. Prominent wetland units throughout the study area would be selected where data would be collected by listening to frog choruses (sound monitoring) at night and sampling tadpoles. Baited funnel traps would also be set for the aquatic *Xenopus*.

The EcoClassification process will be utilised to determine the PES of various biophysical attributes of rivers relative to the perceived reference condition. **The steps followed are as follows**:

- Determine reference conditions for each specialist field (water chemistry, hydrology, geomorphology, fish, riparian vegetation and aquatic invertebrates);
- Determine the Present Ecological State (PES) for each specialist field and the EcoStatus;
- Determine the trend for each specialist field and the EcoStatus;
- Determine causes for the PES and whether these are flow or non-flow related;
- Determine the Ecological Importance and Sensitivity (EIS) of the biota and habitat;
- Determine the Recommended Ecological Category (REC) for each specialist field as well as for the overall EcoStatus for the site; and
- Determine alternative Ecological Categories (ECs) for each component as well as for the overall EcoStatus to provide various scenarios.

The following index models would be utilized for river ecosystems where applicable: Hydrological Driver Assessment Index (HAI); Geomorphology Driver Assessment Index (GAI); Physico-chemical Driver Assessment Index (PAI); Fish Response Assessment Index (FRAI); Macro Invertebrate Response Assessment Index (MIRAI); and Riparian Vegetation Response Assessment Index (VEGRAI). Adaptations of the methods will be made, where necessary, to facilitate their application to non-perennial rivers in the study area, in discussion and to the approval of the PMC.

The standardised methods for the operationalisation of Resource Directed Measures for wetland ecosystems, as laid out in DWS (2016), will be utilised for wetland assessments. For the priority wetland areas identified, the PES and EIS of the selected systems/sites will be determined using the recently revised versions of the WET-Health (Macfarlane *et al*., 2020) and WET-EcoServices (Kotze *et al*., 2020) tools, together with the procedure developed by Rountree *et al.* (2013) for Wetland EIS determination. Upon completion of the PES and EIS assessments for the wetlands, a Recommended Ecological Category (REC) for each wetland unit will be determined.

#### 4.1.8. Scenario Analysis

The DRIFT – Downstream Response to Imposed Flow Transformation method is a tool developed to facilitate a specialist prediction on how a defined set of flow reductions/additions would change their field indicator species. A series of flow-reduction levels will be decided upon, and a workshop will be held where the various specialists use their collected field data to predict the consequences of the flow reduction scenarios (a range of low flows and the number of flood events). A similar approach would be applied to the priority wetland areas, using the water balance approach to define any changes to water inputs and outputs as well as any changes in the pollution loading to the system that may result.

#### 4.1.9. Management Class Decision-Making Process

Water resource categories have already been proposed for the G30 and F60 catchments (Table 2). These categories will need to be assessed against the findings of the specialist EcoClassification and Scenario Analysis.

**Table 3: Proposed water resource categories in the study area, where A/B = near natural; B=largely natural and C=moderately modified ecological condition**

| Quaternary Catchment | River name | Mainstem / Cumulative Ecological Category | Average Tributary / Incremental Ecological Category | Wetland area (% of quaternary) and Ecological Category |
|---|---|---|---|---|
| F60A | Brak | B | B | 0.001% [1% in A/B] |
| F60B | Klein-Goerap | B | B | - |
| F60C | Soul | B | B | 0.001% [1% in A/B] |
| F60D | Groot-Goerap | B | B | 0.001% [19% in A/B] |
| F60E | Groot-Goerap | B | B | 0.001% [3.5% in A/B] |
| G30A | Papkuils | C | C | 4.1% [35% in A/B! |
| G30B | Kruismans | C | C | 0.9% [10% in A/B] |
| G30C | Bergvallei | C | C | 1.5% [7% in A/B] |
| G30D | Verlorenvlei | C | C | 0.8% [3% in A/B] |
| G30E | Verlorenvlei | B | C | 7.9% [3% in A/B] |
| Estuary(G30E) | Verlorenvlei | C | | - |
| G30F | Langvlei | C | C | 1.5% [5% in A/B] |
| G30G | Jakkalsvlei | C | C | 0.9% [11% in A/B] |
| G30H | Sandlaagte | C | C | 1.4% [25% in A/B] |

#### 4.1.10. Reserve Implementation, Ecospecs and Monitoring

An outcome of the Reserve determination study will also be providing clear guidelines on how it is proposed to implement the Reserve recommendations. Recommendations will also be provided towards the rehabilitation of the aquatic features, particularly where the identified impacts are non-flow related.

Ecological Specifications and monitoring procedures to assess the specifications will be provided by each of the ecological specialists.

A monitoring programme will be designed to ensure that the ecological condition of the rivers and wetlands can be assessed easily and cost-effectively.

## 4.2 Estuary

The Ecological Freshwater Requirement studies on the estuaries will follow the methods as described in DWAF (2008): Resource Directed Measures for Protection of Water Resources: Methodologies for the determination of ecological water requirements for estuaries. Version 2. These are the same as for rivers and wetlands, as described above.

This document sets out the proposed work plan, scheduling of tasks and the budget for the above. The CSIR proposes to undertake this study in collaboration with several organisations and institutions as listed in the Project team. Because the estuarine habitats are also closely associated with the rivers and wetlands in the study area, the determination of the estuarine Reserve will be integrated with the assessments for the rivers and wetlands.

## 4.3 Groundwater

The groundwater resources in the Sandveld have been monitored for several years now by Julian Conrad (GEOSS) from 1995 as well as the Dept. of Water and Sanitation, and the results are becoming meaningful. The substantial collection of data and the understanding of the groundwater resources that have been developed over the years of working in this area will be utilized to determine the groundwater Reserve.

The Reserve determination for groundwater will follow the latest GRD methodologies: An important aspect of the groundwater Reserve for this area is ensuring integration of ground and surface water knowledge and approaches. This aspect is described in more detail in the following section.

The key activities include the tasks described below.

### *4.3.1. Delineate the units of analysis and describe the status quo of the groundwater resource*

Firstly delineate geohydrological response units by identifying lithological boundaries of aquifers and aquitards. For the G30 catchments, geology dictates the flow of groundwater from the mountainous areas towards the coast. Many of the coastal wetlands and rivers are located on large fault systems. Resource units will be defined much like the current quaternary catchments are delineated, although some of the upper inland catchments may be combined with the lower areas if groundwater flow systems connect.

### *4.3.2. Link socio-economic and ecological value and condition of the groundwater resource*

Groundwater nodes and study areas need to be established to predict probable surface water – groundwater areas of interaction, specifically, of groundwater supplying water to rivers, springs, wetlands, estuaries and other terrestrial ecosystems. This will be done by the determination of reference conditions for the catchments. Groundwater level, geological fault systems, location of springs and groundwater contribution to baseflow and wetlands will need to be taken into account.

### *4.3.3. Quantify the groundwater requirements*

Present-day conditions and degree of modification will need to be calculated. This will be done by calculating the current groundwater abstraction volumes. Municipalities do have to measure actual use and the data should be readily available for both catchment groups, although data for the Matzikama Municipality has proved difficult to obtain and this could impact the availability of data for the F60 catchments. Although it has been gazetted that other groundwater users must install flowmeters and monitor their abstraction, this has not been implemented widely and especially for the G30 and F60 catchments. Obtaining accurate abstraction volume for groundwater used within the mining and agricultural sector might prove difficult.

Groundwater levels for the F60 catchments will be reliant on DWS monitoring data that are spaced far apart and could be outdated as current monitoring is not occurring in the area. For the G30 catchments, groundwater level data is available from DWS, the Potato SA monitoring program as well as private farms that monitor their groundwater levels. The data is clustered in certain areas of data gap areas defined towards the north of the G30 catchments.

Groundwater quality data is lacking for the F60 catchments and also limited for large areas of the G30 catchments. Basic chemistry like EC values is more freely available.

### *4.3.4. Assess system and set baseline category*

Aspects critical to the groundwater assessment are determining the level of stress. Indexes or indicators are selected to describe the baseline category and are used in scenarios to describe change. They should cover the main physical and chemical aspects of the system, including issues raised by stakeholders. For the G30 catchments, the focus will be on increased demand for agricultural and municipal use and the effect of this perceived effect of this displayed through long term water level and quality monitoring. Areas with declining water levels will be highlighted. An increase in groundwater development in upper catchments of systems that feed into the Verlorenvlei will need to be considered in detail. For the F60 catchments, the increase in mining activity, as well as municipal demand, will be the focus with less being placed on abstraction for agricultural use that is limited for the catchment.

Stress will need to be defined and allocated per GRU. The groundwater stress index reflects water availability versus water used. Groundwater use should include water utilised by current water users; water required to sustain the Reserve as well as for Basic Human Needs.

### *4.3.5. Level of Confidence*

At this point, it is expected that due to the level of available data, the groundwater Reserve determination for the F60 catchment cluster will be of a Rapid level of confidence. For the G30 catchment cluster, more data is available, but the system is more complex and existing data does not account for real current conditions, the Reserve determination is thus expected to fall under the intermediate level of confidence. These are based on the initial assessment of the available data and the overall geohydrological setting and could change during the assessment. As both the F60 and G30 catchments have a sole dependency on groundwater for most of the basic human and agricultural requirements, the need for a comprehensive reserve determination is clear. The focus will thus remain on obtaining the highest level of confidence during the study. For both catchments, some areas will have higher levels of confidence assigned to them due to the availability of data.

### *4.3.6. Scenario development and recommendations*

This phase will normally be part of the bigger assessment where groundwater has been integrated into the other components of the Reserve. Management recommendations will need to be defined. Factors that will need to be taken into account include Existing lawful use, WUL licences, No influence zones, Conservation of water for irrigation, Municipal demand management, Wellfield and regional monitoring and Cooperative governance. A crucial aspect is the effect of meeting the groundwater contribution to the surface water baseflow required to achieve the REC.

## 4.4 Integration

One of the major problems facing this project is trying to correctly determine the catchment boundary in terms of the groundwater flow characteristics. Thus far a surface water delineated boundary has been used, and from initial estimates, this boundary does not seem to capture the extensive amount and interconnectivity of groundwater in the system. It is presumed that a larger regional groundwater flow might be coming from the south-east and this has already been postulated by Nel, (2005).

A proposed approach to identifying the extent of the groundwater boundary is to consider the isotope composition of water within and outside of the Olifantsriviersberge to constrain this regional groundwater source, or a constant head boundary could be applied to the surface water domain for the model where inflow is occurring. The likely amount of time required to complete this is difficult to predict, but field sampling is required which can amount to at least three weeks worth of work. The model implementation is rapid, but if one were to develop a model which uses a surface water boundary for the surface water components and a groundwater boundary for the groundwater components, some model development is required (estimated at least two to three weeks). The potential for this has already been discussed with the model developer at Jena University (Dr Sven Kralisch) and some ideas of how this can be implemented within the HRU delineation procedure.

A major problem facing the rainfall/runoff model performance as well as the simulation of peak flow is getting a good representation of high-altitude precipitation. While three new rainfall stations have been installed at the confluence of the Hol, Kruismans and Krom Antonies Rivers, the foot of the Piketberg Mountains as well as at Piketberg Bo, the model regionalisation still requires high altitude precipitation adjustment. While a lapse rate adjustment approach has been used for the neighbouring catchment, the Berg River (Watson *et al*., 2020b), the component still requires substantial modification before it can successfully be implemented. In an attempt to get a better representation of the spatial distribution of precipitation for the catchment, the South African Defence Force at Langebaanweg has been contacted and a request was made for the radar data. Through a station bias correction, the secondary radar data has the potential to provide better estimates of precipitation for the high-altitude parts of the catchment.

As part of a recent modelling approach conducted for the Groen River in the Northern Cape, a new river seepage component has been developed and this has shown substantial promise for improving the physical representation of semi-arid and arid conditions using hydrological models (Watson *et al*., 2021). This component has a vast application **for the Verlorenvlei**, given that the rivers are non-perennial and significant transmission losses occur during the first stages of river flow. Furthermore, the seepage and loss of water for the lake itself need to be quantified, to confirm the theory of dominant surface runoff contribution. For this to be done, an indication of the hydraulic conductivity of the sediment within Verlorevlei needs to be constrained. Using a double ring infiltrometer or falling head test, an indication can be made of the saturated as well as unsaturated hydraulic conductivity, which in conjunction with a reservoir component can be used to simulate the water level of the Verlorenvlei. This would include a minimum of 2 weeks of fieldwork and 3 weeks of model implementation and development.

The data required for the project includes the up-to-date daily climate data obtained from SAWS and Agricultural Research Council (ARC) which includes measurements of precipitation as well as temperature (min, max, mean), relative humidity, wind speed, solar radiation or sunshine duration, which would be used to determine reference potential evaporation for the hydrological model. Further fieldwork is also required to download borehole sensors from monitoring wells. While several sensors have been installed as part of a previous project and have been running since 2015, the replacement of these 3 level loggers (R 10 000 each) would be allowed for continuing the dynamic water level measurements, which is important for constraining anthropogenic water use.

Existing are largely models proposed to be utilised (with updates where necessary) to support the team’s understanding of ground and surface water interactions that will allow for more informed EWR recommendations to be made that will have a more integrated approach. **Figure 15** shows the linkages between the models and data used to inform the surface interaction understanding.

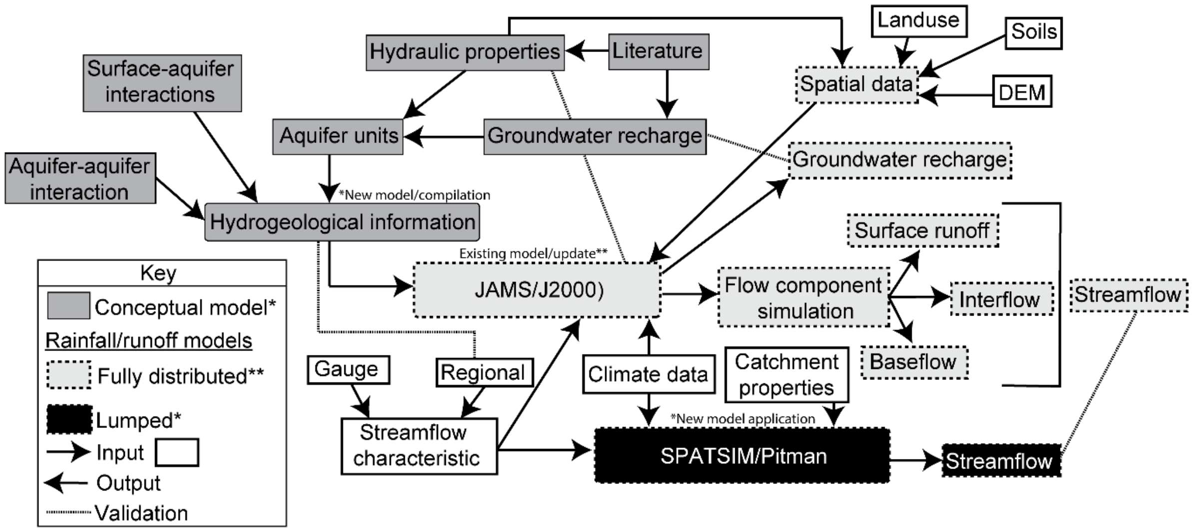



**Figure 15.** Schematic of the linkages between the modelling aspects for the project

## 4.5. Socio-economic

Develop an understanding of the socio-economic profile of the population utilizing the water resources in the study area as well as their use of the water resources. Groundwater is a particularly important source of water for human use in the drier areas of the catchments under consideration. Determination of the groundwater-dependent population in the area will be undertaken.

"The Basic Human Needs Reserve provides for the essential needs of individuals for subsistence or Schedule 1 use, served by the water resource in question and includes water for drinking, for food preparation and personal hygiene. Typically, this is limited to a total volume of water calculated as the population multiplied by 25 litres per person per day. This is applicable where people do not have any water supplied via pipes or water services systems and where people are directly dependant on the water resource for their daily survival.

# 5. PROJECT TASKS AND SCHEDULING

The scope of work to be provided shall be according to the following phases and include but not be limited to the following tasks:

## 5.1 Project Tasks

### *5.1.1. Phase 1 - Project inception*

The inception phase is a critical phase of the project that will allow for the scope of the project to be clearly defined from the onset. This will include:

- An inception team meeting to align team members with the scope and approach for the project;
- An inception meeting with the client to gain a common understanding and agreement on the specific approach;
- Collect background and historical information for the project and update background information;
- List available water resource models and evaluate their applicability to this project;
- Undertake gap analysis and compile recommendations on how to deal with information and data gaps; The gap analysis will specifically need to address the following technical aspects which are most likely underrepresented in past studies:
- ▪ Groundwater classification in areas where aquifers are extensively utilised but do not necessarily make a direct contribution to annual flows of rivers (e.g., Sandveld)
- ▪ Wetland inventories have not been compiled and the condition and importance of wetlands are in general unclear;
- The F60 tertiary catchment area has not been addressed in any of the previous studies;
- Compile a proposed schedule of meetings;
- Compile a proposed capacity building programme and implementation schedule;
- Compile draft inception report for comment; and
- Revise and finalise the inception report.

The inception phase of the project is expected to take three to six weeks as it contains a number of the initial information collection aspects for the project.

### *5.1.2. Phase 2 – Review of water resources information and data gathering*

1. **Review all previous studies and resource models**
    - Collect all previous studies and data
    - Evaluate historic studies and data
    - Conduct a gap analysis to determine data needs
2. **Reporting**
    - Compile draft review report
    - Project management committee meeting
    - Finalise data review report
    - Capacity work session 1
    - Water resource information and data report

#### *5.1.3. Phase 3 – Reserve determination for surface water*

1. **Rivers reserve determination**
    - Draft rivers reserve report
    - Project management committee meeting
    - Review of rivers reserve report
    - External review of report
    - Final rivers reserve report
2. **Rivers reserve reporting**
    - Draft report: Implementation and management proposals for the rivers reserve
    - Project management committee meeting
    - Review of rivers reserve report
    - External review of report
    - Final rivers reserve report

#### *5.1.4. Phase 4 - Reserve determination for Wetlands*

1. **Wetlands reserve determination**
    - Site selections
    - Field data collection - season 1
    - Field data collection - season 2
    - Wetlands Reserve determination workshop
    - Capacity building session
    - Workshop proceedings
2. **Reporting wetland reserve determination**
    - Draft wetland reserve report
    - Review of wetland reserve report
    - External review of report
    - Final wetland reserve report

#### *5.1.5. Phase 5 - Reserve determination for Estuaries*

1. **Estuaries reserve determination**
    - Estuary delineation
    - Field data collection - season 1
    - Field data collection - season 2
    - Estuary Reserve determination workshop
    - Monitoring programme recommendations
    - Capacity building session
    - Workshop proceedings
2. **Estuaries reserve Reporting**
    - Draft estuaries reserve report
    - Review of estuaries reserve report
    - External review of report
    - Final wetland reserve report

#### *5.1.6. Phase 6 – Groundwater Reserve Determinations*

1. **Groundwater reserve determinations**
    - Site selection field visit
    - Field data collection 1
    - Field data collection 2
    - Field data collection 3
    - Current groundwater use determination
    - Determine allocatable water
    - Compile monitoring programme
    - Groundwater integration workshop
    - Capacity building work session
    - Workshop proceedings

2. **Groundwater reserve reporting**
    - Draft groundwater reserve report
    - Project Management Committee meeting
    - Review of groundwater reserve report
    - External review of report
    - Final groundwater report

#### *5.1.7. Phase 7 – Project closure*

1. Final draft technical integration reports
2. Revision of final draft technical reports
3. Compilation of the Reserve legal templates
4. Submission of all documents and project deliverables

## 5.2 Project Scheduling

The Gant charts for the project deliverables and task scheduling are provided in the following tables. The reserve determinations for rivers, wetlands, estuaries and groundwater will be conducted in parallel. The groundwater tasks will continue three months longer than the rest, due to the need to report on the groundwater use and allocatable resource availability.

Each reserve determination discipline will culminate in an integration workshop for the particular resource component. The integration between the resource components will be achieved with the attendance and input of the project leaders of the other disciplines during each of the discipline workshops. A final overall integration workshop will be held during which all discipline leaders will participate.

## Table 4: Gant chart for the reporting, client engagements and key milestones

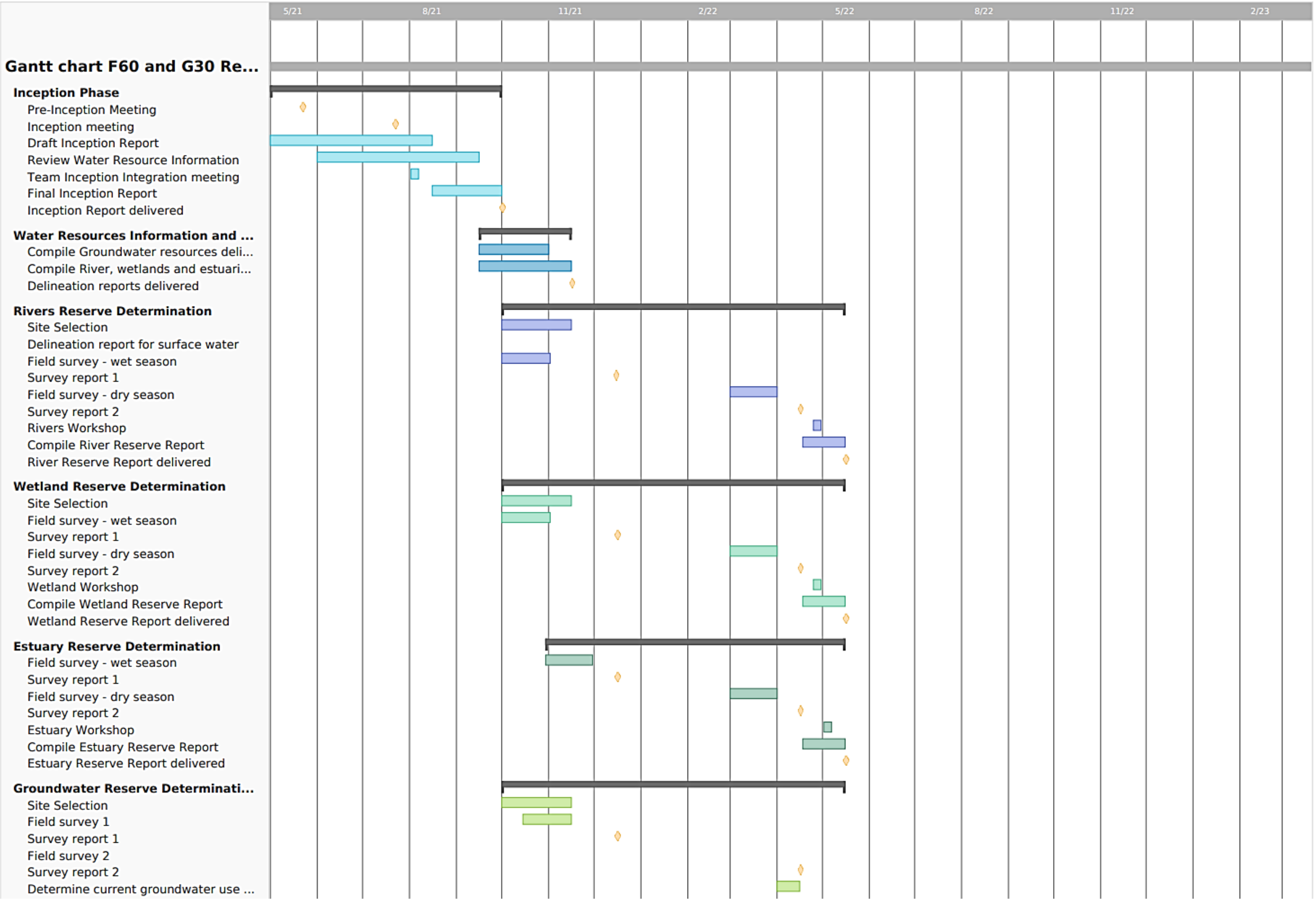
| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task description | Project management and coordination | | | | | | | | | | | | | | | | | | | | | | | |
| Progress reports | | | QR 1 | | | QR 2 | | | QR 3 | | | QR 4 | | | QR 5 | | | QR 6 | | | QR 7 | | | QR 8 |
| Client meeting / Liaison | CM 1 | | | CM 2 | | CM 3 | | | | | | CM - 4 | | | CM - 5 | | | CM - 6 | | | CM - 7 | | | |
| Project management comittee meetings | | | PMC 1 | | PMC 2 | | | | | | | PMC - 3 | | | | | | PMC - 4 | | | | | | |
| Capacity building work sessions | | | | | | CB WS 1 | CB WS2 | | | | | | | | | | | | | | | | | |
| Capacity building work sessions | | | | | | | CB WS 3 | | | | | | | | | | | | | | | | | |
| Capacity building work sessions | | | | | | | | | | | | | | CB WS 4 | | | | GW WS | | | | | | |
| Specialist workshops | | | | | | | | | | | | | | RWS | | | | CB WS 5 | | | | | | |
| Specialist workshops | | | | | | | | | | | | | | WWS | | | | | | | | | | |
| Specialist workshops | | | | | | | | | | | | | | EWS | | | | | | | | | | |
| Technical reports | | | Rep 1 | | Rep 2 | | | | | | | | | | | Report 3 | | | | | | | | |
| Technical reports | | | | | | | | | | | | | | | | Report 4 | | | | | | | | |
| Technical reports | | | | | | | | | | | | | | | | Report 5 | | | Report 6 | | | | | |

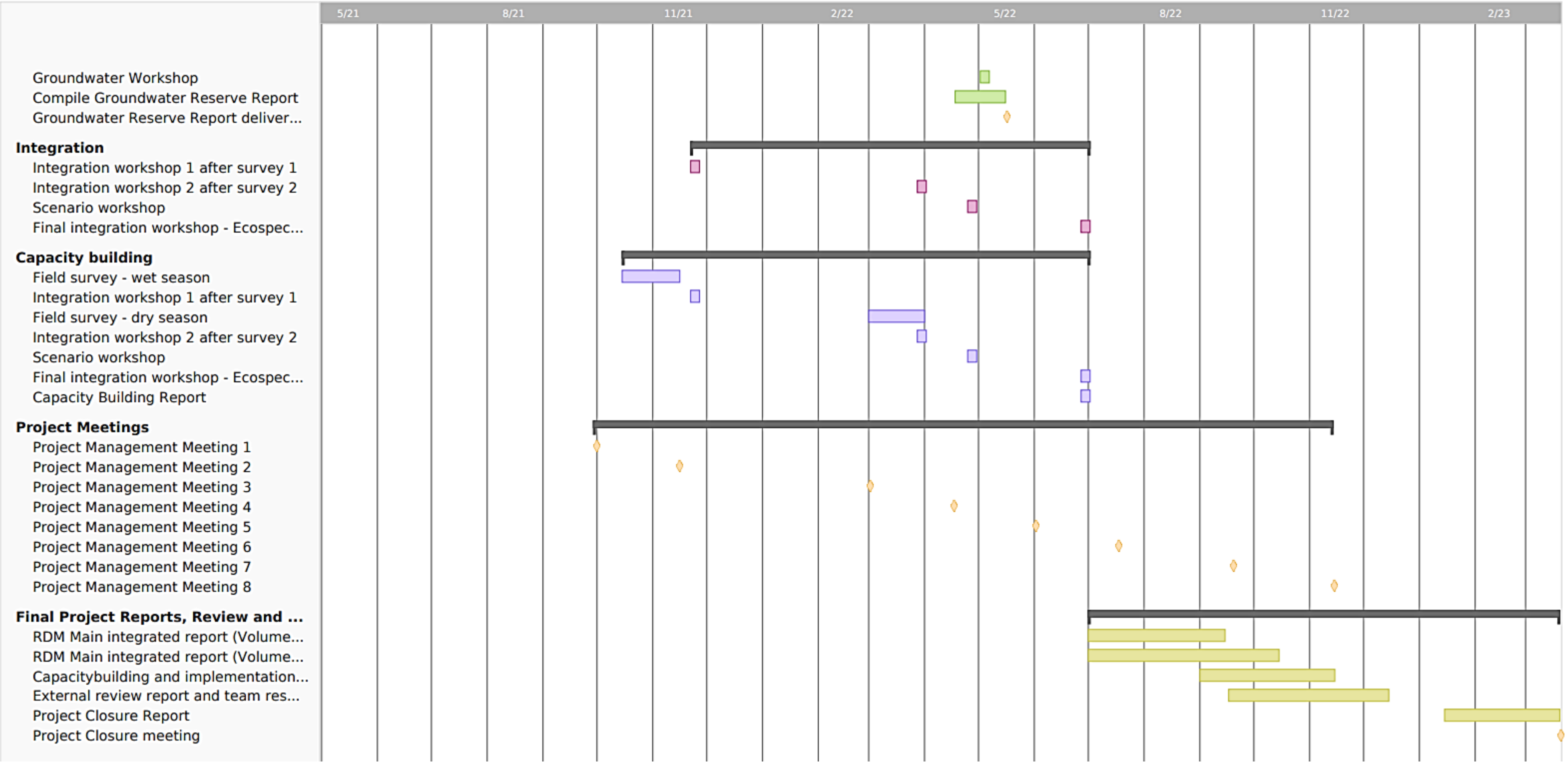
| | | |
|---|---|---|
| QR - | Quarterly report | (8 reports) |
| CM – | Client meeting /liaison | (7 engagements) |
| CB WS - | Capacity Building Workshop | (5 capacity building work sessions) |
| Rep - | Reports | (7 reports) |
| RWS - | Rivers integration workshop | (1 workshop) |
| WWS - | Wetlands integration workshop | (1 workshop) |
| EWS - | Estuarine integration workshop | (1 workshop) |
| PMC - | Project management committee meetings | (8 meetings) |

**Reports:**

| | | |
|---|---|---|
| Report 1 | - | Inception report |
| Report 2 | - | REVIEW OF WATER RESOURCES INFORMATION AND DATA GATHERED |
| Report 3 | - | Rivers reserve determination report |
| Report 4 | - | Wetland reserve determination report |
| Report 5 | - | Estuaries reserve determination report |
| Report 6 | - | Groundwater reserve determination report |
| Report 7 | - | Integration report |

**Table 5: Gant chart of the tasks and scheduling of the proposed work**




5/21
8/21
11/21
2/22
5/22
8/22
11/22
2/23
Groundwater Workshop
Compile Groundwater Reserve Report
Groundwater Reserve Report deliver...
Integration
Integration workshop 1 after survey 1
Integration workshop 2 after survey 2
Scenario workshop
Final integration workshop - Ecospec...
Capacity building
Field survey - wet season
Integration workshop 1 after survey 1
Field survey - dry season
Integration workshop 2 after survey 2
Scenario workshop
Final integration workshop - Ecospec...
Capacity Building Report
Project Meetings
Project Management Meeting 1
Project Management Meeting 2
Project Management Meeting 3
Project Management Meeting 4
Project Management Meeting 5
Project Management Meeting 6
Project Management Meeting 7
Project Management Meeting 8
Final Project Reports, Review and ...
RDM Main integrated report (Volume...
RDM Main integrated report (Volume...
Capacitybuilding and implementation...
External review report and team res...
Project Closure Report
Project Closure meeting

## 6. DELIVERABLES

The following deliverables will be provided:

- Minutes of client meetings and project management meetings;
- Monthly progress reports;
- Interim Technical Milestone reports;
- Inception report;
- Water resource information and data report;
- Rivers Reserve Report and supporting data and notes from workshop discussions;
- Wetlands Reserve Report and supporting data and notes from workshop discussions;
- Estuaries Reserve Report and supporting data and notes from workshop discussions;
- Groundwater Reserve Report and supporting data and notes from workshop discussions;
- Technical Integration Report that will include the Reserve Implementation and Management Recommendations, EcoSpecs and Monitoring Recommendations as well as summarise all the Reserve recommendations.
- Draft Reserve legal templates; and
- Capacity building plan and programme.

Seven formal main Reports are envisaged:

Report 1 - Inception report

Report 2 - Review of Water Resources Information and Data Gathered

Report 3 - Rivers reserve determination report

Report 4 - Wetland reserve determination report

Report 5 - Estuaries reserve determination report

Report 6 - Groundwater reserve determination report

Report 7 - Integration report

Report 8 - Implementation and management proposals for the Reserve

**Table 6: Summary of detailed deliverables and proposed timelines**

| Report number | Task | DWS Due date | DWS commenting due date |
|---|---|---|---|
| 1 | 2.3.1 Draft inception | 15 August 2021 | 31-Aug-21 |
| 2 | 2.3.2 Final Inception report (report that has been review by PMC) | 30 September 2021 | 25-Oct-21 |
| 3 | 2.3.3 Review of water resource information and gap analysis – Report summarising: Rainfall, hydrology, flow, water quality, water level and groundwater data. Summary of preliminary determinations of the ecological Reserve for groundwater, surface water, wetlands and estuaries in the study area. | 16 February 2022 | 28-Feb-22 |
| 4 | 2.3.4 Water resources Delineation report (Volume 1 - Groundwater): Delineation and defining of groundwater resource units and relation to surface water resources | 16 March 2022 | 30-Mar-22 |
| 5 | 2.3.5 Water resources Delineation report (Volume 2 (Rivers, wetlands and estuaries): Delineation and defining of surface water resource units and study sites | 16 March 2022 | 30-Mar-22 |
| 6 | 2.3.6 EWR Site survey 1 report (dry season EWR assessment Surface and Groundwater) | 20 April 2022 | 04-May-22 |
| 7 | 2.3.7 Eco classification report | 04 May 2022 | 18-May-22 |
| 8 | 2.3.8 Ecological Water Requirements: Surface, groundwater, Wetlands and Estuaries Draft reports | 13 May 2022 | 31-May-22 |
| 9 | 2.3.9 EWR Site survey 2 report (wet season EWR assessment Surface and Groundwater) | 21 September 2022 | 07-Oct-22 |
| 10 | 2.3.10 EWR Scenario report – ecological categories and EWRs to achieve ecological conditions. System operations options to achieve scenarios | 12 October 2022 | 28-Oct-22 |
| 11 | 2.3.11 Set ecological objectives (Ecospecs) for each Ecological Category | 26 October 2022 | 09-Nov-22 |
| 12 | 2.3.12 Quantify EWR for groundwater, surface water, wetlands and estuaries related to the REC or EC affected by operational Scenario | 09 November 2022 | 25-Nov-22 |
| 13 | 2.3.13 RDM Main integrated report (Volume 1 -Groundwater) | 30 November 2022 | 15-Dec-22 |

| | | | |
|---|---|---|---|
| 14 | 2.3.14 RDM Main integrated report (Volume 2 (Rivers, wetlands and estuaries) | 30 November 2022 | 15-Dec-22 |
| 15 | 2.3.15 Capacity building and implementation report | 10 December 2022 | 15-Jan-23 |
| 16 | 2.3.16 External review report. Submission of study reports for external review. External review and project et team responses to the review | 10 December 2022 | 27-Jan-23 |
| 17 | 2.3.17 Reserve template | 01 February 2023 | 15-Feb-23 |
| 18 | 2.3.18 Project closure report and meeting | 15 February 2023 | 30-Mar-23 |

## 7. PROJECT TEAM OVERVIEW

The project team consists of four sub-teams of individuals that are working in specialised aquatic and groundwater fields. These sub-teams consist of the following:

- Rivers and Wetlands
- Estuaries
- Groundwater, and
- Integration.

The proposed rivers and wetlands teams consist of the individuals listed in Table 5. A summary of the background and experience of the team members is provided in Appendix A.

**Table 7: Project team members, roles and affiliations**

| Name | Years of experience | Role |
|---|---|---|
| Dana Grobler | 33 | Project Management |
| Toni Belcher | 31 | Ecological assessments |
| Louise Dobinson | 18 | Hydrology |
| Martin Kleynhans | 20 | Hydraulics |
| Dean Impson | 25 | Fish |
| Linda Rossouw | 35 | Ephemeral streams |
| Nico Rossouw | 35 | Water quality |
| Charlie Boucher | 50 | Vegetation |
| Julian Conrad | 30 | Groundwater lead |
| Lizanne Smit | 4 | Hydrogeology |
| Andrew Watson | 17 | Surface/Groundwater modelling |
| Lara van Niekerk | 22 | Estuaries - lead |
| Susan Taljaard | 30 | Estuaries - water quality |
| Janine Adams | 30 | Estuaries - macrophytes |
| Stephen Lamberth | 25 | Estuaries - fish |
| Gavin Rishworth | 10 | Estuarine - birds |
| Tony Williams | 48 | Wetland birds |
| Tony Barbour | 28 | Socio-economic use |
| Marius Burger | 33 | Frogs |
| Dean Ollis | 20 | Wetlands |
| Nantale Nsibirwa | 5 | Hydrology support |
| Yentl Swartz | 2 | River support |

The success of the project is critically dependant on the collaboration between the project team members and the various individuals that are dealing daily with the water resource management functions in the region and proto-CMA. The regional staff members also understand very well the challenges and pressure on the groundwater and surface water resources in the study area. For this reason, the project team will collaborate closely with the regional office and proto-CMA staff members. The collaborating staff members are listed in Table 8.

**Table 8: DWS Western Cape - participation in the G30 and F60 Reserve determination study**

| Name | Surname | Designation |
|---|---|---|
| Melissa | Lintnaar- Strauss | Water Resources Support: Resource Protection |
| Nokulunga | Memela | Water Resources Support: Resource Protection |
| Bentley | Engelbrecht | Water Resources Support: Resource Protection |
| Thembisa | Torch | Berg-Olifants Proto-CMA |
| Sipiwo | Xongo | Berg-Olifants Proto-CMA |
| Rassie | Nieuwoudt | Berg-Olifants Proto-CMA |
| Brian | Dyson | Water Resources Support: Geohydrology |
| Ashton | Van Niekerk | Water Resources Support: Geohydrology |
| Bayanda | Zenzile | Water Resources Support: Geohydrology |

## 8. CAPACITY BUILDING

Capacity building and knowledge transfer is a priority and will be undertaken at various levels within the project. It is suggested that the Resource Protection Measures Section in the Western Cape Regional Office assign at least two members of their staff (ground and surface water). These two staff members would be included in all of the data collection and technical deliberations within the project. In addition, it is proposed that a one to two-day workshop be held with DWS and any other officials working in the area that the DWS feel would benefit from a Capacity building and Knowledge transfer Workshop that would present the findings of the Reserve determination assessments as well as the recommendations on the implementation of the Reserve, possibly using case studies of existing water use authorization applications in the area.

Each key project team member will be joined by a junior scientist from the institutions from which the project team members originate (i.e., the University of Stellenbosch and the University of the Western Cape). The purpose of this team arrangement is to ensure that junior scientists and students are provided with an opportunity to work within the project and to participate in each of the work sessions and integration workshops.

Each workshop will be used as a capacity session and Mr Dana Grobler will compile a curriculum for the project to be executed during the project.

The list of students will be submitted to the DWS for approval. Progress with each HDI participant and seconded DWS regional office staff member will be reported to the DWS.

The use and interpretation of the Reserve determination results in decision making remain a challenge. The capacity building programme will focus in particular on these aspects. The recipients of this component of the capacity building will be primarily the DWS regional and proto-CMA staff members.

The list of key project team members that will have a specific role for mentoring is provided below in Table 8.

**Table 9: Project team members and linked capacity building candidate**

| Name of mentor | Company | HDI | Affiliation of HDI |
|---|---|---|---|
| Dana Grobler | BlueScience (Pty) Ltd | Yentl Swartz | BlueScience (Pty) Ltd |
| Toni Belcher | BlueScience (Pty) Ltd | Nantale Nsibirwa | Zutari (Pty) Ltd |
| Louise Dobinson | Zutari (Pty) Ltd | Nantale Nsibirwa | Zutari (Pty) Ltd |
| Linda Rossouw | BlueScience (Pty) Ltd | Student | UWC |
| Julian Conrad | GEOSS (Pty) Ltd | | GEOSS (Pty) Ltd |
| Andrew Watson | BlueScience (Pty) Ltd | Student | US |
| Janine Adams | NMU | Student | NMU |
| Dean Ollis | BlueScience (Pty) Ltd | Student | UWC / US |

The following members of the DWS will be included in the capacity building initiates of the project:

Barbara Weston – Surface water
Gladys Makhado – Surface water

Bhekisisa Cele – Surface water
Kwazikwakhe Majola– Groundwater
Philani Khoza – Groundwater
Stanley Nzama - Groundwater

Participation of DWS officials (CD: WEM (RDM), Regional Offices) in the capacity building for the project, as listed in Table 8, will ensure that there is active sharing of ideas and contribute to the broadening of the RDM skills base.

# 9. PROJECT MANAGEMENT AND ADMINISTRATION

## 9.1 Project Management Committee (PMC) – Role and function

The purpose of the project management committee is to provide a management mechanism to ensure the management of the study and the execution of tasks identified in the terms of reference for the study. The execution of the project within the approved budget is to be overseen by the PMC. The PMC should also assist with preventing potential conflicts, preventing delays and finding solutions to any projects associated with the project.

**Table 10: List of PMC members**

| Name | Directorate | Designation |
|---|---|---|
| Yakeen Atwaru (YA) | Reserve Determination | Director |
| Barbara Weston (BW) | Reserve Determination | Scientific Manager |
| Gladys Makhado (GM) | Reserve Determination | Scientist Production |
| Bhekisisa Cele (BC) | Reserve Determination | Scientist Production |
| Adaora Okonkwo (AO) | Water Resource Classification | Scientist Production |
| Kwazikwakhe Majola (KM) | Reserve Determination | Scientific Manager |
| Philani Khoza (PK) | Reserve Determination | Scientist Production |
| Dana Grobler (DG) | Blue Science (Pty) Ltd | |
| Toni Belcher (TB) | Blue Science (Pty) Ltd | |
| Lebogang Matlala (LM) | Water Resource Classification | Director |
| Tovho Nyamande (TM) | Source Directed Controls | Director |
| Stanley Nzama (SM) | Reserve Determination | Scientist Production |
| Melissa Lintnaar-Strauss (MLS) | WC Regional Office: Water Resources Support - Resource Protection | Scientific Manager |
| Bentley Engelbrecht (BE) | WC Regional Office | Scientist Production |
| Bayanda Zenzile (BY) | WC Regional Office: Water Resources Support - Geohydrology | Deputy Director |
| Ashton van Niekerk (AvN) | WC Regional Office: Groundwater | Scientist Production |
| Brian Dyson (BD) | WC Regional Office: Groundwater | Control Scientific Technician |
| Xolani Hadebe (XH) | Water Use Efficiency | Director |
| Jacky Jay (JJ) | Water Resource Management Planning Sub-Directorate: Economic and Environmental Studies | Scientist Production |
| Fanie Fourie (FF) | Water Resource Planning System | Scientific Manager |
| Pieter Viljoen (PV) | Water Quality Planning | Scientific Manager |
| Mashudu Murovhi (MM) | CMA | Director |
| Jenny Pashkin (JP) | Water Resource Planning System | Deputy Chief Engineer |

## 9.2 Project Steering Committee (PSC) – Role and function

The PSC is typically a voluntary body operating at a strategic level, and which represents a body of interested and affected parties, affiliated to a specific discipline that could assist with the technical aspects of the study, assist with information available and to obtain outstanding information. Further to this, PSC can assist in reviewing technical aspects of the study, ensure transparency, avoid duplication of effort and aid in establishing an open, consultative, and co-operative governance approach.

Stakeholders representing specific sectors of society (e.g. agriculture, mines, conservation, civil society) will be identified and asked to serve on the PSC for the duration of the project. The PSC members will be key stakeholder representatives that will oversee the project and provide strategic advice and guidance. The PSC will meet at key intervals during the study period to guide and provide input into the project deliverables.

## 9.3 Liaison forums in the study area

### *9.3.1 Verlorenvlei inter-Governmental task team (VIGTT)*

The purpose of the interdepartmental task team is provided in Appendix B.

To enable co-operative governance for a coherent and co-ordinated inter-governmental approach to addressing the environmental quantity and quality concerns in Verlorenvlei estuary and associated wetlands in the catchment area.

The development of an VIGTT acknowledges that the key legal mandates for addressing protection and environmental quality are held by different spheres of government and harnessing this coordinated capacity is essential to addressing the purpose of the TT.

The proposed members of the task team are listed in Table 11.

**Table 11: Verlorenvlei Inter-Governmental Task Team members**

| | | |
|---|---|---|
| **DoA** | Jan Smit | JanS@elsenburg.com |
| **DoA** | Ashia Petersen | ashiap@elsenburg.com |
| **DoA** | Francis Steyn | franciss@elsenburg.com |
| **WCDM** | Charles Malherbe | cjmalherbe@wcdm.co.za |
| **Cedarberg Mun** | Danne Joubert | dannej@cederbergmun.gov.za |
| **CapeNature** | Ernst Baard | ebaard@capenature.co.za |
| **CapeNature** | Elbie Cloete | ecloete@capenature.co.za |
| **CapeNature** | Pierre de Villiers | estuaries@capenature.co.za |
| **CapeNature** | Callum Beattie | cbeattie@capenature.co.za |
| **DWS** | Mellisa Lintnaar-Straus | Lintnaar-StraussM@dws.gov.za |
| **DWS & CMA** | Thembisa Torch | TorchT@dws.gov.za |
| **DWS** | Mashudu Murovhi | MurovhiM@dws.gov.za |
| **DWS** | Debbie Henne | HeneB@dws.gov.za |
| **DWS** | Rassie Niewoudt | NieuwoudtR@dws.gov.za |
| **DWS** | Bryan Dyason | BDyason@dws.gov.za |
| **DWS** | Barbara Weston | westonb@dwa.gov.za |
| **DWS** | Gladys Makhado | makhadog@dws.gov.za |
| **DEA&DP** | Wilna Kloppers | wilna.kloppers@westerncape.gov.za |
| **DEA&DP** | Zayed Brown | zayed.brown@westerncape.gov.za |
| **DEA&DP** | Achmad Bassier | achmad.bassier@westerncape.gov.za |
| **DEA&DP** | Dale Wakefield | dale.wakefield@westerncape.gov.za |
| **DEA&DP** | Helena Jacobs | helena.jacobs@westerncape.gov.za |
| **DEA&DP** | Zaahir Toefy | zaahir.toefy@westerncape.gov.za |
| **DEA&DP** | Zaidah Toefy | zaidah.toefy@westerncape.gov.za |
| **DEA&DP** | Marlene Laros | marlene.laros@westerncape.gov.za |
| **DEA&DP** | Mellisa Naiker | mellisa.naiker@westerncape.gov.za |
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### *9.3.2 Verlorenvlei Estuary Management Forum*

The Verlorenvlei Estuary Management Forum (VEMF) was constituted in January 2011. It is an Estuary Advisory Forum which provides a platform for government bodies and communities to interact and discuss matters relating to Verlorenvlei. It is a good platform for knowledge sharing and garnering public participation. The forum works to and is mandated to fulfil a list of actions, arising from the Verlorenvlei Estuary Management Plan. The following stakeholders make up the Verlorenvlei estuary management forum: Cape Nature, WESSA, BirdLife SA, Landowners, West Coast District Municipality, LandCare, DEA Enforcement: Oceans & Coast, Department of Forestry and Fisheries, Department of Water Affairs and Sanitation, and others.

No Estuary Advisory Forum exist for the other estuaries within the study area. The Municipal Coastal Committee is a possible alternative forum for these estuaries.

# 10. COMMUNICATION AND LIAISON

The PMC has identified two entities with whom the project team will need to engage and liaise. The project team will inform the listed committees of the purpose of the study and will keep the committees informed of the progress of the study.

The distribution of any study results will only be conducted only with the formal approval of the client (DWS).

The study is limited to the determination of the Reserve and broad-scale public consultation will not be conducted by the project team.

# 11. PEER REVIEW

## 11.1 Peer reviewer appointment and process

The appointed service provider will consult with the DWS to nominate and to obtain approval for the appointment of one or two scientific peer reviewers. The complexity of the Reserve determination study and the number of disciplines that are incorporated in the study will render a single peer-review scientist highly unlikely.

## 11.2 Purpose of the peer review process

The purpose of the independent peer-review process is to ensure that the prescribed methods of the DWS were followed and that the results from the study are scientifically sound and defendable from a regulatory perspective.

It is most likely that a peer reviewer for the surface water component and another reviewer of the groundwater component will be appointed.

The PMC indicate that it is important that the peer reviewer be appointed as early as possible to ensure adequate time to respond to input and comments from the reviewer(s).

# 12. DATA STORAGE AND PRESENTATION

## 12.1 Data Storage

Data collected and analyses generated during the study will be properly collated, audited and stored and provided to DWS at the end of the project. Current data storage systems such as the Water Management System and the Freshwater Biodiversity Information System will be investigated for storage of data. Until the data can be suitably storage on a system supported by DWS it should be stored by the project team.

The 2014 PES/EIS database is to be used for Eco categorisation of the river reaches and updated based on the project findings.

## 12.2 GIS

GIS maps and data will be prepared in accordance with DWS latest specifications for electronic spatial data. In accordance with the provisions of the wetland data management strategy, all wetland data and layers that have refined the wetland mapping in the NWM5, will be submitted to SANBI and DWS:RQIS.

# APPENDIX A: SUMMARY OF THE BACKGROUND AND EXPERIENCE OF PROJECT TEAM MEMBERS

## Rivers and wetlands team

### *Dana Grobler – Project manager and habitat integrity and integration*

Dana has **33 years of experience** in various aspects of water resource and water services management aspects in Southern Africa. Dana's career started in the Department of Water and Sanitation (1988 – 1999), and then as an advisory consultant to the Department (1999 – 2004) for the establishment of the RDM functions within the DWS.

Dana was the co-author of the first version of the RDM method manuals which was published in 1999. During the period 2000 – 2006, he has managed many of the comprehensive Reserve determination studies which were conducted by the DWS.

Dana has managed the RDM FETWater capacity building network, which comprised the collaboration of 5 South African Universities and the Flemish Government from 2003 – 2010 (FETWater – framework programme for training capacity building in the water sector in SADC). More than 141 professionals have been trained in this programme and a master's degree programme was developed and later implemented at the University of North West. Dana has been a part-time guest lecturer in the programme since 2018.

He has multidisciplinary skills across the water resource and water services sectors.

### *Toni Belcher – River and wetlands Integration, macro invertebrates*

Toni has **31 years of experience** in the water sector in Southern Africa, which includes specific experience related to the determination of the ecological reserve and the specific study area of the G30 and F60 catchment areas.

Toni has conducted more than 500 freshwater assessments studies as input into EIA decision-making processes. Toni has conducted more than 100 water use license applications.

Development of RDM (Resource Directed Measures) curriculum for a Masters degree programme at University of science institutions in South Africa.

Free State river health monitoring programme.

Classification of the water resources of the Olifants Doorn Water Management Area.

Graphic design, layout, technical compilation and preparation of print-ready glossy publications for the State-of-River reports for the Breede and Berg Rivers South Africa

Adopt-a-River: Eerste River Stellenbosch: training of staff members in river awareness of 50 unemployed people from the Stellenbosch Local Municipality

Development and piloting of a National Strategy to Improve Gender Representation in Water Management Institutions, where the focus is on improving the capacity (specifically amongst women) to participate in water-related decision making.

Compilation of a background document as well as a framework management plan towards the development of an integrated water resources management plan for the Sandveld;

Aquatic specialist to the City of Cape Town project: Determination of additional resources to manage pollution in stormwater and river systems;

Prepare and supply ecological flow requirements to the Department of Water Affairs project: Development of reconciliation strategies for selected towns in the Southern sub-region;

Framework for Education and Training in Water (FETWATER), Resource Directed Measures Network partner which has undertaken training initiatives on environmental water requirements in the SADC region;

Resource Directed Management of Water Quality: Development of training materials, Department of Water Affairs and Forestry; and

More than 200 aquatic ecosystem assessments as input into the environmental impact assessment and water use authorisation processes and providing recommendations on water resource impact mitigation measures primarily in the Western and Northern Cape.

Women in water and education awards

***Dean Ollis – Wetland specialist studies***

Dean Ollis is an aquatic scientist specialising in the ecology of inland aquatic ecosystems (rivers and wetlands). He holds an M.Phil in Environmental Science from the University of Cape Town (graduated 2000) and an MSc in Ecological Assessment from Stellenbosch University (graduated cum laude 2004). Dean has approximately 20 years of experience working in both the academic and consulting sector, having worked at the University of Cape Town (Department of Botany & Zoology, Freshwater Research Unit), the University of the Western Cape (Department of Geography and Department of Earth Sciences), the Freshwater Research Centre NPC (still an active research associate) and as a member of the Freshwater Consulting cc for 12 years. Since March 2019, he has been conducting consulting work as a sole proprietor, trading as "Inland Waters Consultancy".

Dean is involved in a mix of consulting work, research, and teaching and capacity building. He has a particular interest in the testing and development of methods for the assessment of inland aquatic ecosystems, having been centrally involved in the development of a classification system for wetlands and other inland aquatic ecosystems in South Africa, and the development of a refined suite of tools for the assessment of the Present Ecological State (PES) of wetland ecosystems (culminating in the publication of WET-Health Version 2).

Dean remains actively involved in teaching and capacity building, including the running of a post-graduate module on the Management of Inland Aquatic Ecosystems at the University of the Western Cape in 2019 and 2020. He has also assisted with the running of short courses on the SASS5 aquatic invertebrate sampling method (with the Freshwater Research Centre) and the fieldwork component of the "Tools for Wetland Assessment" short course (coordinated by Rhodes University in association with Ground Truth Consulting). Dean is a member of the South African Wetland Society (previously a Board Member) and the Southern African Society of Aquatic Scientists, as well as a registered Professional Natural Scientist with the South African Council for Natural Scientific Professionals (SACNASP).

***Dr Andrew Watson – Surface water modelling***

Andrew has a broad background in science holding a BSc, Honours and Master's degree in Hydrology from the University of Kwa-Zulu Natal. He has modelling experience with J2000, MODFLOW, Pitman, ACRU, SCS, HYDRUS and experience with isotope fingerprinting. During his PhD (Earth Sciences, Stellenbosch University) he specialized in the use of hydrological and hydrogeological models to improve understanding of river flow dynamics in water-stressed semi-arid (ephemeral) environments. His studies have focussed on the Verlorenvlei, where he has been working for the last 5 years and have developed several new modelling solutions. Furthermore, his research is focusing on understanding drivers of runoff change for the area, by quantifying the impacts of climate and land-use change on water resources.

***Louise Dobinson – Hydrological specialist studies***

Louise is a hydrology specialist who is primarily involved in water resources projects, focussing on catchment hydrological modelling and streamflow assessments as well as system modelling, including yield analysis and planning. She also has experience in working on environmental impact assessments (EIAs), reserve determination studies, flood risk assessments and hydrological assessments of water resource schemes. She has been involved in the Reserve determination for the Olifants Doorn, RQO for Berg, RQO for the Breede Gouritz and various smaller projects involving the application of hydrological models.

***Martin Kleynhans – Hydraulics engineering specialist***

Martin is a civil engineer with **18 years** of experience. His expertise includes water resources planning, flood hydrology, river hydraulic modelling including environmental hydraulics and flood modelling, engineering in rivers and wetlands, design and construction supervision of large hydraulic and flood protection structures, stormwater modelling and water resources systems modelling. Environmental hydraulics projects he has been involved with include hydrodynamic modelling of the Nylsvlei floodplain for impact assessment and determining eco-system services delivered by the wetland; writing a chapter on river rehabilitation for a guide to environmental hydraulics in South Africa; acting as the hydraulic expert in a research project to determine vegetation zones on river banks correlated to river flow regimes, and acting as the hydraulics expert for the determination of the environmental water requirements on several rivers including the Limpopo, Mzimkhulu, Mzimvubu and Senqu Rivers.

***Nantale Nsibirwa – Hydrology support***

Nantale is a hydrologist and she has a detailed understanding of the fundamental components that make up the hydrological cycle, with a good knowledge of current topics in environmental hydrology. She has advanced hydrological modelling skills to aid water resources management investigations and has a good understanding of the key concepts and theories in environmental management. Furthermore, she has an advanced insight into Geographical Information Systems (GIS) and its applications. Nantale holds an MSc degree in Hydrology from the University of KwaZulu-Natal, South Africa. She also completed a BSc (Hons) Hydrology degree and a BSc Hydrology and Geography degree from the same institution.

***Dr Linda Rossouw – Ephemeral streams and water quality***

Linda has three decades of experience working as a Water Quality and Environmental Specialist on river and reservoir systems in Southern Africa. She specialises in water quality assessments, water quality monitoring, environmental impact assessments, water quality and ecological reserve determinations and project management.

Linda is responsible for managing water quality and other environmental-related projects and tasks on integrated water resource development and research projects. Linda's key strengths are concentrated on extensive experience as a discipline lead for surface water quality investigations, assessments and management; catchment-scale water quality assessment and management; eutrophication assessment and management; guideline development for water quality management; design of water quality monitoring and information systems; assessment of the impacts of new developments on surface water quality; and training client staff in water quality monitoring and assessment. She has also been responsible for the management and execution of environmental impact assessments and environmental impact management.

Linda holds a PhD degree in Environmental Management from the University of the Free State (2012). She obtained her Masters degree in Limnology (1985), her Honours degree in Zoology (1980) and her Bachelor of Science in Zoology, Botany and Biochemistry (1979) from the University of Johannesburg, South Africa. Linda is registered as a Professional Natural Scientist with the South African Council for Natural

Scientific Professions (SACNSP). She is also a fellow member of the Water Institute of Southern Africa (WISA) and a member of the Southern African Society of Aquatic Scientists (SASAqS) and IAIAsa.

***Nico Rossouw – Water quality specialist***

Nico is a water quality specialist with more than three decades of experience working on river and reservoir systems in Southern Africa. He specialises in water quality assessment, water quality modelling, water quality management and water quality decision support systems (DSSs). His key strengths are concentrated on extensive experience as a discipline lead for reserve water quality determinations being a key member that developed and refined the reserve water quality protocols, surface water quality investigations, assessment & management; catchment-scale water quality assessment and management; modelling water quality in rivers and reservoirs on a catchment scale; hydrodynamic water quality modelling of reservoirs; eutrophication assessment and management; guideline development for water quality management; design of water quality monitoring and information systems; assessment of the impacts of new developments on surface water quality and training client staff in water quality monitoring and assessment.

Aside from his project experience in South Africa, Nico has gained valuable experience working on projects in the Western Cape, specifically the Berg, Breede and Olifants River catchments. He is regularly called on to provide training to client staff in water quality assessment and management, resource water quality objectives, water quality modelling, etc. He is also an invited lecturer at the University of the Free State on water quality and limnology.

Nico obtained a Master of Science in Limnology from the University of the Free State (UFS) in 1986 as well as a Bachelor of Science (Honours) in Zoology in 1980 and a Bachelor of Science in Zoology and Biochemistry in 1979, both from the University of Johannesburg. He is registered as a professional natural scientist with the South African Council for Natural Scientific Professions (SACNASP). He is also a fellow of the Water Institute of Southern Africa (WISA) and a member of both the South African National Committee on Large Dams (SANCOLD) and the Southern African Society of Aquatic Scientists (SASAqS).

***Dr Charlie Boucher – Specialist vegetation studies***

Charlie Boucher has more than fifty years of botanical, ecological and vegetation survey research experience. He is a specialist in Southern African riparian and wetland vegetation ecology, of the littoral vegetation of South Africa and the general vegetation of southern South Africa. Experienced in the rehabilitation of vegetation in the Cape. Undertaken research into Cape endemic plants, rare species, utilizable species, invader problem plants and riparian & wetland vegetation zonation patterns through South Africa and Lesotho. Nineteen years full-time lecturing experience presenting numerous courses and guidance annually to 1st, 2nd, 3rd, honours, 23 masters and six PhD students. Specialist consultant to the South African and Western Cape Provincial Government and private firms on selected environmental issues requiring botanical ecological expertise.

### *Dean Impson: Fish specialist studies*

Dean Impson has an MSc in Ichthyology and Fisheries Science from Rhodes University (1988) and has more than **25 years** of working experience as CapeNature's fish scientist when he was based in its Scientific Services section at Jonkershoek outside Stellenbosch. During this time, he undertook several fish surveys across the Western Cape Province and produced as the senior author or co-author over 150 publications (scientific, semi-scientific, popular)(see CV). Dean also has given 34 presentations at scientific conferences in South Africa and internationally. Most of these publications and presentations have dealt with freshwater fish conservation and management.

Dean worked closely with DWS in the River Health Programme in the Western Cape from 2000 to 2010. This led to the publication of at least seven State of the River reports, where Dean contributed to the fish section. He has been CapeNature's representative participating in stakeholders meetings of several reserve studies undertaken in the Western Cape, including the Olifants-Doring. He also participated as a steering committee member in several Water Research Commission projects between 2000 and 2019.

Dean took early retirement from CapeNature in July 2020 and now works as a consultant based in Somerset West.

### *Marius Burger – Amphibian specialist studies*

Marius Burger has more than **33 years** of experience in faunal and amphibian work in Africa. Marius has compiled more than 130 faunal specialist reports for various environmental consultancies and biodiversity projects. He has published 44 scientific peer-reviewed papers, 75 semi-scientific and popular articles, authored/edited three books, 34 chapters/accounts in books, and presented 50 papers/posters at national/international symposia. Marius is an extraordinary Lecturer with the African Amphibian Conservation Research Group, Unit for Environmental Sciences and Management, North-West University (2015 – present).

### *Dr Tony Williams – Wetland bird specialist studies*

Tony Williams has been a professional ornithologist since 1973 and sole or co-author of >110 peer-reviewed scientific papers. Tony is a specialist avian scientist in nature conservation organisations in Namibia and South Africa for the 25 years prior to his retirement.

## Estuaries team

The estuarine project team were selected for their experience in the application of EWR method for estuaries, as well as their knowledge of the systems in the region. They will be able to assess the appropriateness of the prescribed methodologies in circumstances that varies from pans, coastal lake to true estuarine systems. The estuarine team consists of the following key members:

### *Dr Lara van Niekerk – Estuary team leader*

Lara van Niekerk specializes in the hydrodynamics of estuaries and has been involved in over **50 EWRs** on estuaries, as a project leader and specialist. Lara van Niekerk specialises in the physical dynamics of estuaries; estuarine condition assessments; environmental flow requirements; and estuary management and policy. Lara led the team of specialists the assessed the health and ecosystem condition of all of South Africa's estuaries as part of the National Biodiversity Assessment 2018 and 2011. Lara is part of a core team that develop environmental flow requirements technologies for South Africa, e.g., Version 1, 2 and 3 of the EWR methods for estuaries. She also led the project that developed the desktop assessment of South Africa's estuaries.

Lara has played a leading role in defining and delineation the 'Estuary Functional Zone' and incorporating it into South African legislation. As well as developing an 'Estuarine Ecosystem Classification' for 290 estuaries and 42 micro-estuaries. She was also involved in understanding the impact of climate change on estuaries and was the lead author of South Africa's estuarine chapter in 3de National Communication on Climate Change. Lara played a lead role in the development of the generic framework for estuary management plans as part of the GEF funded CAPE Estuaries Programme 2005 - 2010. She also formed part of the core team that wrote the Guidelines for the Development and Implementation of Estuarine Management Plans in terms of the National Estuarine Management Protocol for the Department of Environment Affairs in 2015. She has also been involved, or led, 5 Estuary Management plans, e.g., Verlorenvlei, Goukou, Klein Brak, Bot, Klein.

Lara is the author/co-author of 32 papers in national or international journals peer-reviewed and more than 70 scientific reports. In addition, Lara, in collaboration with this team, has developed and present the Estuarine Management Training module for South Africa (accredited through Nelson Mandela University by Prof Adams), which has trained over 250 practitioners in government and civil society. She also helped developed and present the Estuarine Monitoring Course aimed at particle improvement of South Africa measurement capabilities.

### *Dr Susan Taljaard – Estuary water quality*

Dr Susan Taljaard specializes in coastal and estuarine water quality and management, practising in these fields for more than **30 years**. She is actively involved in applied research on the biogeochemical characteristics and processes of coastal systems, specifically estuaries, and the responses to global change pressures and has published over 30 peer-reviewed journal articles on related matters. Susan is also involved in the design and application of coastal and estuarine management plans and best practice guides, for example, she was project leader for South Africa's National Programme of Action to protect the marine environment from land-based activities – a project commissioned by the Department of Environmental Affairs. Susan is part of the core team that developed the ecological water requirement (EWR) methods for estuaries since 1999 and also played a lead role in the development of the generic framework for estuary management plans as part of the GEF funded CAPE Estuaries Programme. She has been involved in numerous EFR studies (>20) in South Africa, as a water quality specialist but also as a coordinator of estuarine components.

***Prof Janine Adams- Estuary vegetation***

Prof Janine Adams is a botanist with expertise in the environmental flow requirements of estuaries. She is a National Research Foundation rated scientist, has published over 130 scientific papers in peer-reviewed journals and supervised 20 MSc and 20 PhD studies. In 1999 Janine led the group that was responsible for the development, testing and publishing of methods for determining the environmental flow requirements of estuaries to allow the implementation of the National Water Act. Janine has strong ties with the Resource Directed Measures Directorate of the Department of Water and Sanitation and has managed several environmental flow requirement studies on estuaries.

***Project team experience (estuaries)***

Collectively the proposed project team has extensive experience in EWR studies for estuaries and the application thereof. Various members on the project team have experience in managing, or making specialist contributions to EWR and/or Classification studies (e.g. Gouritz WMA EWR, Mvoti to Mzimkulu Classification, Olifants estuary RDM, Orange estuary EWR). Other project experiences related to estuary management and water requirement studies include:

**Development of a method for the determination of ecological water requirements in estuaries (1999 to 2012)**

The project team, in particular Lara van Niekerk, Dr Susan Taljaard, Prof Janine Adams and Dr Stephen Lamberth, has been part of South Africa's core team that developed and revised South Africa's EFR methods for estuaries, in studies commissioned by South Africa's Department of Water and Sanitation (DWS) and the Water Research Commission. The methodology required standardised estuarine health assessment procedures, considering looked at hydrology, hydrodynamics, water quality, habitat/sediment, microalgae, macrophytes, invertebrates, fish and birds. Version 2 is currently officially being applied in South Africa (RSA DWAF, 2008).

**Development of a generic framework for Estuary Management Plans (2007, 2009, DEA 2015)**

The CSIR, with contributions from various lead authorities, were responsible for the development of the proposed National Estuarine Management Protocol (Van Niekerk and Taljaard 2003) which is now a requirement under South African legalisation (National Environmental Management: Coastal Zone Act. The National Estuarine Management Protocol follows an adaptive management approach which requires: 1) the setting of strategic vision and management objectives, 2) the development of management strategies,3) the implementation of the strategies, 4) the monitoring of the estuary and 5) an evaluation or assessment of the results.

**Proposed National Estuarine Management Protocol for South Africa (2007)**

The National Estuarine Management Protocol also calls for the development of Estuarine Management Plans. The CSIR was the project leader for the development of the Generic Framework for Estuarine Management Plans and estuarine management guidelines for the C.A.P.E. Estuaries Management Programme, e.g., C.A.P.E. Estuaries Guideline 1: Legislation about Management of Environmental Threats within Estuaries (Van Niekerk and Taljaard 2007).

**Development of resource monitoring procedures for estuaries (2003)**

In addition, the CSIR was the project leader for the development of the Resource monitoring procedures for estuaries for application in the Ecological Flow Requirements studies and implementation process (Taljaard *et. al.* 2003). The monitoring procedures provide the ideal starting point for the development of the generic monitoring procedures as they are broad enough to allow for the impacts of all potential pressures on the estuaries to be monitored.

## Groundwater team

GEOSS has been involved within the Sandveld for 25 years, with BlueScience also being involved in freshwater studies and public participation meetings during this time, with the University of Stellenbosch having used the Sandveld as a detailed research site intensively for the past 10 years.

The groundwater components of the reserve determination study will require exceptional insight and application of solution-orientated thinking to enable the application of methods and use scenarios to be able to produce a useful output to determine baseflow contributions and current stress concerning groundwater use. The groundwater project team consist of the following key members:

### *Julian Conrad – Groundwater team leader*

Julian is a hydrogeologist and has been working in the field of geohydrology for **30 years.** Julian has also been involved in the geohydrological assessment of the Sandveld (G30 catchments) since 1995. This included the establishment of Groundwater Reserves in 2003, working closely with DWS on the project. He has been involved with groundwater supply to the 5 towns of the area and his involvement continues in the region with Water Use Licence Applications and ongoing groundwater monitoring for Potatoes South Africa. Julian has also been involved in mining projects and groundwater supply projects within the F60 catchments as well.

Julian was with the CSIR for 11 years (1990 – 2001) and in 2001 established the geohydrology and Earth Science consultancy, GEOSS.

The extensive list of groundwater projects that were undertaken in the study area by GEOSS is provided in the attachment to this proposal.

### *Lizanne Smit – Hydrogeologist*

Lizanne is a hydrogeologist and has been working in the field of geohydrology for **4 years.** During this time, she has been involved in multiple groundwater assessments, monitoring and supply studies within the Sandveld area. She has worked with both the farmer and the municipal sectors within the G30 area. She holds a BSc (Hons) in Economic Geology from Stellenbosch University.

Her relevant experience includes the following:

- Groundwater Licensing projects: this included fieldwork, hydrogeological investigations, Section 27 report writing, engaging with DWS and submitting on the eWULA Authorisation system (including integrated license applications).
- Municipal Supply and Management projects: this entailed community and landowner meetings, data collection, organization of drilling and overall project management through engaging with the different stakeholders. Municipal staff training, writing groundwater management plans and geohydrological reports as well as consolidated progress and impact reports.
- Numerical Modelling projects through data collection, constructing a conceptual model, setting up a numerical model, steady-state and transient calibration, running different abstraction scenarios and compiling a comprehensive report.
- Groundwater monitoring projects: this included hydrocensus work, assessment of current systems and infrastructure, development of a monitoring plan and network, GIS mapping and report writing.
- Drilling and yield test projects: this included on-site drilling supervision, core logging, constructing borehole logs, yield test management and analysis with findings outlined in a subsequent comprehensive report.
- Groundwater impact assessment projects entailed sampling, data analysis and setting up a risk matrix to quantify risks involved and outlining mitigation measures in a comprehensive report.

### *Hendre Henn – GIS Specialist*

Hendre is a GIS Specialist and has been working in the field of geohydrology for **4 years.** He holds a BSc (Hons) in Geoinformatics from Stellenbosch University.

His key skills include the following:

- Background in Geographical Information System (GIS) concepts, including satellite remote sensing technology (LiDAR and Aerial Imagery).
- GIS software experience include ArcGIS, ENVI, eCognition, Geomatica, QGIS, FUSION (LiDAR) and Aquabase.
- General experience of Python and RStudio, and basic Java programming abilities. Other software skills include Microsoft Office packages, particularly Word, Excel and PowerPoint.
- Web development skills include working with HTML and CSS, with basic Javascript knowledge, as well as generic Django Python Web framework experience.
- Database design skills include Python (including various libraries) and SQL to explore and analyse data.

## Socio Economics

### *Tony Barbour – Socio economic specialist*

Tony Barbour has 28 years' experience in the environmental sector. His experience includes ten years as an environmental consultant in the private sector in South Africa followed by four and a half years at the University of Cape Town's Environmental Evaluation Unit. In 2004 he established his own environmental consulting company, Tony Barbour Environmental Consulting and Research, with a focus on Social Impact Assessment (SIA), Due Diligence Assessments, Strategic Environmental Assessment (SEA), Independent Review Work, Training and Capacity Building and Environmental Project Management. He has undertaken in the region of 260 SIAs for a broad range of projects, including dams and other large infrastructure projects.

Tony is the author of the Guidelines for Social Impact Assessment for the Department of Environmental Affairs and Development Planning, Western Cape, (2007). These Guidelines are used throughout South Africa. He also was the project manager for the development of a Social Assessment and Development Framework for the Department of Water Affairs and Forestry, South Africa, including the development of guidelines for Social Impact Assessment (2005). These guidelines aimed to assist DWAF to identify, assess and manage social impacts (positive and negative) during the design, development, operation and closure of projects.

**Other experience includes:**

Social Specialist for identification of multi-sector water-related investment opportunities in the Eastern Nile Basin, World Bank and Eastern Nile Technical Office (2015);

Social specialist for assessment of large dam developments on the Eastern Nile Basin, specifically the Blue Nile (Abbay River) in Ethiopia and the consequences for the downstream countries of Sudan and Egypt, World Bank and Eastern Nile Technical Office (2012-2013);

Social specialist for development and design of the Decision Support System for the Nile Basin. Input included the development of social indicators used to assess water-related projects and development scenarios (dams and irrigation schemes) in the Nile Basin (2012);

Social specialist for the water resource classification of the Olifants/Doorn Catchment Area (Western and Northern Cape Province) (2011-2012).

## APPENDIX B: Terms of reference VIGTT