Are wetland plant communities in the Cape Flora influenced by environmental and land-use changes?

By: Carla-Louise Ramjukadh

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Supervisors: Emeritus Assoc. Prof. Jenny Day &

Assoc. Prof. Muthama Muasya

Declaration

This thesis reported original research carried out in the Department of Biological Science, University of Cape Town, between 1987 and 2013. All data presented are original. Any assistance received is fully acknowledged.

Signed by candidate

Carla-Louise Ramjukadh

Date

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Abstract

Considerable attention has been given over the past few years to the distribution and environmental condition of wetlands in South Africa. A 1987-1989 study investigated over one hundred wetlands to establish unique discernible features for grouping and classifying wetlands in the Cape Floristic Region. In the current study, a representative subset of the wetlands surveyed in 1988/89 was re-examined. This thesis characterizes and assesses wetland plant communities and wetland types in both data sets, attempts to identify the major environmental factors influencing plant species distribution in the wetlands, assesses changes in plant species community composition over time; and asks whether surrounding land-use has influenced these. In the current study, of the 142 plants species recorded, 114 were identified to species with 28 to genus level. The historical vegetation data includes 173 plants, of which 115 were identified to species with 58 to genus level.

Multivariate cluster and non-metric multidimensional scaling analyses were used to distinguish plant community groups. For the historic data four plant community groups could be distinguished, and five could be identified for the present-day data. Indicator species describing the plant community groups in the different data sets were identified. Single diagnostic species such as, *Sarcocornia natalensis* and *Ficina nodosa* strongly described wetland plant communities for the present-day vegetation. No single dominant species described the historical vegetation data. The relationship between environmental variables and species composition was investigated using Distance-based Linear Modelling (DistLM). Complete environmental data were available for only 17 wetland sites in the historical data so analysis of the relationship between environmental variables and plant species communities was performed only on this subset. Four variables were examined: pH, electrical conductivity

(EC), altitude, and annual rainfall. The DistLM results revealed that none of the environmental variables were statistically correlated to the historical plant species composition data. Environmental data of seven variables pH, EC , altitude, rainfall, phosphate ($P0_4$), nitrite ($N0_2$) + nitrate ($N0_3$) and ammonium (NH_4) were examined separately to investigate relationship differences in the plant communities, for 30 wetland sites in the present-day study. Altitude, pH and EC were all significantly ($p < 0.05$) correlated to present-day species composition Two-way crossed ANOSIM revealed a significant difference (global R = 0.74, p = 0.001) between the plant community groups across the survey years. PERMANOVA was used to test change over time of the plant species composition and environmental variables across the years revealed the effect of survey years to be significant ($p < 0.05$) for plant species composition and non-significant ($p > 0.05$) for the environmental variables. In general, environmental variables do not appear to have changed over time but a significant change in plant species composition has occurred. Land-use dynamics were assessed by applying GIS techniques and analysis on ortho-rectified aerial images. Forty-eight percent of the wetland sites exhibited a change in land-use.

Wetland plant community differences are apparent between the historical and present vegetation data. It is clear that one of the historic plant communities has split in the present-day data. To some degree, certain wetland plant species describe and reflect their respective wetland types due to plant species habitat requirements for establishment and growth. The DistLM did not clearly describe the relationship between the environmental variables and the plant species communities for the historical data. More specifically, altitude was the best environmental descriptor to describe the relationship of the plant species communities in the present-day study. Overall, a biological shift in the plant community groups, although statistically does not appear to be driven by changes in the environmental parameters investigated.

The analysis of land-use in and around wetland sites identified many depressional wetlands as having experienced the greatest changes over time between the data sets. This result was supported by several depressional wetlands having indicator species that are indicators of disturbance, such as nutrient enrichment. Water chemistry measurements for those wetlands supported this finding. From this study a biological change in plant species communities can be distinguished over the past 25 years. The changes have been greatest in depressional. The change in plant communities does not appear to be driven by the environmental variables that were examined in this study, but appea5s to be driven by changes in the surrounding land-use.

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CHAPTER 1

Introduction and Literature review

1.1 General introduction and background information

Over the past few years considerable attention has been given to the distribution and environmental condition of wetlands in South Africa. In the 1980s, the importance of wetlands and the alarming rate at which they were disappearing and degrading was recognized, by the Foundation for Research Development of the Council for Scientific and Industrial Research (CSIR). Prior to this, Kwa-Zulu Natal had been the only Province that mapped and recorded the status of their wetlands on a large scale (e.g. Begg, 1986; 1987; 1989a). Thus the CSIR funded a wetlands research project conducted by Drs Jackie King and Mike Silberbauer from 1988-1989. The aim of the study was to identify way to classify wetlands in the south-Western Cape, based on common wetland plant and invertebrate species and related water chemistry (King and Silberbauer, 1991).

King and Silberbauer (1991) sampled 103 wetlands within the Fynbos, Succulent Karoo and Nama Karoo Biomes during the wet winter months of 1988 and 1989. Biological, physical and chemical aspects of approximately 69 wetlands were surveyed in detail. The most common plants associated with each wetland were collected qualitatively together with water samples and invertebrates. The wetland plant collection is housed in the Bolus Herbarium at the University of Cape Town.

With the availability of historical work done by King and Silberbauer (1991a & unpublished) this study seeks to explore the opportunity to examine the composition of wetland vegetation from various wetland types, the potential change over time in terms of species assemblage composition and the environmental drivers behind that change.

1.2 What is a wetland?

Wetland ecosystems are defined as areas with water that either covers or saturates the ground for at least part of the year, and have anoxic soils and hydrophilic vegetation (Mitsch and Gosselink, 2000). Wetlands may be permanently flooded (such as marshes and swamps), some may be seasonally flooded (such as many riparian wetlands) and some may have saturated soils with occasional standing water (such as prairie potholes and vernal pools). Wetlands are recognized and defined by the South African National Water Act 36 of 1998 (NWA), as *"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."* The legal definition thus creates uncertainty as to whether all aquatic ecosystems are considered wetlands or not. The Ramsar Convention, on the other hand, defines wetlands in a broad sense as *"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including marine water the depth of which at low tide does not exceed six meters"* (Ramsar Convention Secretariat, 2011). With various definitions in mind, Mitsch and Gosselink (2007) proposed that wetlands can be characterized by three key components: presence of water either near or at the surface, standing permanently or at least part of the year (during the wet season); unique soil conditions different from those of the surrounding upland; and vegetation adapted to wet conditions (hydrophilic vegetation)

Based on these definitions the definition of Ollis *et al*. (2013) will be used to define wetlands, as being areas *"which are transitional between aquatic and terrestrial systems, and are generally characterised by (permanently or temporarily) saturated soils and hydrophytic vegetation. These are, in some cases, periodically covered by shallow water and/or may lack vegetation"* was used for the purpose of this thesis.

1.3 Wetlands in the environment

Wetlands are productive ecosystems that provide habitat for plants and animals, resulting in high biodiversity. They are important hydrological control agents, regulating stream-flow, reducing flooding, storing water, and moderating surface runoff. Wetlands support many people by providing various goods and services. They supply clean water, acting as filtration systems by removing soluble and insoluble pollutants; they provide raw materials and are frequently socio-culturally important areas as well (King and Silberbauer, 1991; Davies and Day, 1998).

The protection of wetlands is seen to be one of the factors that have the potential to improve the quality of water and resource conservation in South Africa (Richardson and van Wilgen, 2004). South African legislation recognizes their importance in both the National Water Act (in the establishment of "Ecological Reserve" for wetlands) and the National Environmental Management Act of 1998, which requires conservation planning and management of the environment (including wetlands).Attention has been given over the past few years to South African wetlands in an attempt to fill the knowledge gap concerning their distribution, status and value (King and Silberbauer, 1991b). The value of wetlands has required the commitment by countries around the world, including South Africa, to becoming signatories to the Ramsar Convention and assessing and monitoring the integrity and condition of selected wetland ecosystems.

1.3.1 Wetlands as habitats for plants and other biodiversity

Wetlands support a variety of plants specifically adapted to being inundated for variable periods of the year. The hydrological regime of a wetland is an integral factor influencing the composition, distribution and diversity of wetland plant species (Mitsch & Gosselink, 2000; Mucina and Rutherford, 2006; Keddy, 2007). In turn, the composition of the vegetation provides habitat for organisms such as invertebrates, birds, reptiles, amphibians and mammals (Cronk & Fennesay, 2001). Wetland types and associated habitats can be grouped into habitat units in which characteristic patterns of plant assemblage are expected (SANBI, 2009).

Within wetlands, hydrological zones may be present, and range from permanently to seasonally or temporarily wet (Figure 1.1). These hydrological zones provide different conditions that suit different plant species. The exact delineation of these habitats is not simple as water levels tend to fluctuate seasonally and from year to year. Water level varies with rainfall, infiltration and evapo-transpiration, thus hydrological zonation changes spatially with seasons.

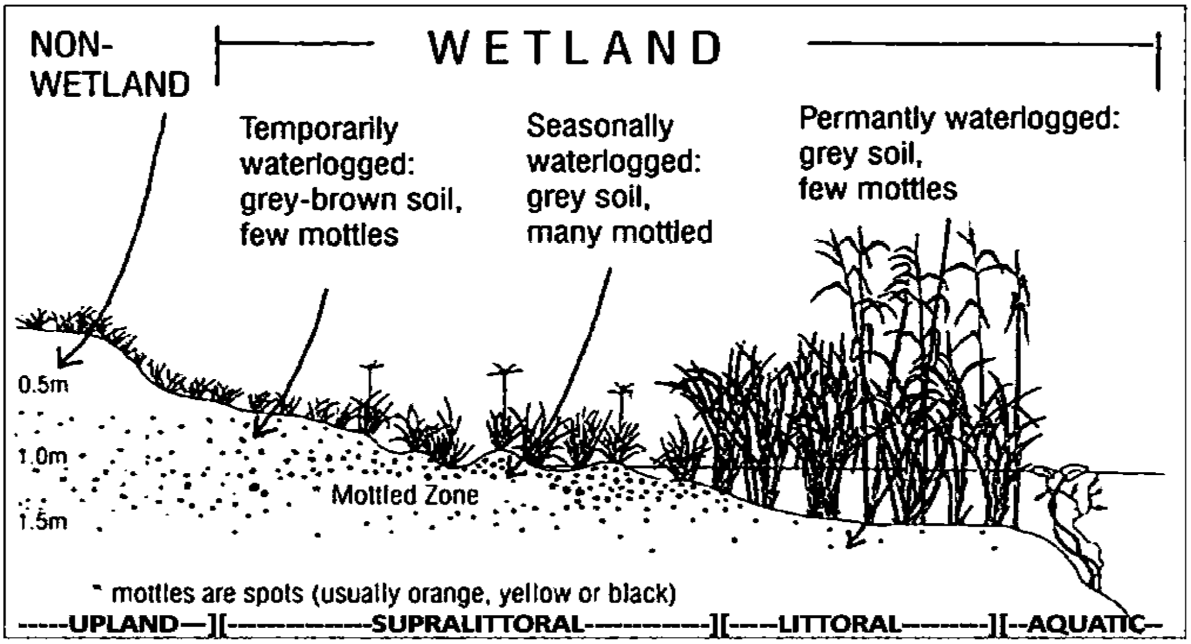

Figure 1.1 A Cross-section through a wetland, indicating how vegetation changes along a soil wetness gradient. (Corry 2012 adapted from Kotze, 1999)

Three hydrological habitats or zones are generally recognized (US EPA, 2002; Corry 2012; Figure 1.1), and are distinguished by the residence time of water inundating or saturating the substrate of wetlands. The generally accepted wetland zones are:

- The *supra-littoral zone*, which is temporarily to seasonally saturated and dominated by vegetation that does not usually occur in standing water, although the roots can at times cope with anoxic conditions;
- The *littoral zone*, which is seasonally to permanently saturated or inundated and dominated by emergent vegetation;
- The *aquatic zone*, which is permanently inundated and sometimes supports floating or submerged vegetation.

Any of the three zones may or may not be present within a wetland depending on availability of water and the type of substrate found in the wetland. Wetland plants are species which are morphologically and physiologically adapted to growing in wetlands, either in water or on the water, or where soils are saturated long enough for anaerobic conditions to exist in the root zone (Cowardin *et al*., 1979; Sorrell *et al*., 2000; Cronk and Fennesey, 2001). Plants that are physiologically dependent on water and where at least part of the generative cycle requires part or all of their structure to be submerged in, or floating on, water are known as "hydrophytes" (Cook, 2004). Hydrophytes can be either floating or rooted in the substrate, and have their shoots floating on the surface of the water or submerged. Plants not physiologically dependent on water but able to tolerate long periods of submergence are known as "helophytes" (Cook, 2004). Wetland plant communities usually include both hydrophytes and helophytes.

1.4 Classification of wetlands

Investigating wetlands requires the classification of aquatic systems as wetlands and the recognition that there are different types of wetlands therefore, a standardised classification system is needed. Classification of wetlands permits the division of wetlands into units/groups, which share similar characteristics. From this data on the extent, role and status of these different wetland types can be captured. Such a system is useful as it allows for management and conservation strategies for different wetland types to be established (Finlayson and van der Valk, 1995). The classification of wetlands is required to facilitate the management and conservation of wetlands by the NWA of South Africa (Jones, 2002).

Wetland classification systems are available in varies countries, such as United States and Australia (e.g. Cowardin *et al*., 1979; Semeniuk and Semeniuk, 1995) but these classification systems have been developed on characteristics best suited for wetland types found on those continents and therefore are not necessarily applicable to wetlands in South Africa. Wetlands are diverse spatially and temporally and vary greatly between continents and within countries. Within South Africa, there is considerable variation in the types of wetlands found. This variability requires wetlands to be assigned to locally applicable types (Jones, 2002).

A suite of characteristics that affect wetland processes and patterns should form the basis for differentiating wetland types (Jones, 2002). The way an inland aquatic system functions is based on two essential characteristics: hydrology, the movement of water; and geomorphology, landform characteristics (Semenuik and Semenuik, 1995; Finlayson *et al*., 2002; Ellery *et al*., 2008; Kotze *et al.,* 2008; Ollis *et al*., 2013).

Hydrology (the movement of water) and geomorphology (landform characteristics) are the principle foundations of the hydrogeomorphic (HGM) approach to wetland classification is founded (Brinson, 1993). Classification systems based on hydrological and geomorphological characteristics to differentiate between wetland types are widely accepted for robustness and consistency (Ollis *et al*., 2013). The South African National Biodiversity Institute (SANBI) classification of wetlands and other aquatic ecosystems by Ollis *et al*. (2013) is based upon on this fundamental approach and is the classification system used to type wetlands in the current study.

Ollis *et al*. (2013) used *Landform* (the shape and setting of the wetland system); *Hydrological characteristics* (defines the nature of water movement into, through and out of the wetland system) and *Hydrodynamics* (the direction and strength of water flow through the wetland system) to establish a wetland classification system for South African wetlands and other inland aquatic systems.

1.5 Wetland plant communities

A plant community can be defined as “a characteristic group of plants that naturally grow together in a particular and homogenous environment” (Maarel and Franklin, 2013). The species composition of that plant community is determined by the interactions of factors such as climate, soil type, and position in the landscape (Cronk and Fennesey, 2001; Mitsch and Gosselink, 2007).A change in wetness gradient within a wetland results in a change in plant community, as one moves from the open water, to the wetland edge and into the terrestrial habitat. Valuable information can be obtained from the changes in species composition especially in defining wetland boundaries and the environmental conditions of that wetland (US EPA, 2002; van Ginkel *et al*., 2011).

1.5.1 Wetland plant communities as indicators of change

Plant community composition thus changes along environmental gradients (Whittaker, 1976). Direct or indirect gradient analyses have shown that the distribution of species forms a pattern within the landscape as a result of interactions with the surrounding physical and biological environment (Whittaker, 1965, 1967; van der Valk and Davies, 1976). Plant species can survive within a range of environmental conditions but changes outside of this range results in changes in the plant community (Whittaker, 1962). The species assemblage present at any time thus characterizes, or represents, a particular set of environmental conditions present at a given location. (Mitsch and Gosselink, 2000; Keddy, 2000). Plants are thus useful for monitoring and assessing impacts (Adamus *et al.,* 2001).

Wetland plants are useful biological indicators as they are the most visible and common biotic component of wetland ecosystems. The unique association between climatic and hydrological factors, which shape wetlands within the landscape, make plant communities some of the best indicators of change (Bedford, 1996). Both current and historical environmental conditions are often reflected in plant species composition, and a change in species composition over time can indicate environmental change (Cronk and Fennesey, 2001).

1.5.2 Anthropogenic impacts on wetland plant communities

Globally, humans have modified plant communities extensively. Between different types of land-uses, small or extensive remnants of natural or semi-natural vegetation may survive and flourish, even though in a modified form. Vegetation and landscape ecology are progressively becoming linked. Landscape ecology looks at the description, analysis and explanation of spatial patterns of plant community and land-uses types within a given landscape or region. The methods involve remote sensing and geographical information science (GIS) (Kent, 2012).

Many studies have searched for patterns of plant community response to biotic and abiotic, natural and anthropogenic alterations to the environment (Adamus *et al.*, 2001). Natural or anthropogenic disturbances can remove a species or prevent its growth, or can open areas providing an opportunity for new species to become established (Cronk and Fennesey, 2001). Increases in the intensity and/or frequency of natural disturbances altered by anthropogenic effects are considered as human-induced disturbances (e.g. Kent and Coker, 1992; Deacon, 1992; Clarkson *et al.*, 2004; Corry, 2012). Human disturbances may alter the physical or chemical environment of a wetland resulting in change in the biota and the scale of these disturbances may be localised or catchment-wide (Cronk and Fennesey, 2001). The forces that threaten wetland ecosystems are the same forces that threaten wetland plants. Four major classes of impacts are described in Table 1.1.

Table 1.1 Human-induced threats to wetlands and wetland plants

Threat	**Description**
Hydrologic alterations	Human activities (e.g. agriculture, flood control and urbanization) result in hydrological changes (ter Braak and Wiertz, 1994; Cronk and Fennesey, 2001), which in turn lead to either a decrease or increase in wetland area or a change in hydrologic regime. An alteration in hydro-period can significantly change the distribution of wetland species, allowing, or preventing species from occurring.
Alien and invasive species	The impact of invasive and alien species can be severe, resulting in an alteration of the nutrient cycle, development of monoculture stands of vegetation and the extirpation of indigenous species. Alien invasive species tend to use more water in the ecosystem therefore a loss in indigenous biodiversity is a major threat not just for wetlands but many other types of ecosystems, especially in arid and semi-arid regions, such as South Africa (Richardson and van Wilgen, 2004). The number of rare, threatened or endangered species, which are dependent on unique wetland type for their habitat, may increase due to the extensive loss of wetland area combined with degradation of those remaining.
Impacts of global change	Human activities often have a negative effect on land use patterns, atmospheric chemistry, and climate (Vitousek, 1994). The increase in mean annual temperature and changes in hydrological cycle will drive many changes in wetland plant communities.
Alteration to wetland habitat	Alteration to wetland habitats can have very significant effects on wetland ecosystems and can result in wetland loss. Many have recognized and concluded that alteration and/or loss in wetland habitat area, is a complex interaction of factors, acting at different spatial and temporal scales (e.g. Turner and Cahoon, 1987; Kesel, 1988; Boesch et al., 1994; Day *et al*., 1995; 1997 Day *et al*., 2000).

1.5.3 Classifying techniques for wetland plant community

Wetland plant communities can be classified in the basis of species assemblages. Such classifications employ multivariate analytical techniques to summarise attributes of wetland vegetation in terms of plant communities (Little, 2013). Several techniques are available.

- *Hierarchical analysis* is used commonly in vegetation studies and is based on a (dis)similarity matrix such as that of Sorenson or Bray-Curtis (Sharma, 1996). This information is displayed visually using cluster dendrograms. The different wetland community groups can be identified/defined post-hoc using either subjective methods or objective measures, such as ANOSIM, PERMANOVA and PERMDISP. These methods assess the homogeneity or heterogeneity within the wetland community groups (Sharma, 1996; Little, 2013).
- *Ordination* is used to discover patterns and underlying structures in the multivariate data (e.g. non-metric multidimensional scaling (MDS)) (Kenkel, 2006; Little, 2013). Ordination has been used to assess the effects of management practices on wetland plant communities (e.g. Hall *et al.,* 2008); in restoration studies (e.g. Rooney and Balely, 2011); in studies on the effects of alien invasive species (e.g. Mills *et al*., 2009); and in understanding how environmental degradation affects wetland systems (e.g. Carr *et al*., 2010). Several ordination techniques reduce variability to express the main patterns in the data using correlation between multiple variables (Little, 2013). When examining changes with time in detail, it is sensible to focus the ordination plot on year by eliminating the trends in space (i.e. differences among plots). This allows assessment of the statistical significance of the change with time (ter Braak and Wiertz, 1994).

- *Indicator species analysis* is a technique that identifies certain species as indicators for different groups of sites or plant communities (e.g. SIMPER analysis) (Little, 2013). This type of analysis determines how exclusive or not a particular species is within a group or plant community. Exclusive indicator species can then be used to describe plant communities (Ronney and Bayley, 2011), differentiate wetlands, and associate plant species with different wetland conditions (Johnston *et al*., 2007).

1.6 Relationship between wetland plants and wetland type - Do wetland plants reflect wetland type?

Wetland vegetation is the most noticeable feature of a wetland and has been used extensively as an indicator of wetland presence and extent (US EPA, 2002). American and European ecosystem managers have traditionally used vegetation to describe different types of wetlands. In addition wetland plants can be used as indicator of wetland (water) quality and integrity (Cronk and Fennesey, 2001).

Many wetland plants, largely monocots, are widely distributed, although some species are endemic to small areas or to specific wetland types (Cronk and Fennesey, 2001). It may therefore, be possible to identify wetland types by the plant communities present although it very little, if any, literature is available on the subject for Africa. Plant communities have been used to characterize wetlands in the United States (Cowardin *et al*., 1979) where dominant plant species are used to describe subclasses within the classification scheme. Other literature has shown that certain species depend on a unique wetland type (Griggs and Jain, 1983; Keeley, 1988; Baskin, 1994; Messmore and Knox, 1997). In California many endemic species, such as the mint *Pogogyne abramsii,* and grasses belonging to the genera *Neostapfia, Tuctoria,* and *Orcuttia,* are now rare and endangered due to the destruction of vernal pools in the state (Griggs and Jain, 1983; Keeley, 1988; Baskin, 1994). *Helenium virginicum,* a species of Asteraceae is a narrow endemic restricted to 25 sinkholes in West Virginia and listed as endangered or threatened (Messmore and Knox, 1997).With the rapid rate of urbanization and industrialization, the list of threatened species dependent on a single wetland type is probably growing, not only in the United States but worldwide.

1.7 Wetland mapping techniques

Lyon and McCarthy (1995) provide useful insight on how wetlands can be mapped in the environment and of the different tools and platforms that can be used to do so. The use of aerial and satellite remote sensing allows the recording and assessing of the conditions of wetland features in the environment. These methods are periodic however, change being documented through a series of observations over time. The two main objectives involving remote sensing data and wetlands are: 1) resources mapping, which involves obtaining baseline information on the type, extent and condition of wetland plant communities, and 2) detection of change in those communities. These types of data are of interest to those involved in management and conservation of wetlands and the resources that wetlands provide.

1.7.1 Detecting change with aerial photography

Remotely sensing data and technology are useful to inventory wetlands and track changes in the extent and plant communities over time. Furthermore, these techniques are important for the conservation of wetland ecosystems and for preventing future losses, not just for wetland biodiversity but, of ecosystem goods and services (MacDonald, 1999; Ozesmi and Bauer, 2002). Over the years, aerial photography and satellite images, together with Geographical Information Systems (GIS), have been used to produce vegetation, hydrological and land-use maps. These maps can be overlain to compare previous and current conditions, identifying areas of change (McDonald, 1999; Ozesmi and Bauer, 2002).

Detection of change in wetlands requires that ecological data be collected under optimum conditions so that effective comparisons can be made between several points in time. Change detection projects involves the use of one or a more historical aerial photographs to document natural or anthropogenic changes (Lyon and McCarthy, 1995). Examining the rate of environmental change over time, using these long-term data provides the opportunity to interpret biological responses, the extent of wetland boundaries and increases or decreases in the fragmentation of wetland communities, and to offer future predictions of change (Lyon and McCarthy, 1995; MacDonald, 1999 Gosz *et al*., 2010).

1.8 Historical comparisons of wetlands

In recent years, qualitative and quantitative changes in wetland patterns, and the reasons for those changes, have become a hotspot in wetland studies (Xie *et al*., 2010).

Williams and Lyon (1991) studied historical changes in wetland area between 1939 and 1985 in the wetlands of the St. Marys River, Michigan, USA. A digital database together with GIS software was used and constructed for photo interpretation, mapping and digitizing of aerial photographs. Past, present and potential changes in the wetlands were considered in the historical inventory to determine their changes over time. They concluded that: there were no significant changes in the total area of wetland; that changes in the emergent wetland plants appeared to be related to changes in water level; and, that long-term successional trends were indicated.

Lee and Lunetta (1996) reviewed methods for producing an inventory of, and detecting change in, wetlands and investigated the ability of aerial photography and satellite imagery to detect wetlands and to monitor change, and the cost associated with maintaining a database of wetland inventories. They examined historical studies from across the United States that utilized aerial and satellite imaging for various wetland, riverine and land cover/use projects at local and regional levels. The interpretation of the aerial photography studies (at a scale of 1:24 000) provided insights as to the best remote sensed imaging (film type) and what time of year and day imagery should be acquired for various wetland types and their respective vegetation types. Data sources on different wetland features and change detection analysis such as wetland boundary delineation, vegetation growth, natural vegetation removal, etc. have become available from these different projects, for future use. The costs involved in producing in-depth detail for wetland delineation were found to be more expensive than wetland resource mapping. The projects involving satellite imaging are more technical in interpretation in wetland identification, resource analysis and land cover/current use of wetlands. These projects covered larger areas of the project sites and at a lower cost but aerial photography and other sources of image data were usually needed to refine the satellite image data.

Rebelo *et al*. (2009) reviewed two case studies that were conducted at different spatial scales. The first study investigated wetland change on the Muthurajawela Marsh and the adjoining Negombo Lagoon, in Sri Lanka. The changes in land cover and land use in and around the wetland complex were captured and analysed using satellite data from 1992 to 2002. Due to the increase of pressure of urbanization in the wetland complex, to quantify changes and the drivers of those changes, an inventory and assessment of the wetland complex was carried out. In summary, in terms of wetland management, the increased urbanization and industrialization with in the wetland complex contributed to wetland loss and degradation. The second study, at a much broader scale, remote sensing techniques were used in another study to assess inland wetlands in southern Africa. Land cover changes within and around the

Lake Chilwa wetland complex in Malawi, were identified and mapped. The multiple land-use practices of these wetlands were assessed, during the dry and the wet seasons, by means of field and aerial photography to classify main vegetation classes based on dominant land cover and land use. The purpose of this study was to reveal the sustainability of agriculture and dependent livelihoods of the surrounding settlements in the wetlands for management intervention.

1.9 Wetland HGM types in the Greater Cape Floristic Region

Wetland distribution and character are both the reflection and modification of their physical backgrounds. Thus wetland distribution together with climatic and geographic data was used to provide insight about the type of wetlands and why they occur where they do by King and Silberbauer (1991a).

Seven inland wetland HGM types are recognized by Ollis *et al.* (2013):

- *Rivers* are linear landforms with distinctive bed and banks carrying concentrated flow of water permanently or periodically. Both the active channel and the riparian zone are included in the unit.
- *Channelled valley-bottom wetlands* are located along a valley floor with a distinctive river channel running through.
- *Unchannelled valley-bottom wetlands* are located along a valley floor but without a distinctive river channel.
- *Floodplain wetlands* associated with depositional processes of a river system are located on flat or gently sloping areas, adjacent to a alluvial river channel periodically inundated by over-topping,

- *Depressions* are wetlands with closed or partly closed elevation contours that increase in depth towards the centre. Flat-bottomed depressions are typically referred to as pans. Depressions may have inlets, outlets, a combination, or neither.

- *Seep*s are located on gently to steeply sloping valley slopes, with gravity-driven unidirectional movement of water and sediment down-slope.

- *Wetland flats* are situated on a plain or a bench and are associated with weak multidirectional movement of water, due to the lack of change in gradient.

Further subdivision of inland systems is based on descriptors, which include structural, chemical and biological indicators. "Structural" descriptors refer to the origin of the wetland system i.e. whether the system is natural or artificial. "Chemical" descriptors refer to salinity and pH. Biological descriptors refer to vegetation. Use of vegetation for further classifying wetlands can be important for conservation planning, rehabilitation and wetland health assessments even if the vegetation is invasive and alien, croplands or plantations. Vegetation affects the biotic biodiversity of a wetland system and the way in which the ecosystem functions. The Ollis *et al.* (2013) classification system distinguishes between unvegetated areas, which consist either of bare substratum or of open water, and vegetated areas. These in turn are divided into vegetation form (i.e. aquatic, herbaceous, shrub/thicket or forest) and vegetation status (i.e. indigenous or alien).

Classifying wetlands based on their vegetation can be useful, as vegetation links hydrological, edaphic and biogeochemical indicators (US EPA, 2002). Wetland vegetation however, responds rapidly to anthropogenic and natural disturbances, which can be a disadvantage as rapid changes can be missed or not detected at all in long-term datasets

(Little, 2013) so vegetation will reflect the environment of wetlands and how they are managed easily (Sieben, 2011).

1.9.1 Wetland vegetation in the Greater Cape Floristic Region

Because of fragmented literature and localized focus the composition of wetland vegetation in South Africa is poorly known, with most botanical research involving terrestrial vegetation (Mucina *et al*., 2006; Sieben, 2011). Furthermore, only a few wetland ecologists are trained in sampling and identifying wetland plants, which together with lack of data, makes comparison from one site to another difficult (Sieben, 2011).

'*The Vegetation of South Africa, Lesotho and Swaziland'* edited by Mucina *et al*. (2006) includes the classification of wetland vegetation types for the first time, in the history of South African vegetation mapping. This classification is based on a broad-scale meta-analysis of the available information and recognizes the need for a more rigorous and data-intense wetland vegetation classification. Wetland vegetation is largely distinct from the surrounding terrestrial vegetation. Many freshwater wetlands within the Greater Cape Floristic Region are currently included within terrestrial vegetation units due to their small extent, lack of data and the extensive degree of endemism of the plants (Mucina *et al*., 2006). When mapping the spatial distribution of larger wetland vegetation units, however, Mucina *et al*. (2006) classified wetland vegetation based on azonality, hydrological regime and salinity as follows:

- *Freshwater wetlands* are typically wetlands with stagnant or slow-flowing water where the dominant species are reeds such as *Phragmites australis.*
- *Alluvial vegetation* is found on the fringes of watercourses such as rivers suited to supporting wetlands characterized by flooding and associated disturbance (floodplain wetlands). Vegetation associated with alluvia is primarily structured by environmental

gradients reflecting the habitat differences vertically and longitudinally along river courses. Alluvial habitats arise from three basic zones, which in turn describe and give rise to different plant species in those zones. Lower banks (aquatic/wet bank) are populated by temporary herb species. Reeds dominate banks of slow-flowing rivers. Grasslands are usually found on the lower and middle banks and riparian thicket on the higher dry bank.

- *Inland saline vegetation* is diverse in character and originates from salt-bearing substrates or mineral-rich groundwater aquifers. Typically, vegetation patterns form at the edge of the pan floor and on the banks of the pans with salt tolerant vegetation, where the centre of the pan is devoid of vegetation.

Within the three main wetland vegetation types mentioned above, the following vegetation units are recognized by Mucina *et al.,* (2006) and are found in wetland habitats in the Core Cape Region:

- Freshwater wetlands:
    - *Cape lowland freshwater wetlands* are freshwater inland vleis (depressions) in the Western Cape, such as Verloerenvlei (West coast), De Hoop vlei, vleis on the Cape Flats, Papenkuils wetland, vleis on the Agulhas Plain and the Wilderness Lake system found between George and Knysna. Found at altitude ranging from 0 to about 400m these wetlands are located with renosterveld and alluvia fynbos.
    - *Cape vernal pools* are seasonal habitats which, occur in the Western Cape from the Cape Peninsula, to the Cape Flats, up the West Coast and far as Niewoudtville and Vanrhynsdorp in the Northern Cape. This vegetation unit occurs from 50 to 850 m above sea level.

- Alluvial vegetation (what river ecologists refer to as riparian vegetation):
  - *Fynbos riparian vegetation* predominantly located within the Western Cape partially found in the Eastern Cape in narrow bands of vegetation along the upper reaches of rivers flowing through mountain fynbos, mainly in alluvial thickets and *Prionium serratum* (palmeit) dominated vegetation bands. The altitude of this vegetation unit ranges from near sea level to 1 300 m.
  - *Cape lowland alluvial vegetation* is found on the broad alluvia of the middle and lower reaches of rivers and tributaries of the Western Cape (e.g. Olifants, Breede, Berg, Gouritz and many more) altitude ranging from 20-300m above sea level.
- Inland saline vegetation
  - *Cape inland salt pans* distribution of these salt pans is largely confined to the Western Cape, although some are found in the Eastern Cape. Most pans range from 0-150 m, but a few reach 500m above sea level. Saline habitats, such as saline alluvia, saline floodplain flats and slope saline scars are included into this vegetation unit (e.g. Yzerfontein Soutpan, Noordhoek, the salt pans/vleis of the Agulhas Plain and Karsrivier).

Recent work by Sieben (2011) provides a central database for the inventory of existing wetland vegetation data from all types of data sources, a standardized sampling protocol and a provincial classification of wetland vegetation types. Currently completed only for three Provinces in South Africa namely, KwaZulu-Natal, Free State and Mpumalanga but includes other comparable studies across the country as well. This wetland vegetation classification is not complete, as many provinces still require sampling of wetland vegetation to be done but it does provide an overview and guidance for the future.

The majority of literature in South Africa does not report on the diversity of wetland plant species and their conservation status. The Red List of South African plants by Raimondo *et al*. (2009), however does provided this required information, in terms of a species status, distribution, habitat and the rationale behind its given status. Examining known wetland plants in the Red List of South African plants (2009) revealed that *Isolepis bulbifera,* a species endemic to wetlands found on the Cape Flats of the Western Cape, to be considered extinct due to urbanisation and introduction of alien invasive plants in its known habitat. *Ficinia distans*, found in fynbos seeps species is vulnerable as all known localities are possibly threatened by coastal development and alien invasive species. On the Agulhas Plain, *Ficina latifolia* is endangered. Its known localities are in danger as the result of crop cultivation, invasive alien plants and urbanization. *Aponogeton angustifolius*, encountered during my field sampling at Bokkekraal wetland (currently known as Papenkuils wetland) in Worcester, is a vulnerable species with a narrow distribution range, being found mostly in isolated population at the edges of vleis (lakes) and slow flowing rivers. The habitat of this species is continuing to degraded as a result of altered hydrological regimes associated with urbanization and upstream agriculture. *Cotula filifolia*, is a critically endangered species, also encountered during my fieldwork in marshy and damp places. The range of this species with its small area of occurrence (10 km^2), has become fragmented, and the extent is continuing to decline severely due to agricultural and urban development. These are just a few examples of wetland plants illustrating species, which are vulnerable, threatened or extinct in wetland habitats found across the Western Cape Province of South Africa. Separating out the wetland species from the terrestrial plants can be helpful in the management of wetland habitats and their species diversity by conserving those endemic to certain wetland types and the region.

1.10 Rationale of the study

With an increasing population the need for urban, industrial and agricultural expansion is great, and takes place at the expense of our environment, particularly wetland ecosystems (Dini, 2004). In the past, South African wetlands have not been properly managed and conserved. Between 35% and 50% of South Africa’s wetlands have been lost or are seriously threatened and degraded (Macfarlane *et al*., 2009). This is due to the conversion of wetlands to alternative land-use activities or degradation as a result of over-exploitation, pollution, invasion of alien plants and hydrological modification (Turner *et al*., 2000; Dini, 2004; Turpie *et al*., 2010; Sieben, 2011). A number of anthropogenic factors contribute to the changing status of wetlands; urbanization and agricultural activities have been identified as being among the dominant causes of the degradation of wetlands (e.g. Begg, 1987; Vitousek et al., 1997; McKinney 2002; Alam *et al*, 2011).

The goal of the present project was to investigate whether wetland vegetation and associated environmental variables in the Core Cape Region have changed over the past 25 years. Current plant community assemblages are compared with those identified by King and Silberbauer for the same wetlands in an attempt to identify the trajectories and drivers of change in the wetland vegetation.

1.11 Research Aim and objectives

The aim of this dissertation was to assess plant community composition and identify the environmental factors that affect community assemblage distribution past and present, as a basis of inferring change over time.

To fulfil the aim of the study the following objectives were set:

- to characterize and assess wetland plant communities and wetland types of the Core Cape Region in the late 1980s and currently
- to identify major environmental factors influencing plant species distribution in the wetlands in the late 1980s and currently
- to assess changes in plant community composition over time; and in relation to changes in surrounding land-use.

1.12 Hypotheses

In order to achieve the aims and objectives of the thesis, the following hypotheses were developed:

1. wetland plant communities have not changed between 1988/89 and 2012/13
2. wetland plants are good indicators for wetland presence and delineation, but do not describe wetland type.
3. wetland plants are sensitive to environmental change. A shift in the environmental factors of wetlands, due to land-use change, will result in a shift in the plant species composition.

1.13 Structure of this thesis

Chapter 1 introduces the study by providing the background information, rationale, aims and objectives of the study and presents a review of the literature. The methods and study area are described in Chapter 3; Chapter 4 presents the results of the study which are discussed in Chapter 5; Chapter 6 provides conclusions and recommendations.

In this chapter, I have introduced the background, the rationale of the study and explored the literature on wetlands, their role in the environment and their recognition ecologically in terms of wetland vegetation, on a global scale, and in South Africa. The general contents and methods used to obtain the necessary information needed to investigate area are described in Chapter 2.

CHAPTER 2

Materials and methods

2.1 Study area

The area of classification and inventory of the King and Silberbauer (1991a) wetlands were identified from 1:50 000 topographical maps (South Africa 1953-1987). The study area lies south of 31º 30’ S and west of 22º 00’ E. This project focused chiefly on wetlands in the Core Cape Region (Figure 2.1). The study sites (Figure 2.2) are embedded within various vegetation types and capture various ecological gradients (altitude, rainfall, soil) and land use types (Table 2.1)

The Core Cape Region (CCR) (Figure 2.1), previously called the Cape Floristic Region (CFR) and now included in the Greater Cape Floristic Region (GCFR) (Manning and Goldblatt, 2012) covers an area of 90 760 km^2. It is dominated by the Fynbos biome and characterized by small-leaved, sclerophyllous shrubs and geophytes. The distribution of the Fynbos Biome is largely defined by the CCR which comprises 82.5 % of the biome. The sharp inland boundary of the region is the result of the link between the Fynbos and the Cape Fold Belt and in turn is a result of multiple ecological factors such as rainfall and soils (Manning and Goldblatt, 2012).

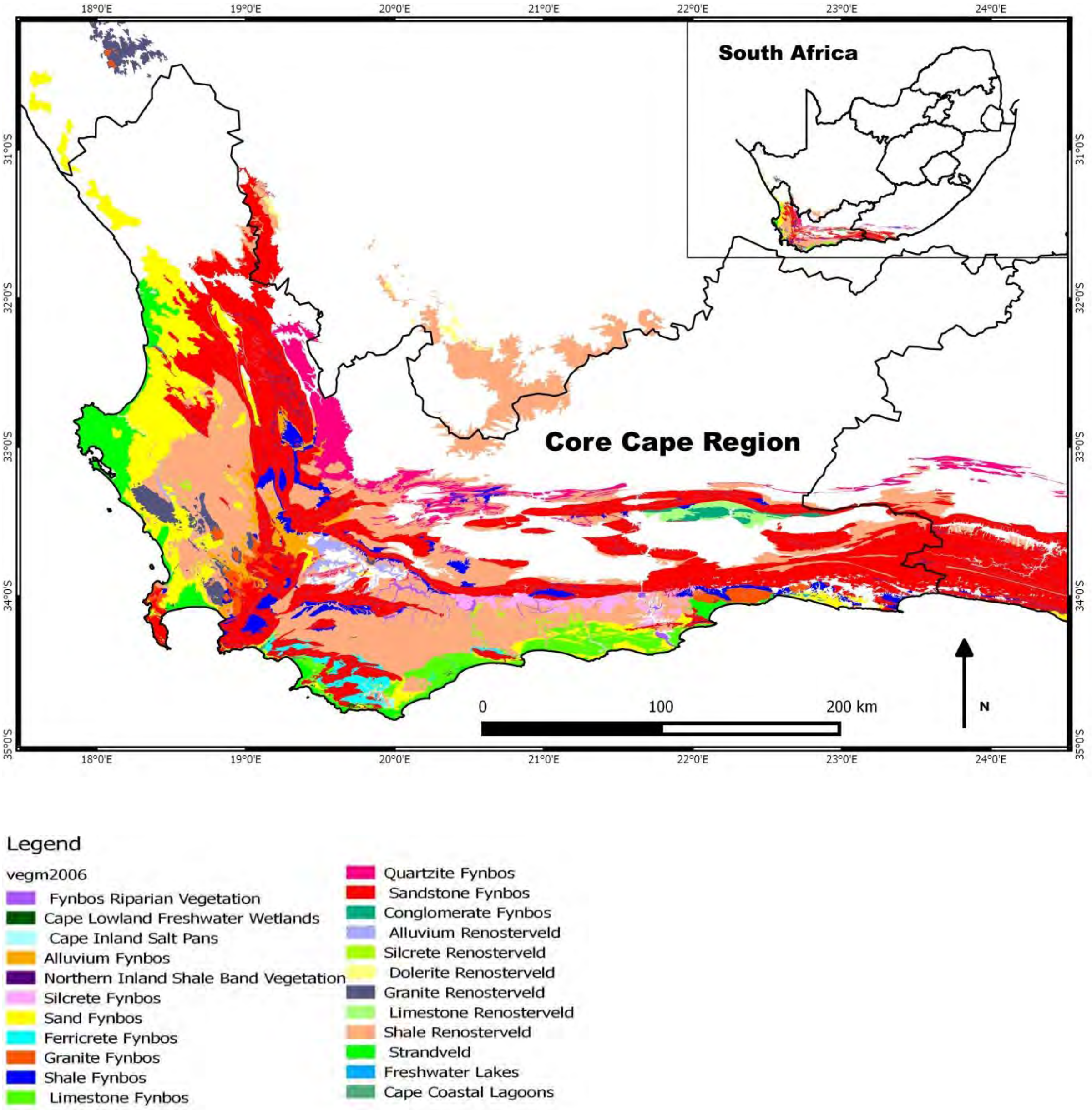

Figure 2.1 The study area with the different vegetation units found in the Greater Cape Floristic Region with corresponding legend of broad vegetation types of the Western Cape. (South African National Biodiversity Institute (SANBI), 2006; generated from vegm2006.shp from Mucina *et al*., 2006)

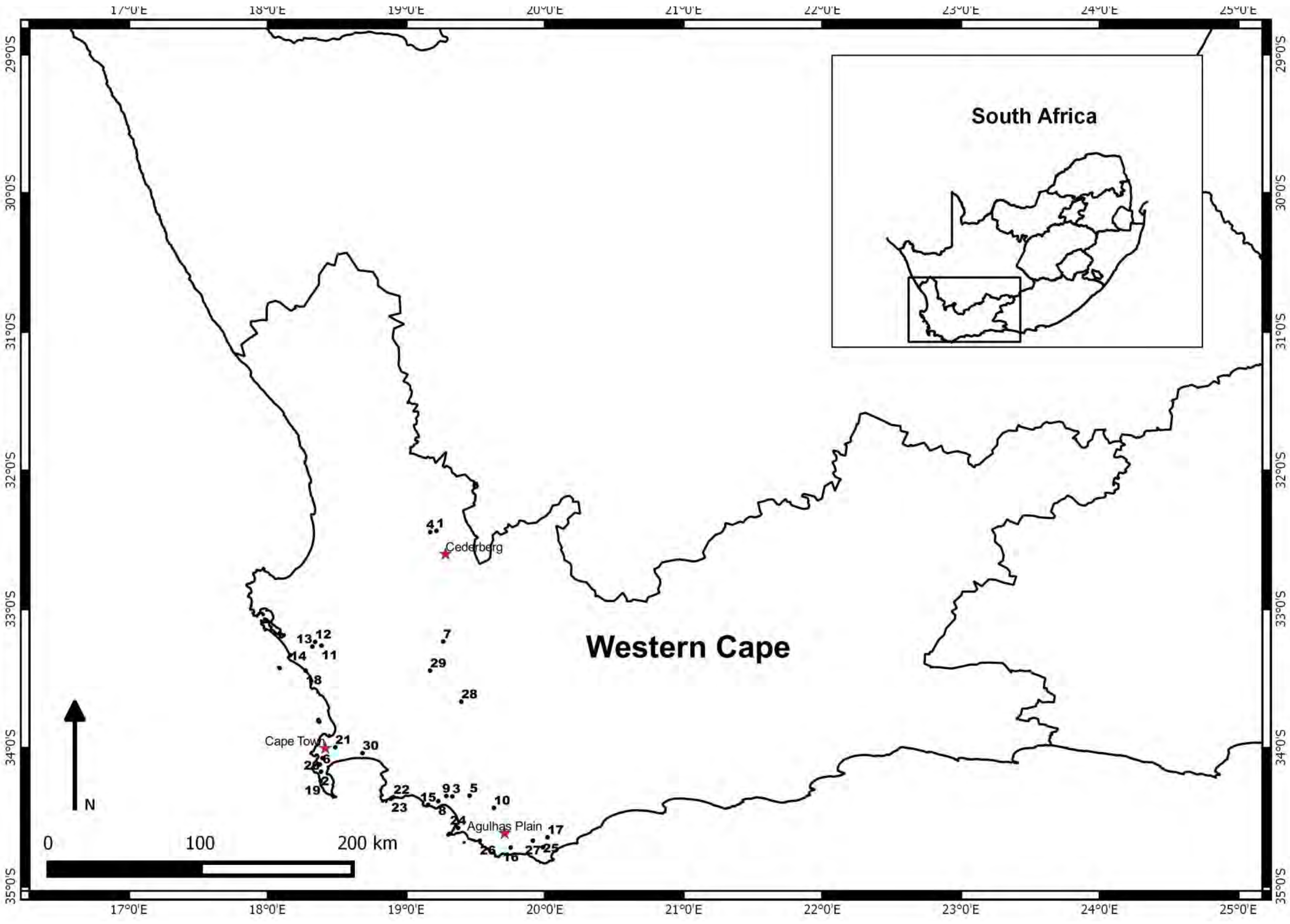

Figure 2.2 The study area with the different wetland sites in the Western Cape. (SANBI, 2006; generated from vegm2006.shp from Mucina *et al*., 2006)

The GCFR is characterized by Mediterranean climate with winter rainfall and summer drought (de Moor and Day, 2012). Rainfall varies dramatically across the landscape varying from 2000 mm per year, in the mountains, to less than 200 mm on the interior slopes and to the north. In the west rainfall is experienced mainly in the winter months with hot and dry summers, where the east receives more all year round rainfall (Manning and Goldblatt, 2012).

Different types of soils characterize different types of vegetation in the GCFR. The majority of the soils in the GCFR are derived from the sedimentary Table Mountain, Witteberg and the Bokkeveld Groups, of the larger Cape Supergroup. Soils resulting from this lithology are mostly acidic, coarse-grained sandy soils, poor in nutrients in the mountains; fine-grained clay soils richer in nutrients, on the lower slopes, and limestone on some of the coastal lowlands between the Agulhas Plain and Mossel Bay (Lambrechts, 1979; Cowling *et al*., 2003; Manning and Goladblatt, 2012).

Three broad vegetation types found in the CCR are recognized by Mucina *et al*. (2006) and Manning and Goldblatt (2012) are:

- *Fynbos* covering half of the CCR, is the most common vegetation type, found on the nutrient poor quartzitic sandstones, is characterized by Proteaceae, Ericaceae and Restionaceae.
- *Renosterveld* found on nutrient richer fine-grained clay soils is dominated by Astereceae.
- *Strandveld* littoral vegetation found along the west and south coasts is dominated by sclerophyllous broad-leaved shrubs and a few noticeable succulents.

At a finer spatial scale, within these three broad vegetation types smaller vegetation units can be found due to the heterogeneity of the geological substrate (i.e. the soils) (Rebelo *et al*., 2006). For instance, Cape Flats Sand Fynbos is found on acidic soil, while Cape Flats Dune Strandveld occurs on alkaline, calcareous sand (Corry, 2012). The different terrestrial and azonal wetland vegetation units identified by Mucina *et al*., (2006) in which the study wetlands are embedded in can be seen in Table 2.

There are six phytogeographic subcentres recognized in the Core Cape Region (Figure 2.3). The occurrence of wetlands in these subcentres indicates correlation between the distribution of wetlands and the geographic distributions of plant species and/or vegetation types in the Greater Cape Floristic Region (Table 2.1).

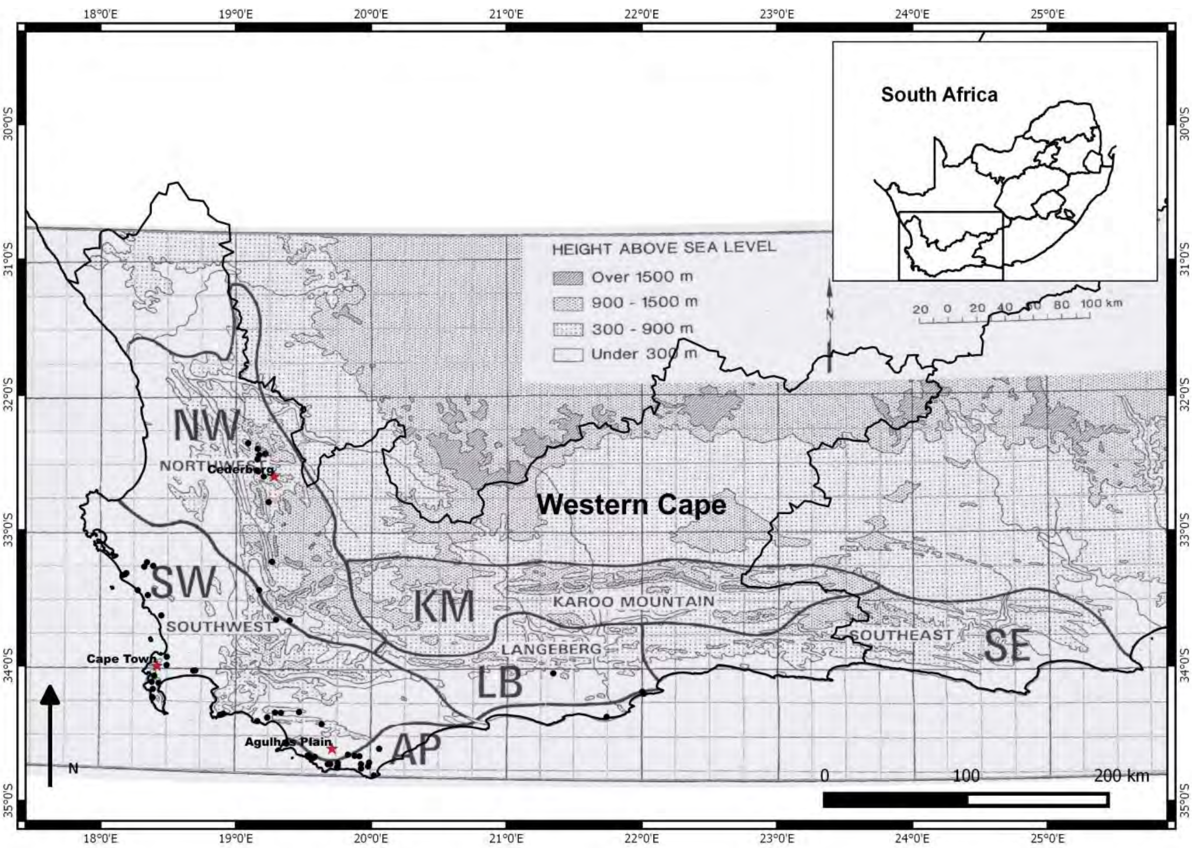

Figure 2.3 Phytogeographic subcentres of the Cape Region. The occurrence of wetlands in each of these subcentres is indicated by abbreviations NW (Northwest Centre), SW (Southwest Centre), AP (Agulhas Plain), KM (Karoo Mountain Centre), LB (Langeberg Centre) and SE (Southeast Centre). (Adapted from Goldblatt and Manning, 1999)

Table 2.1 Study sites and their names, wetland codes, wetland type, phytogeograsphic centre, GPS coordinates, altitude, and vegetation type.

Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*., 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**GPS coordinates**	**Alt (m)**	**Vegetation type** (Mucina and Rutherford, 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*., 2006)
1. Blomfontein	E201/03	Seep	NW / Cederberg	Nature reserve	-32.43487 S 19.21802 E	1360	Northern Inland Shale Band Vegetation	
2. Kleinplaats dam west	G203/01	Seep	SW / Simonstown	Natural land, Dam	-34.177136 S 18.388042 E	270	Peninsula Sandstone Fynbos	
3. De diepte gatt	G403/05	Seep	SW/ Hermanus	Agriculture	-34.344131 S 19.326265 E	270	Elim Ferricrete Fynbos	
4. Driehoek	E201/06	Channelled valley-bottom	NW / Cederberg	Nature reserve	-32.431429 S 19.148417 E	890	Cederberg Sandstone Fynbos	
5. Elias gat	G403/03	Channelled valley-bottom	SW / Stanford	Agriculture	-34.344649 S 19.457385 E	133	Cape Lowlands Freshwater Wetland	Western Rûens Shale Renosterveld
6. Silvermine dam inflow	G203/18	Channelled valley-bottom	SW / Silvermine	Nature reserve	-34.074198 S 18.39558 E	455	Peninsula Sandstone Fynbos	
7. De vlakte	H101/06	Channelled valley-bottom	NW / Wolseley	Agriculture	-33.243237 S 19.276012 E	881	Kouebokkeveld Shale Fynbos	
8. Hemel en aarde	G403/02	Unchannelled valley-bottom	SW/ Hermanus	Agriculture	-34.383843 S 19.234312 E	72	Elim Ferricrete Fynbos	

Wetland name	Wetland code	**Wetland type** (Ollis *et al*., 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**GPS coordinates**	**Alt (m)**	**Vegetation type** (Mucina and Rutherford, 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*., 2006)
9. Belsvlei	G403/04	Unchannelled valley-bottom	SW / Hermanus	Agriculture	-34.351257 S 19.275621 E	260	Elim Ferricrete Fynbos	
10. Salmonsdam	G404/01	Unchannelled valley-bottom	SW / Stanford	Nature reserve	-34.429853 S 19.630989 E	160	Cape Lowlands Freshwater Wetland	Elim Ferricrete Fynbos
11. Kiekoesvlei	G103/01	Saltpan (Depression)	SW / Darling	Agriculture	-33.263346 S 18.388672 E	55	Cape Inland Salt Pan-Inland Saline Vegetation	Swartland Shale Renosterveld
12. Koekiespan	G103/02	Saltpan (Depression)	SW / Darling	Agriculture	-33.263346 S 18.343378 E	57	Swartland Shale Renosterveld	
13. Burgerspan	G103/03	Saltpan (Depression)	SW / Darling	Agriculture	-33.268797 S 18.343378 E	70	Cape Inland Salt Pan-Inland Saline Vegetation	Swartland Granite Renosterveld
14. Rooipan	G201/01	Saltpan (Depression)	SW / Darling	Private land	-33.33108 S 18.163746 E	2	Cape Inland Salt Pan-Inland Saline Vegetation	(E) Saldanha Flats Strandveld (W) Langebaan Dune Strandveld
15. Vermont pan	G403/01	Saltpan (Depression)	SW / Hermanus	Residential	-34.412113 S 19.159634 E	18	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos

Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*., 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**GPS coordinates**	**Alt (m)**	**Vegetation type** (Mucina and Rutherford, 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*., 2006)
16. Melkbos pan	G501/16	Saltpan (Depression)	AP / Agulhas	Nature reserve	-34.718951 S 19.752137 E	30	Cape Lowland Freshwater Wetland	Agulhas Sand Fynbos
17. Varkensvlei	G501/20	Saltpan (Depression)	AP / Agulhas	Agriculture	-34.645037 S 20.021475 E	4	Agulhas Limestone Fynbos	
18. Rondeberg	G201/04	Depression	SW / Darling	Private Conserved land	-33.442746 S 18.274639 E	15	Langebaan Dune Strandveld	
19. Groot rondevlei	G203/04	Depression	SW / Cape Point	Nature reserve	-34.238923 S 18.382338 E	3	Cape Flats Dune Strandveld	
20. Noordhoek soutpan	G203/12	Depression	SW/ Noordhoek	Residential	-34.117678 S 18.383351 E	3	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos
21. Kenilworth race course	G203/13	Depression	SW / Kenilworth	Race course, conservation area	-33.998567 S 18.488071 E	25	Cape Flats Sand Fynbos	
22. Malkkopsvlei / Bass Lake	G401/01	Depression	SW / Betty's bay	Residential	-34.356007 S 18.9070761 E	10	Hangklip Sand Fynbos	

Wetland name	**Wetland code**	**Wetland type** (Ollis *et al.*, 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**GPS coordinates**	**Alt (m)**	**Vegetation type** (Mucina and Rutherford, 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al.*, 2006)
23. Groot witvlei	G401/03	Depression	SW/ Betty's bay	Residential	-34.361941 S 18.891045 E	8	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos
24. Gaansbaai	G403/09	Depression	SW / Gaans Bay	Open land	-34.576939 S 19.375242 E	37	Overberg Dune Strandveld	
25. Soetendalsvlei	G501/08	Depression	AP / Agulhas	Agriculture, nature reserve	-34.726928 S 19.984579 E	2	Cape Inland Saltpan- Inland Salt Vegetation	(E) Agulhas Sand Fynbos (W) Central Rûens Shale Renosterveld
26. Pearly Beach	G501/10	Depression	AP / Pearly Beach	Private open land	-34.67011 S 19.527988 E	2	Cape Lowland Freshwater Wetland	(S) Overberg Dune Strandveld (N) Agulhas Sand Fynbos
27. Wiesdrif	G501/18	Depression	AP / Agulhas	Agriculture	-34.669606 S 19.912607 E	4	Cape Inland Saltpan- Inland Salt vegetation	Central Rûens Shale Renosterveld
28. Bokkekraal	H101/01	Depression*	NW/ Worcester	Agriculture	-33.66648 S 19.397121 E	198	Breede Alluvium Fynbos	
29. Verrekyker	H101/05	Depression	NW / Wolseley	Conservation, agriculture	-33.43415 S 19.1774 E	252	Breede Alluvium Fynbos	

Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*., 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**GPS coordinates**	**Alt (m)**	**Vegetation type** (Mucina and Rutherford, 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*., 2006)
30. Khayelitsha pool	G204/02	Depression* (Floodplain)	SW/ Khayelitsha	Residential-Rural, Urban	-34.03913 S 18.686666 E	18	Cape Lowland Freshwater Wetland	Cape Flats Dune Strandveld

*Depressions = Floodplain wetlands but have been described as depressions as they are cut-off from the main river channel and function as depression.

2.2 Historical field data collection

A selection and inventory of wetlands for the field study were made from 1:50 000 topographical maps of the Western Cape. The aim of such a collection was based on obtaining a wide geographical spread of wetlands (Silberbauer and King, 1991). With funding being prematualy terminated sampling could only be done once-off, in 103 wetlands, within the Fynbos, Succulent Karoo and Nama Karoo Biomes during the wet winter months of 1988 and 1989. Biological, physical and chemical aspects of about 69 wetlands were surveyed in detail.

2.2.1 Environmental variables

Surface water samples and basic in situ physico-chemical variables such as electrical conductivity (EC) and pH, was measured in the field; salinity measurements were taken in wetlands with high EC readings. Filtered water samples were taken from a core group of 42 wetlands and analysed in the laboratory for total dissolved solids, and major ions.

2.2.2 Plant collection and identification

There was no documented sampling procedure that described the methods employed in the previous study in collecting the floral data. With the help of the previous plant collection book, field notes, map drawings and conversations with the previous researchers, it was concluded that sampling was conducted on a visual basis of the presence/absence of dominant wetland vegetation associated with each wetland. The wetland plant collection is housed in the Bolus Herbarium at the University of Cape Town.

2.3 Present-day field data collection

A total of 37 wetland sites where sampled from June 2012 to November 2013. To reduce the effect of seasonality in comparison between current and historical data by sampling occurring within the same month as samples collected in the previous study.

2.3.1 Environmental variables

At each site with water present *in situ* water parameters were measures using multi meters. Conductivity was measured at 25º C in mS/cm, using a Crison CM 35 (accuracy of ± 0.05% of the reading) or an Orbeco Hellige Series 150 multimeter (accuracy of 2% of the reading, range: 0.0 uS/cm – 500 mS/cm). The pH calibrated for pH 4 and 7, was measured by a Crison pH 25 (accuracy of ± 0.01 pH units) or an Orbeco Hellige Series 150 multimeter (accuracy of ± 0.02 pH units). All meters were always inter-calibrated to avoid errors when using two different machines.

Unfiltered and filtered water samples were collected for major ions and nutrient analysis. Two-hundred and fifty millilitres of filtered water was collected and analysed for nutrients by the Oceanography Department of the University of Cape Town. Two-hundred and fifty millilitres of unfiltered water preserved in mercuric chloride was collected for analysis for total nutrients, analysed by the South African National Department of Water Affairs.

Other environmental variables considered were rainfall and altitude. Rainfall data was obtained from South African Weather Services and the altitudes were obtained from topographical maps of the Western Cape from the National Geo-Spatial Information of the Rural Development and Land Reform Department in Mowbray, Cape Town (Mapping and Surveying Department)..

2.3.2 Plant collection and identification

The sampling procedure used in the study was same as the one followed as King and Silberbauer for comparative purposes and because time and budget constraints did not allow collection of a more intensively collected plant data set. Plant sampling was done on a visual basis on the most common plants species, in and around the wetland water body where necessary specimens of each species were collected.

Easily visible plants were identified in the field were possible. Species that could not be identified in the field were collected and pressed for later identification. Photographs were taken of all plant species and the habitat in which they were found. Records were made from three different vegetative forms found within wetlands; emergent, submerged and floating plants.

Plant samples were identified with the aid of field guides, the use of the Bolus Herbarium, with assistance from Dr Terry Trinder-Smith, Curator of the herbarium and specialists in the Department of Biological Sciences at University of Cape Town. Most specimens could be identified to species, but some could only be identified to genus or family, as many plants were not flowering during the wet sampling periods.

2.4 Analysis of aerial photographs

Digitized aerial photographs were obtained from the National Geo-Spatial Information of the Rural Development and Land Reform Department in Mowbray, Cape Town (Mapping and Surveying Department). Historical images for different parts of the study area were available for different times ranging from 1986 to 1991. These images were compared with ortho-rectified 2010 colour aerial photographs (Figure 2.4).

With the use of Quantum Geographic Information System v 2.2.1 (QGIS) the historical aerial photographs were geo-rectified, and digitized to allow change in land-use in and around the wetland sites to be visually assessed. The catchment boundaries of certain wetlands were difficult to establish, and thus a 1 km standardized buffer zone around all the wetlands was established. The rationale behind this was that land-use closest to the wetland would have more direct and easily identifiable/detectable impact that those catchment wide. In the case of river systems, a 1 km wide X 1 km in length buffer was drawn parallel to the river from the sampling point. Land-use change was assessed within these buffer zones for comparative purposes (Figure 2.3 C). The resultant images were then used to identify land-cover classes:

- Development, either
    - Formal residential or
    - Informal residential or
    - Industrial
- Natural/Undeveloped land
- Agriculture (Crop farming)

Control points such as railways, main roads or intersections were used for geo-referencing. Area of change was estimated by comparing the size (m^2) of the different classes for each year.

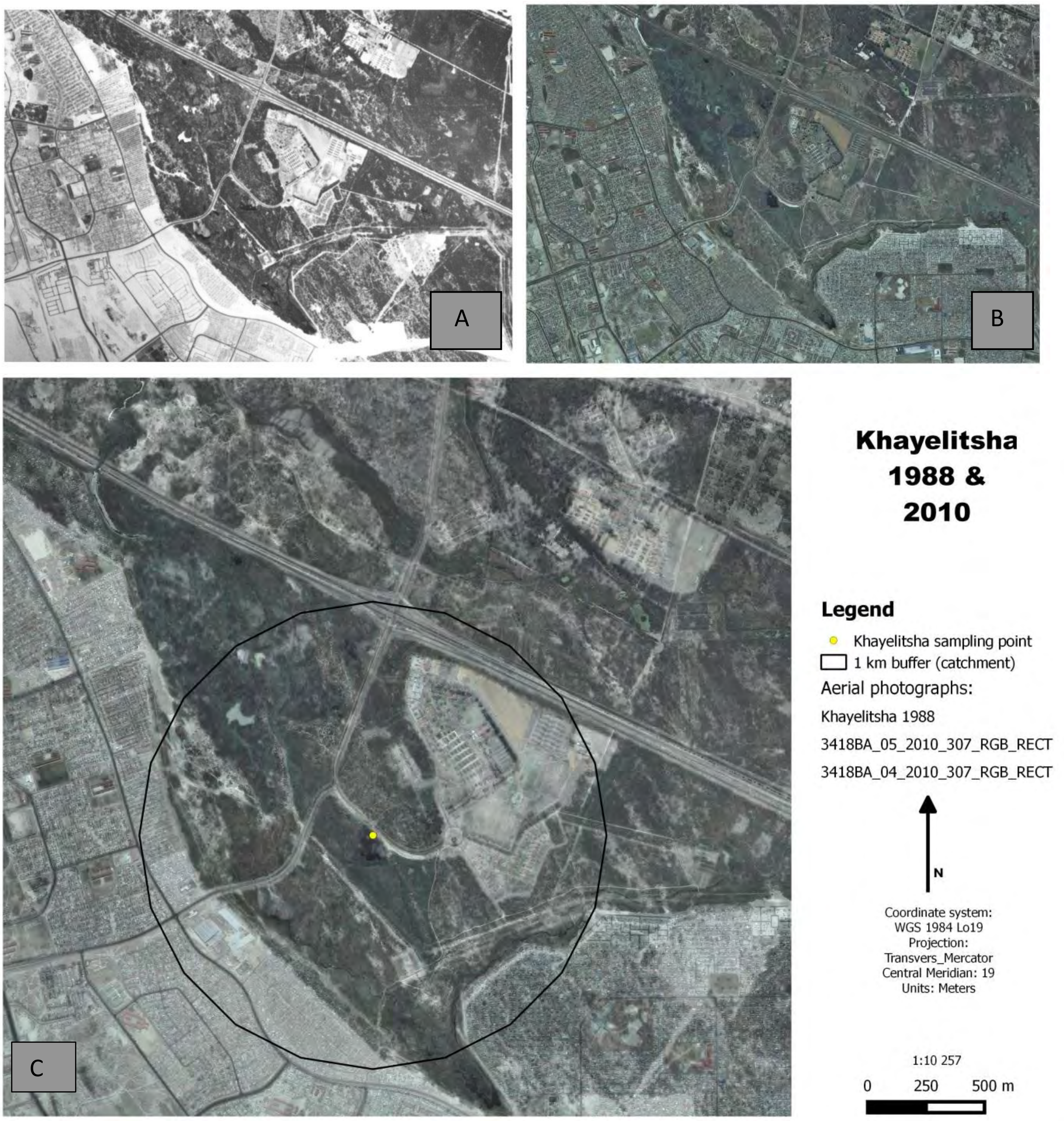

Figure 2.4 Aerial photographs of the wetland site Khayelitsha Pool and surrounding area where A: 1988, B: 2012 and C: showing the outline of the 1 km buffer area which was digitized for the different land-cover classes and the sampling point in the wetland.

2.5 Statistical analysis

Multivariate statistics were used to analyse both plant and environmental variables. The statistical analysis package Plymouth Routines in Multivariate Ecological Research (PRIMER-E: Clarke and Gorley 2006) and its add-on Permutational Multivariate Analysis of Variance (PERMANOVA+: Anderson *et al*. 2008) were used for all analyses of the historical and present data sets. All tests for significance were made at $\alpha = 0.05$ and/or 5%.

Plant species data, both the historic and present-day data were available for 37 wetlands. Seven wetland sites were removed from the data set, two being outliers that skewed the data in multivariate space, and five having no historical vegetation data available. Therefore, a total of 30 wetland sites with both historical and present-day data were used in the analyses of the vegetation data, for comparative purposes.

Of the 30 wetland sites environmental data was available for 17 wetland sites in the historical period. Thus analysis of environmental variables related to the historical plant species communities was performed on a subset of the wetlands (n=17). Four variables were examined: pH, conductivity, altitude, and annual rainfall. Nutrient analyses which included phosphate ($P0_4$-P), nitrite ($N0_2$-N) + nitrate ($N0_3$-N) and ammonium (NH_4-N) for the historic data are patchy and were therefore not be included as this would have resulted in further reduction of sample size. Environmental data for 30 wetland sites in the present-day study were examined separately to investigate relationships with the plant communities, seven variables were included in the analysis of environmental variables related to the present-day plant species communities, namely pH, conductivity, altitude, rainfall, phosphate ($P0_4$-P), nitrite ($N0_2$-N) + nitrate ($N0_3$-N) and ammonium (NH_4-N).

Five of the seven wetland HGM types are recognized by Ollis *et al*. (2013) are found in this study: depressions, channelled valley-bottoms, unchannelled valley-bottoms, floodplain wetlands and wetland seeps. Wetland types that were represented by only one or two sites were analysed together with other similar wetland groups, such as channelled and unchannelled valley-bottom wetland. Floodplain wetlands that were cut-off from the river channel functioned as depressions and were added to the depression group, while salt pans were separated from depressions based on their water chemistry. The following wetland groups were therefore used for analysis of wetland types: depressions, salt pans, valley bottoms and seeps.

The following techniques were used in the analysis of the vegetation and environmental data: Dendrograms determine how similar one sample is to another, grouping like samples, while searching for outliers in the data set. In PRIMER, a group-average linkage classification technique was applied to cluster plant species of similar assemblage composition between sites. The cluster analysis combined with the SIMPROF 'similarity profile' was applied to the resemblance matrix of the samples/sites. SIMPROF is a permutation test, which looks for statistically significant evidence of clusters in the samples/sites. The SIMPROF test is done at every node of a completed dendrogram, a group being sub-divided suggest that samples (sites) in that group illustrates evidence of multivariate pattern, i.e. 'significant' internal structure (Clarke and Gorley, 2006). Therefore, in the figures, the black lines identify the main groups and the branches coloured red indicate that these samples (sites) are significantly similar. Hierarchal cluster analysis was used to determine the different plant communities in the 1988/89 and 2012/13 species vegetation data.

Ordination by non-metric Multidimensional Scaling (MDS) in PRIMER was deemed an appropriate technique displaying the similarity amongst the sites based on plant species composition. The two-dimensional MDS with a stress value of less than 0.2 indicates a good representation of the patterns in the data show inter-sample (dis)similarity optimized to retain inter-sample rank dissimilarity. The visual interpretation of the MDS is such that the distances between sample points is a measure of their degree of similarity and points that are close together will represent samples/sites which are similar in plant species composition, two points further apart are can therefore be seen as more dissimilar or different.

The Analysis of Similarity (ANOSIM) in PRIMER is a non-parametric permutational procedure, applied to the rank data of a resemblance matrix that allows testing of the null hypothesis of no difference between groups of sample (Clarke and Gorley, 2006). ANOSIM allows one to test the null hypothesis of no difference by comparing the within-group rank dissimilarity to among-group rank dissimilarity. In the case of the plant species composition data, ANOSIM was used to assess the among-plant communities-types differences, the among-wetland-types differences, and the between-survey-year difference in plant composition above background differences. Two-way crossed layouts with replicates ANOSIM also allowed, for example testing the null hypothesis that there are no differences in plant communities and between the time periods in terms of vegetation species assemblages. However the two-way layout only provides the main effect between the two factors and does not allow one to test for interaction between them (Clarke and Gorley, 2006).

ANOSIM cannot test for interaction effect, therefore to test whether there is a difference over the time periods between plant communities, two-way PERMANOVAs were performed. This allowed testing not only for the difference in main effect between survey-years and among plant communities but also for the interaction effect of compositional difference among plant communities that can depend on years.

The next natural step was identifying species (e.g. plant species/groups) that characterize/differentiate the different plant community groups identified by the cluster analysis, by performing a SIMPER analysis. Examining the pairwise comparisons from an ANOSIM, with a SIMPER analysis will indicate where those differences lie between plant community groups and which wetland species are shared amongst them The SIMPER analysis identified species that are characteristic of, or distinguish between, groups of vegetation species data.

A post hoc test of one-way Permutational multivariate analysis of variance (PERMANOVA), in PERMANOVA+, at 9999 permutations under a reduced model, was conducted to confirm the plant grouping identified in the cluster analysis, plant groups between the two survey years; environmental variables, and environmental variables between the two survey years.

A two factor PERMANOVA, in PERMANOVA+, at 9999 permutations under a reduced model, was conducted to test for the interaction effect between the effects of plant communities and year on the variability in the plant species composition between the two time periods (1988/89 and 2012/13).

In the simplest form (e.g. one-way) PERMANOVA was used to compares the variation due to the group effect of plant communities and survey year to the total within-group variation (residual sum of squares) to test for the null hypothesis of no group difference (Anderson *et al.,* 2008).

PERMANOVA and ANOSIM are both sensitive to differences in dispersion among groups, therefore homogeneity of multivariate dispersions is implicit in the partitioning between groups (Anderson *et al*., 2008). The PERMDISP routine in PERMANOVA+ was used to test for the homogeneity of multivariate dispersion among samples to assess the validity of significant difference determined by PERMANOVA.

Distance-based Linear Modelling (DITSLM) in PERMANOVA+ was used to determine the relative importance of individual environmental variables in explaining differences in the plant species composition between sites. An approach by DISTLM called distance-based Redundancy Analysis (dbRDA) (dbRDA, Lengendre and Anderson, 1999; McArdle and Anderson, 2001) a non-parametric multivariate multiple regression ordination procedure based on any given dissimilarity measure, was implemented as it fits values from the linear model with an overlay of those variables. *P*-values were tested by 9999 permutations of residuals under the reduced model. 'Best', a procedure, which examines for all possible combinations of predictor variables, was chosen as the selection procedure. The regression procedure incorporated an adjusted $R^{\wedge 2}$. Adjusted $R^{\wedge 2}$ is used to compensate for the addition of environmental variables to the model (Anderson *et al.,* 2008).

CHAPTER 3

Results

Plant species data was available for 37 wetlands in the present-day study, while only available for 32 wetlands in the historical study. Seven wetland sites were removed from the present-day data set having no historical biological data available. The same two outlier wetland sites were also removed from the historical data. Therefore a total of 30 wetland sites with both historical and present-day data were used for comparative purposes.

Five of the seven wetland types recognized by Ollis *et al*. (2013) were found in this study: depressions, channelled valley-bottoms, unchannelled valley-bottoms, floodplain and seeps wetlands. The following wetland groups were used for analysis of wetland types (n=30): depressions, salt pans, valley bottoms and seeps. Fifty percent (15) of the wetlands studied were depression wetlands, 23 % (7) were valley-bottom wetlands (i.e. merging channelled and unchannelled), 17 % (5) consisted of salt pans, and the remaining 10 % (3) were seeps.

Presence/absence data of 142 plant species were recorded for the present-day samples and 173 plant species were recorded for the historical samples, in 30 wetland study sites (Appendix 1 and 2). Of the 142 plants species in the present-day study 114 were identified to species and with 28 to genus. Of the 173 species in the King and Silberbauer study 115 were identified to species and 58 to genus.

The first step in the analysis of the plant species communities was to order the presence-absence data in a resemblance matrix. Both data sets were analysed using the Bray-Curtis measure of similarity, and no transformation of the data was needed.

3.1 Characterization of plant communities and wetland types of the Core Cape Region in 1988/89 and in 2012/13

Separate multivariate analyses were carried out on historical and present-day wetland plant species data in order to characterize wetland plant communities.

3.1.1 Multivariate analysis of vegetation data for 1988/89

Characterizing plant communities for 1988/89

The hierarchical clustering (Figure 3.1) of the vegetation in the 30 wetlands identifies four plant communities distinct at a similarity of 12% (SIMPROF, $p < 0.05$). The main groups, in the dendrogram, are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The corresponding MDS (Figure 3.2) low stress value of 0.12 indicates that the two-dimensional MDS plot is a good representation of the patterns in the data.

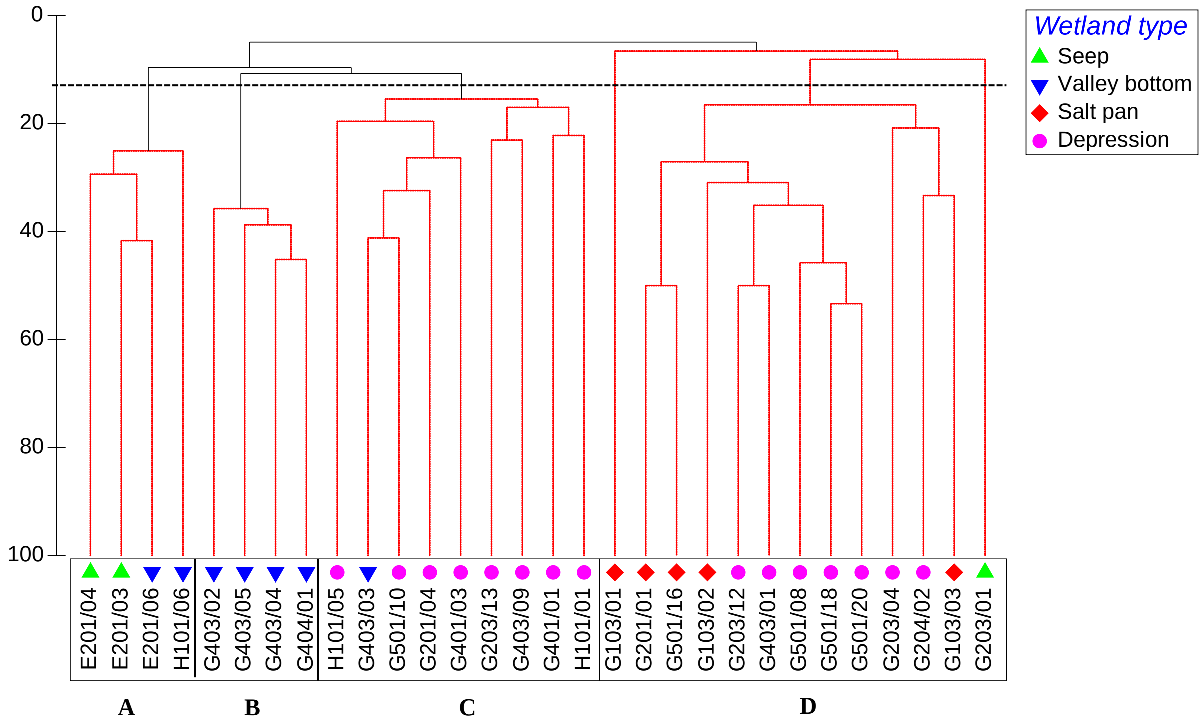

Figure 3.1 Hierarchical cluster analysis illustrating the main plant communities for wetland types for 1988/89. The main groups are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. Wetlands may be identified by their wetland site codes.

There is a gradient across the different plant groups from the upper left (Group A and Group B) to the lower right (Group D). Group D and A has a very modest species composition effect (i.e. spread), while Group B has a much larger effect, with a wider spread across the MDS. In general the MDS plot illustrates the differences between plant communities and the variation within the plant communities. The differences and/or similarities between the plant communities groups can be found in Table 3.1 (pair-wise comparison).

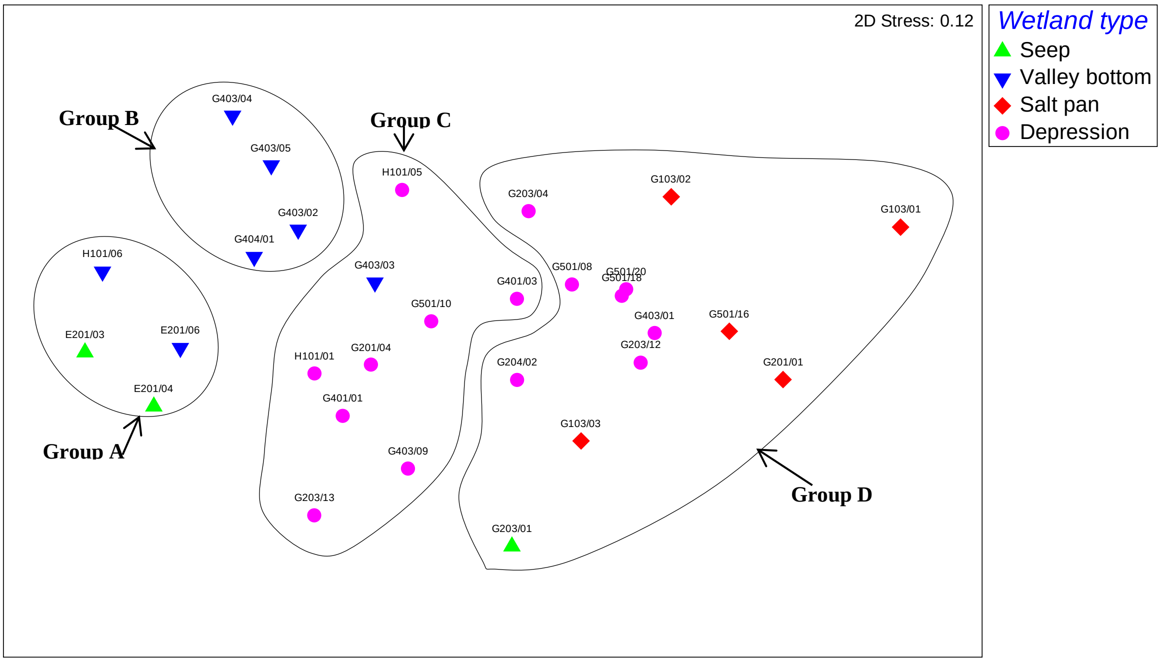

Figure 3.2 MDS plot of the wetland plant communities for wetland type (stress 0.12) as identified by the cluster analysis (n=30) for 1988/89. Wetlands may be identified by their wetland site codes.

Characterizing wetland type for 1988/89

The same vegetation data (of 1988/89) was used in the cluster analysis and MDS plots produced for wetland types, based on the HGM approach (Ollis *et al*. 2013), to ascertain whether wetland plant communities reflect wetland type i.e. using the same plots twice but illustrating different aspects. In general the plant community groups identified by the hierarchical cluster analysis (Figure 3.1) do not consistently group wetlands of the same type. Moreover, the gradient across the different plant groups in the MDS (Figure 3.2) where the role of altitude in shaping community composition was clearly revealed by the clustering of high altitude (Table 3.3, altitude range from 883 to 1369 m) seeps and valley-bottoms (plant community group A) separately from the lower-altitude (Table 3.3, altitude range from 72 to

245 m) depressions and salt pans (plant community Group D) wetlands and the dissimilarity between them.

ANOSIM was performed to test the null hypothesis that there are no differences in species composition between plant communities for 1988/89. The ANOSIM (global $R = 0.62$, $p = 0.001$) suggests significant differences in species composition of different plant community groups. Although the plant community groups appear to be highly significantly different (ANOSIM, $p < 0.05$), the ‘R’ values are close to zero (Table 3.1). This suggests that the groups do not have identical species composition, but that there is an overlap of species with some species occurs in more than one group. The null hypothesis, that there are no differences in observed communities, is true when the ‘R’ values are equal or close to zero. Examining the pairwise comparisons from the ANOSIM with a SIMPER analysis indicates where those differences lie and which species are shared amongst the groups.

The pairwise comparisons (Table 3.1) reveals that the most dissimilar groups are A and B ($R = 0.92$), and groups A and D ($R = 0.76$). Additionally, groups A and D and groups D and B are more significantly different ($p = 0.04$) from each other than are groups A and B, ($p > 0.05$), while most significant similarity is observed groups D and C ($R = 0.51$, $p = 0.01$).

Table 3.1 Analysis of similarity of the Bray-Curtis resemblance of species composition identified by the cluster analysis for 1988/89. Significant groups from each other are marked with *.

Pairwise Tests			
Groups	**R Statistic**	**P-value**	**Possible Permutations**
A, B	0.92	2.9	35
A, D	0.76	0.04*	2380
D, B	0.70	0.04*	2380
A, C	0.63	0.1	715
C, B	0.57	0.1	715
D, C	0.51	0.01*	497420

SIMPER analysis of species composition was used to determine, which species were characteristic of, and distinguished between, the different plant groups. As indicated by the low 'R' values in the ANOSIM (Table 3.1), the SIMPER analysis shows the species shared between plant groups. SIMPER analysis here reveals the percentage contribution of each species per group identified in the cluster analysis (Figure 3.1) for the historical vegetation data. The two species that contributed the most to each group were used to describe respective plant group.

The SIMPER results (Table 3.2) showed that the sites clustering in group A have an average similarity between pairs of sites of 29.3%, made up mainly of contributions from the species *Isolepis prolifera* (35.7%) and *Pennisetum macrourum* (35.7%). The sites in group B have an average similarity of 38.3% and are made up mainly of contributions from the three species *Calopsis paniculata* (18.4%), *Carpha glomerata* (18.4%) and *Cliffortia strobelifera* (18.4%). Sites in group C have an average similarity of 19.1% mainly characterized by *Typha capensis* (29.3%), *Juncus kraussii* (14.8%) and *Laurembergia repens* (10.3%). Finally, sites clustering as group D have an average similarity of 20.2% and largely made up of *Juncus kraussii,* (36.6%) and *Sarcocornia natalensis* (32.4%). The species mentioned above can be considered to be 'typical' of each group. Several species describing communities are shared between more than one plant community groups, namely *Isolepis prolifera* and *Pennisetum macrourum* shared in groups A and C, *Prionium serratum* is shared in groups B and C, while *Juncus kraussii* and *Elegia tectorum* is common to plant community groups C and D.

Table 3.2 Plant species characteristic for 1988/89 communities identified in the cluster. Biotic and environmental differences between the communities are noted. (phytogeographical centres, NW – Northwest, SW – Southwest, AP – Agulhas Plain)

Plant community groups		**Description**
Species	**Contribution %**	
Group A **Average similarity:**	 **29.27**	*Isolepis prolifera – Pennisetum macrourum community*
Isolepis prolifera	35.66	• Characterized by high altitude (883 - 1369 m) and fresh water species. • Wetland types found in this group include seeps and a channelled valley-bottom • Phytogeographical spread of wetlands: – NW: E201/03, E201/04 and E201/06 and H101/06
Pennisetum macrourum	35.66	
Juncus lomatophyllus	4.95	
Laurembergia repens	4.95	
Cyperus thunbergii	4.74	
Elegia capensis	4.74	
Cumulative contribution	**90.70**	
Group B		*Calopsis paniculata – Carpha glomerata – Cliffortia strobilifera community*
Average similarity:	**38.31**	
Calopsis paniculata	18.41	• Characterized by fresh water species, mostly lotic systems at moderately high altitudes (72 – 245m). • Wetland types found in this group are channelled valley-bottoms • Phytogeographical spread of wetlands: – SW: G404/01, G403/02, G403/04 and G403/05
Carpha glomerata	18.41	
Cliffortia strobilifera	18.41	
Psoralea aphylla	8.27	
Pteridium aquilinum	8.27	
Platycaulos major	7.68	
Prionium serratum	7.68	
Erica curviflora	2.81	

Wachendorfia thyrsiflora	2.81	
Cumulative contribution	**92.61**	
Group C **Average similarity:**	**19.06**	*Typha capensis – Juncus kraussii community*
Typha capensis *Juncus krausii* *Laurembergia repens* *Phragmites australis* *Centella asiatica* *Prionium serratum* *Elegia fistulosa* *Psoralea pinnata* *Isolepis prolifera* *Juncus lomatophyllus* *Senecio halimifolius* *Aponogeton distachyos* *Polygonum* sp. *Persicaria decipiens* *Conyza scabrida* *Elegia tectorum* *Pennisetum macrourum*	29.34 14.81 10.29 6.48 5.63 3.65 3.39 3.09 2.51 2.45 2.31 1.27 1.21 1.17 1.12 1.08 1.08	• Characterized by brackish to fresh water species, high nutrients found at low to moderate altitudes (4 – 263 m). • Wetland types found in this group include depressions and a channelled valley-bottom • Phytogeographical spread of wetlands: − NW: H101/01 − SW: G203/13, G401/03 and G403/03 − AP: G501/10.
Cumulative contribution	**92.76**	
Group D		*Juncus kraussii – Sarcocornia natalensis community*
Average similarity:	**20.21**	• Characterized by mostly brackish to saline species and ranging from low to moderate altitudes (2 - 272 m) • Wetland types found in this group include salt pans, depressions and seeps. • Phytogeographical spread of wetlands: − NW: G103/01, G103/02 and G103/03. − SW: G203/04, G204/02, G203/12, G203/01 and G403/01 − AP: G501/08, G501/16, G501/18 and G501/20.
Juncus krausii *Sarcocornia natalensis* *Elegia tectorum* *Bolboschoenus maritimus* *Sporobolus virginicus*	36.55 32.38 11.13 7.90 4.64	
Cumulative contribution	**90.89**	

The post hoc test of the one-way PERMANOVA was conducted to confirm the plant grouping identified in the cluster analysis, and revealed that these groupings are significantly different ($p = 0.001$). The PERMDISP, was performed to test the homogeneity of dispersions, suggests that the differences of the plant community groups is, however not significant ($p = 0.633$). With a non-significant PERMDISP and a significant PERMANOVA result means that there is no difference in the dispersion between the plant community groups but significant differences in the position of the plant community group centroids.

In summary, for the historical data four plant communities and their main indicator species were identified. The differences between the plant community groups were found to be significantly different, but differences should be recognized within the plant groups rather among them. The cluster analysis (Figure 3.1) and MDS plot (Figure 3.2) indicates that the identified plant communities group wetlands of the same type, but not consistently. The next step was to follow the same analysis procedure for the 2012/13 vegetation data and then to see whether the plant communities have changed from those identified for 1988/89.

3.1.2 Multivariate analysis of vegetation data collected for 2012/13

Characterizing plant communities for 2012/13

The hierarchical clustering (Figure 3.3) of the vegetation in the 30 wetlands identifies five plant communities distinct at a similarity of 8% (SIMPROF, $p < 0.05$). The main groups, in the dendrogram, are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The low stress value of 0.1 indicates that the two-dimensional MDS plot (Figure 3.4) is a good representation of the patterns in the data.

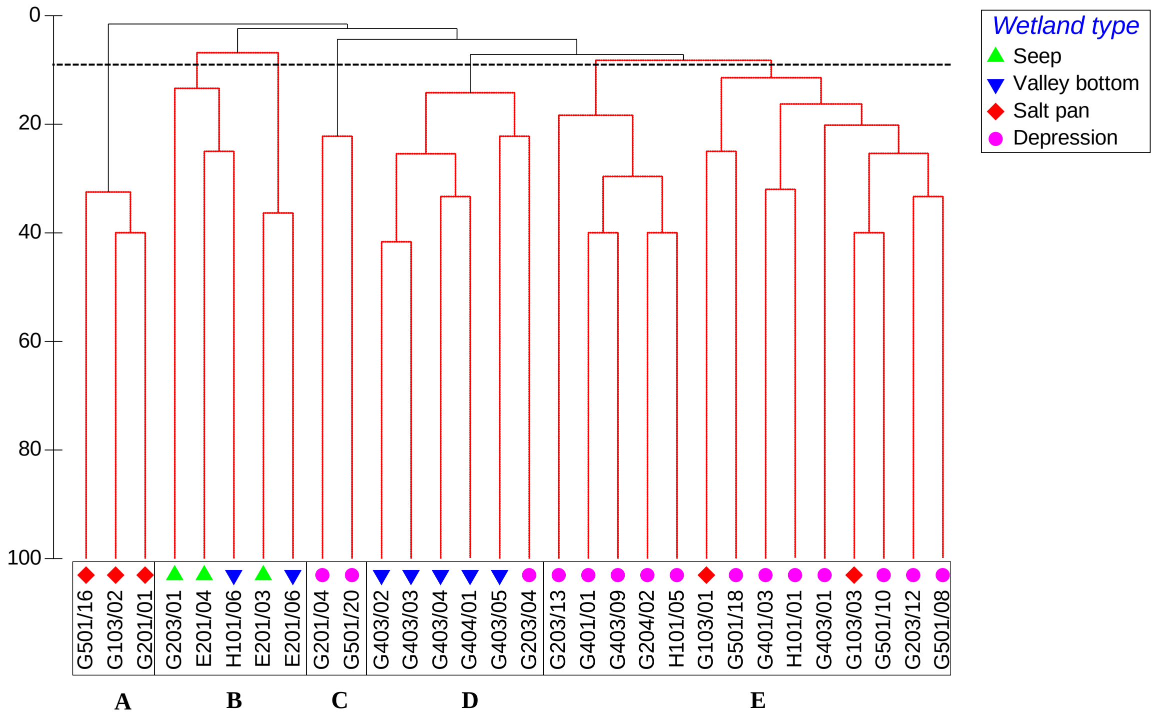

Figure 3.3 Hierarchical cluster analysis illustrating the main plant communities for wetland types for 2012/13. The main groups are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. Wetlands may be identified by their wetland site codes.

The gradient across the different plant communities is not as clear in this data set as in the previous MDS plot of 1988/89 (Figure 3.2). Furthermore, there is a trend from the left (Group Band D) to the lower right (Group A). More specifically, Groups C and A has a very modest species composition effect (i.e. spread), while Group E has a much larger effect, with a wider spread up the MDS plot. In general the MDS plot illustrates the differences between plant communities and the variation within the plant community assemblages of the plant communities. The differences and/or similarities between the plant communities groups can be found in Table 3.4 (ANOSIM, pair-wise comparison).

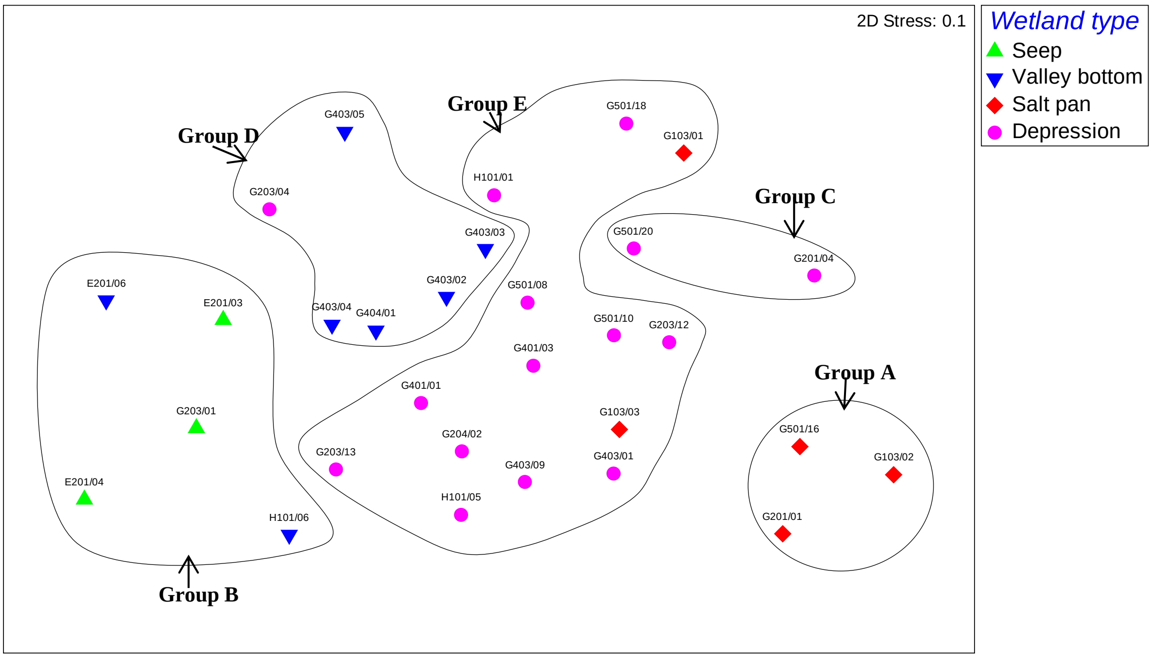

Figure 3.4 MDS plot of the wetland plant communities for wetland type (stress 0.1) as identified by the cluster analysis (n=30) for 2012/13. Wetlands sites may be identified by their wetland site codes.

Characterizing wetland type for 2012/13

The same vegetation data (of 2012/13) was used in the cluster analysis and MDS plots produced for wetland types, to ascertain whether wetland plant communities reflect wetland type i.e. using the same plots twice but illustrating different aspects. In general the plant community groups identified by the hierarchical cluster analysis (Figure 3.3) do not consistently group wetlands of the same type. Moreover, the gradient across the different plant groups in the MDS plot (Figure 3.4), where the role of altitude and wetland chemistry in shaping community composition was clearly revealed by the clustering of high altitude (Table 3.4, altitude range from 272 to 1369 m), freshwater wetlands seeps and valley-bottoms (plant community group B) separately from the lower-altitude (Table 3.4, altitude range from

2 to 57 m) saline salt pans (plant community group A) wetlands and the dissimilarity between them.

ANOSIM revealed significant differences in species composition of different plant community groups for 2012/13 (global R = 0.55, p = 0.001). The null hypothesis, that there is no difference in observed communities, is true when the 'R' values are equal or close to zero. Examining the pairwise comparisons (Table 3.3) from the ANOSIM with a SIMPER analysis indicates where those differences lie and which species are shared amongst the groups.

In the pairwise test (Table 3.3) many of the groups differ but are not significantly different from each other with the exception of groups D and E (R=0.57, p = 0.01). The most dissimilar are groups A and C (R=1), groups A and D, and groups C and D but the relationships between the groups is not significant (p > 0.05). The 'R' values close to zero (e.g. groups E and D) signifying that there is an overlapping of species between the groups.

Table 3.3 Analysis of similarity of the Bray-Curtis resemblance of species composition of plant communities for 2012/13. Significant groups different are marked with *.

Pairwise Tests

Groups	**R Statistic**	**Significance Level %**	**Possible Permutations**
A, C	1	10	10
A, D	0.944	1.2	84
C, D	0.807	3.6	28
B, A	0.769	1.8	56
B, C	0.727	4.8	21
B, D	0.7	0.2	462
B, E	0.573	0.01*	11628
E, A	0.532	0.1	680
E, C	0.417	0.8	120
E, D	0.378	0.06	38760

The SIMPER analysis here reveals the percentage contribution of each species per plant group identified in the cluster analysis (Figure 3.3). The two species that contribute most to each group are used to describe that group.

The SIMPER analysis (Table 3.4) showed that the sites clustering in Group A has an average similarity between pairs of sites of 35.0%, made up mainly of contributions from *Sarcocornia natalensis* (100%) a salt tolerant species. The sites in group B have an average similarity of 12.9% and are chiefly made up of *Pennisetum macrourum* (71.8%) with equal contributions from *Elegia capensis* and *Psoralea oligophyla* (14.1% each). The sites in group C have an average similarity of 22.2% and are characterized by *Ficinia nodosa* (100%). The sites of group D highest contributing species are *Calopsis paniculata* (13.5%) and *Cliffortia strobilifera* (13.5%) and have an average similarity between pairs of sites of 20.8%. Lastly, sites clustering as group E have an average similarity of 14.0%, and is characterised by *Phragmites australis* (33.4%) and *Juncus kraussii* (23.2%). The species mentioned above can be considered to be 'typical' of each group. Several species are shared between more than one plant community groups, namely *Phragmites australis* and *Pennisetum cladestinum* are both shared in group D and E.

Table 3.4 Plant species characteristic for 2012/13 communities identified in the cluster. Biotic and environmental differences between the communities are noted. (phytogeographical centres, NW – Northwest, SW – Southwest, AP – Agulhas Plain)

Plant community groups		**Description**
Species	**Contribution %**	
Group A		*Sarcocornia natalensis community*
Average similarity:	**35.00**	• Similar to historic group D • Characterized by species tolerant of saline conditions found at altitudes ranging from 2 – 57 m. • Wetland types found in this group are saltpans • Phytogeographical spread of wetlands: − NW: G103/02 and G201/01 − AP: G501/16
Sarcocornia natalensis	100	
Cumulative contribution	100	
Group B		*Pennisetum macrourum – Elegia capensis community*
Average similarity:	**12.91**	• Similar to group A of 1988/89 • Characterized by high altitude wetlands (1369 – 272 m) with fresh water species • Wetland types found in this group include seeps and valley-bottoms • Phytogeographical spread of wetlands: − NW: E201/06 and E201/03 and H101/06 − SW: G204/01
Pennisetum macrourum	71.83	
Elegia capensis	14.08	
Psoralea oligophylla	14.08	
Cumulative contribution	**100**	
Group C		*Ficinia nodosa community*
Average similarity:	**22.22**	• Arose from historic group C • Characterized by brackish species at low
Ficinia nodosa	100	

		altitude of 7 – 11 m. • Wetland type found in this group are depressions • Phytogeographical spread of wetlands: – NW: G201/04 – AP: G501/20
Cumulative contribution	**100**	
Group D		
Average similarity:	**20.84**	*Calopsis paniculata – Cliffortia strobelifera community*
Calopsis paniculata	13.52	• Similar to group B of 1988/89 • Characterized by freshwater species at low to moderately high altitudes (8 – 228 m) • Wetland types found in this group are valley-bottoms • Phytogeographical spread of wetland sites: – SW: G404/01, G403/02, G403/04 and G403/03
Cliffortia strobilifera	13.52	
Berzelia lanuginosa	11.45	
Prionium serratum	10.79	
Pteridium aquilinum	8.25	
Psoralea aphylla	7.91	
Carpha glomerata	7.40	
Isolepis prolifera	6.13	
Phragmites australis	6.13	
Laurembergia repens	3.37	
Pennisetum clandestinum	2.56	
Cumulative contribution	**91.03**	
Group E		
Average similarity:	**14.04**	*Phragmites australis – Juncus kraussii community*
Phragmites australis	33.37	• Similar to historic group C & D • Characterized by brackish to freshwater species, some of which establish in high nutrient wetlands ranging from low to moderately high altitudes (4 – 263m). • Wetland types found in this group are depressions • Phytogeographical spread of wetlands: – NW: G103/01 and G103/03, H101/01 and H101/05 – SW:G203/12, G203/13 and G204/02
Juncus kraussii	23.21	
Typha capensis	8.88	
Persicaria decipiens	7.78	
Pennisetum clandestinum	5.77	
Mentha aquatica	5.19	
Schoenoplectus scirpoides	2.61	
Searsia lucida	2.45	
Centella asiatica	2.29	
Cumulative contribution	**91.54**	

The post hoc test of the one-way PERMANOVA was conducted to confirm the plant groupings identified in the cluster analysis (Figure3.3) revealed that these groupings are significantly different (p = 0.001). The PERMDISP was performed to test the homogeneity of dispersions, suggests that the differences of the plant groups is, however not significant (p = 0.675). With a non-significant PERMDISP and a significant PERMANOVA result means that there is no difference in the dispersion between the plant community groups but significant differences in the position of the plant community group centroids.

In summary, for the present-day vegetation data five significantly distinctive plant communities and their main indicator species were identified. The differences between the plant groups were found to be significant, but differences should be recognized within the plant groups rather among them. The SIMPER analysis revealed species such as *Sarcocornia natalensis* and *Ficina nodosa* as 'typical' single dominant species describing groups A and C, respectively. Many of the plant communities in the present-day data are similar to those found in the historical data set but vary in terms of percentage species contribution. For example historical group A, characterized as an *Isolepis prolifera* (35.7%) – *Pennisetum macrourum* (35.7) community type, is described in the present-day group B as a *Pennisetum macrourum* (71.8%) – *Elegia capensis* (14.1%) community type, indicating a shift in the diagnostic plant species over time, as suggested and supported by the PERMDISP. Furthermore, *Ficinia nodosa* characterizes a plant community group in the present-day vegetation data that was not evident in the historical data. The cluster analysis (Figure 3.3) and supported by the SIMPER analyses indicated that the plant communities groups do not consistently group wetlands of the same type. The next step was to analyse the correlations between the environmental variables and the plant species assemblages of 1988/89 and 2012/13.

3.2 What are the major environmental variables influencing plant species distribution in the wetlands?

The variables measured for each wetland consisted of the combination of physical and chemical variables that describe the water chemistry of each wetland. Detailed results (Table 3.5) of the measured water chemistry and other measured variables consisted of altitude, electrical conductivity (EC), pH, phosphate, nitrite + nitrate, ammonium and rainfall for the historic and present-day study. Of the measured water chemistry variables EC historically ranges from 70 to 9770 mS/m, but the present-day values range from 1.5 to 18 300 mS/m. While pH values range historically from 6.4 to 9.8, with the majority between 6 and 7, in the present-day study a few acidic wetlands increase the range from 3.8 to 9.4. Many of the wetlands in the historic study had phosphate values of <0.01mg/L, which is the detection limit. Phosphate ($P0_4$-P) values range from 3.051 to 0.003 mg/L in the present-day data set. Nitrite ($N0_2$-N) + nitrate (N0-N) ranges from 0.01 to 1.31 mg/L in the historical data set whereas in the present-day values are lower, ranging from 0.003 to 0.803 mg/L. Historically ammonium (NH_4-N) values range from < 0.01 (lowest detection limit) to 3.6 mg/L and present-day values from 0.002 to 1.508 mg/ L. Rainfall varied from 263 – 1250 mm per annum in the historical data set whereas in the present-day study rainfall increased to from 398 – 1374 mm per annum.

Table 3.5 Environmental variables for 1988/89 and 2012/13 study wetlands

Wetland name	Wetland code	Alt (m)	EC (mS/m)		pH		Phosphate ($P0_4$-P) (mg/L)		Nitrites ($N0_2$-N) + Nitrates (N0-N) (mg/L)		Ammonium (NH_4-N) (mg/L)		Rainfall (mm/a)	
			1988/89	**2012/13**	**1988/89**	**2012/13**	**1988/89**	**2012/13**	**1988/89**	**201/13**	**1988/89**	**2012/13**	**1988/89**	**2012/13**
Blomfontein	E201/03	1310		4.63		7.2	<0.01	0.003	0.01	0.043	0.03	0.034	499	1374
Driehoek	E201/06	890		1.88		7.55	<0.01	0.005	0.32	0.056	0.04	0.062	430	1374
Kiekoesvlei	G103/01	55		49.5		7.4		0.216		0.803		1.508	396	1374
Koekiespan	G103/02	57	70	18300	9.8	7.76	<0.01	0.125	0.28	0.236	3.60	1.412	354	443
Burgerspan	G103/03	70	9730	13260	7.8	7.77		0.155		0.008		0.547	354	443
Rooipan	G201/01	2	9770	4440	7.3	9.45	<0.01	0.582	0.02	0.01	0.80	0.441	354	443
Rondeberg	G201/04	15	4250	322	8.2	7.43	<0.01	0.014		0.003	0.08	0.045	418	443
Kleinplaats West	G203/01	270	552	180	8.9	4.6	<0.01	0.007		0.063	<0.01	0.065	417	443
Groot Rondevlei	G203/04	3		60		4.04	<0.01	0.014		0.003	<0.01	0.0313		699
Noordhoek Soutpan	G203/12	3	1561	31.2	7.8	6.7	0.17	0.077		0.006	0.78	0.002	335	699
Kenilworth Race Course	G203/13	25	417	1.58	8.1	4.04	<0.01	0.013		0.008	1.02	0.026	750	596
Silvermine Dam Inflow	G203/18	455	23	3.96	4.2	7.67	<0.01	0.022	0.02	0.011	0.11	0.007	765	466
Khayelitsha Pool	G204/02	18	1042	78.7	7.9	7.97		0.728		0.637		0.287	426	655
Malkopsvlei	G401/01	10	72	1447	6.8	8.75	<0.01	0.003	0.03	0.049	0.06	0.06	426	655
Groot Witvlei	G401/03	8		30.9		6.5		0.005		0.063		0.053	1146	919
Vermont Pan	G403/01	18	123.5	19.4	8.3	7.79	0.60	0.231	0.14	0.128	<0.01	0.3159	1146	919

Wetland name	Wetland code	Alt (m)	EC (mS/m)		pH		Phosphate ($P0_4$-P) (mg/L)		Nitrites ($N0_2$-N) + Nitrates (N0-N) (mg/L)		Ammonium (NH_4-N) (mg/L)		Rainfall (mm/a)	
Hemel en Aarde	G403/02	72	500	11.8	8.2	3.8	<0.01	0.003	0.05	0.003	0.17	0.0272	636	919
Elias Gat	G403/03	133		138		6.24	<0.01	0.003	0.05	0.255	0.28	0.0737	591	919
Belsvlei	G403/04	260		26.2		5.48	<0.01	0.003	0.04	0.142	0.04	0.0372	624	919
De Diepte Gatt	G403/05	270		68.5		6.22	<0.01	0.007		0.016	0.80	0.0397	779	919
Gansbaai	G403/09	37		147		6.05	<0.01	0.06		0.003	0.03	0.034	767	919
Salmonsdam	G404/01	160	163	166.5	8.5	6.32	<0.01	0.005	0.01	0.003	0.80	0.0078	465	919
Soetendalsvlei	G501/08	2		20.8		5.4	<0.01	0.003	0.12	0.045	0.21	0.055	603	554
Pearly Beach	G501/10	2	445	1800	6.4	7.6	<0.01	0.009	0.01	0.003	0.03	0.0587	457	554
Groot Hagel kraal	G501/14	77	164	4250	7.9	8.05	<0.01	0.014		0.003	0.16	0.0264	601	554
Melkbos Pan	G501/16	30		189		7.5	0.01	0.01		0.091	0.14	0.239	584	554
Wiesdrif	G501/18	4	1561		7.8		<0.01	0.107		0.003	0.04	0.0317	519	554
Varkensvlei	G501/20	4	109	32	7.3	6.24	<0.01	0.013		0.152	0.39	0.0959	456	554
Bokkekraal	H101/01	198	566	36	6.9	6.2	<0.01	0.003		0.463	0.02	0.037	402	554
Verrekyker	H101/05	252					<0.01	0.127		0.103	0.03	0.049	427	456
De Vlakte	H101/06	881				7.6	<0.01	0.03		0.746	0.04	0.127	511	1374

3.2.1 Multivariate analysis of variance of environmental variables

Complete environmental data was available for 17 wetland sites in the historical period. Thus analysis of environmental variables related to the historic plant species communities was performed on a subset of the wetlands (n=17). Four variables were examined: pH, conductivity, altitude, and annual rainfall. Environmental and water chemistry data of seven variables for 30 wetland sites in the present-day study were examined separately to investigate relationships with the plant communities. Together with the four variables used in the historical data the following nutrients in the water chemistry data were included, namely phosphate ($P0_4$-P), nitrite ($N0_2$-N) + nitrate ($N0_3$-N) and ammonium (NH_4-N). The environmental data were normalised and analysed using Euclidean distance.

Distance-based Linear Modelling (DistLM) was used to determine which environmental variables were largely responsible for the difference in the species assemblages of the different plant communities. 'Best', a procedure which examines for all possible combinations of predictor variables was chosen as the selection procedure. The regression procedure incorporated an adjusted R^2. A distance-based redundancy analysis (dbRDA) a constrained ordination was used to fit the values from the linear model with an overlay of those variables. Separate DistLM analyses were carried out on the historical and present data.

3.2.1.1 Historical relation between vegetation species assemblages and environmental variables

Of the 30 wetland sites, environmental variables were available for only 17 in the historical data so analyse were performed on this subset (n=17) of wetlands. The four environmental variables considered in the DistLM analysis are pH, conductivity, altitude, and annual rainfall. Nutrient analyses for the historic data are patchy and were therefore not be included as this would have resulted in further reduction of sample size.

The DistLM results for the historic data (Appendix 3) revealed that none of the environmental variables are statistically significant ($p > 0.05$) in explaining the relationship between the plant species communities and the environmental variables for 1988/89.

3.2.1.2 Present-day relation between vegetation species assemblages and environmental variables

Seven variables for 30 wetlands ($n = 30$) in the present-day study were available for further investigation. The variables considered in the DistLM analysis are pH, conductivity, altitude, rainfall, phosphate ($P0_4$-P), nitrite ($N0_2$-N) + nitrate ($N0_3$-N) and ammonium (NH_4-N).

The DistLM results (Table 3.6) reveal that the environmental variable best explaining the relationship between the plant species communities is altitude ($p = 0.0005$), which explains 7.6% of the total variation observed. Another variable yielding statistically significant result in pH ($p = 0.0035$, 6.2% of the variation). EC explains 5.0 % of the variation in the model but it is only marginally significant ($p =0.0413$). Results for ammonium (NH_4-N), rainfall, phosphate ($P0_4$-P) and nitrite ($N0_2$-N) + nitrate ($N0_3$-N) are non-significant ($p >0.05$) and explain < 5.0% of the variation in the model. Figure 3.5 shows the DISTLM results by means of a dbRDA plot, where E201/06 and E201/03 are highly influenced by the altitude axis, G103/02, G 103/03 and G201/01 are influenced by the EC and pH axis, H101/01 and G204/02 are influenced by the nitrite + nitrate axis, H101/06 and G403/05 by the ammonium axis.

Table 3.6 Test statistics of the DistLM, based on "Best" procedure and adjusted $R^{\wedge 2}$ selection criterion of transformed environmental variables for wetland species composition for 2012/13 data. Significant results are marked with an *.

DistLM ANOVA table of results

Variables	**SS**	**Pseudo-F**	***P*-value**	**Prop (%)**	**Res *df***
Alt (m)	9206	2.2055	0.0005*	7.55	27
pH	7595.5	1.794	0.0035*	6.23	27
EC (mS/m)	6105.7	1.4236	0.0413*	5.01	27
Ammonium (NH_4-N) (mg/L)	5293.5	1.2256	0.1695	4.34	27
Rainfall (mm/a)	5182	1.1987	0.2129	4.25	27
Phosphate ($P0_4$-P) (mg/L)	4535.3	1.0433	0.4312	3.72	27
Nitrate ($N0_3$-N) + Nitrite ($N0_2$-N) (mg/L)	4286.1	0.98389	0.495	3.52	27

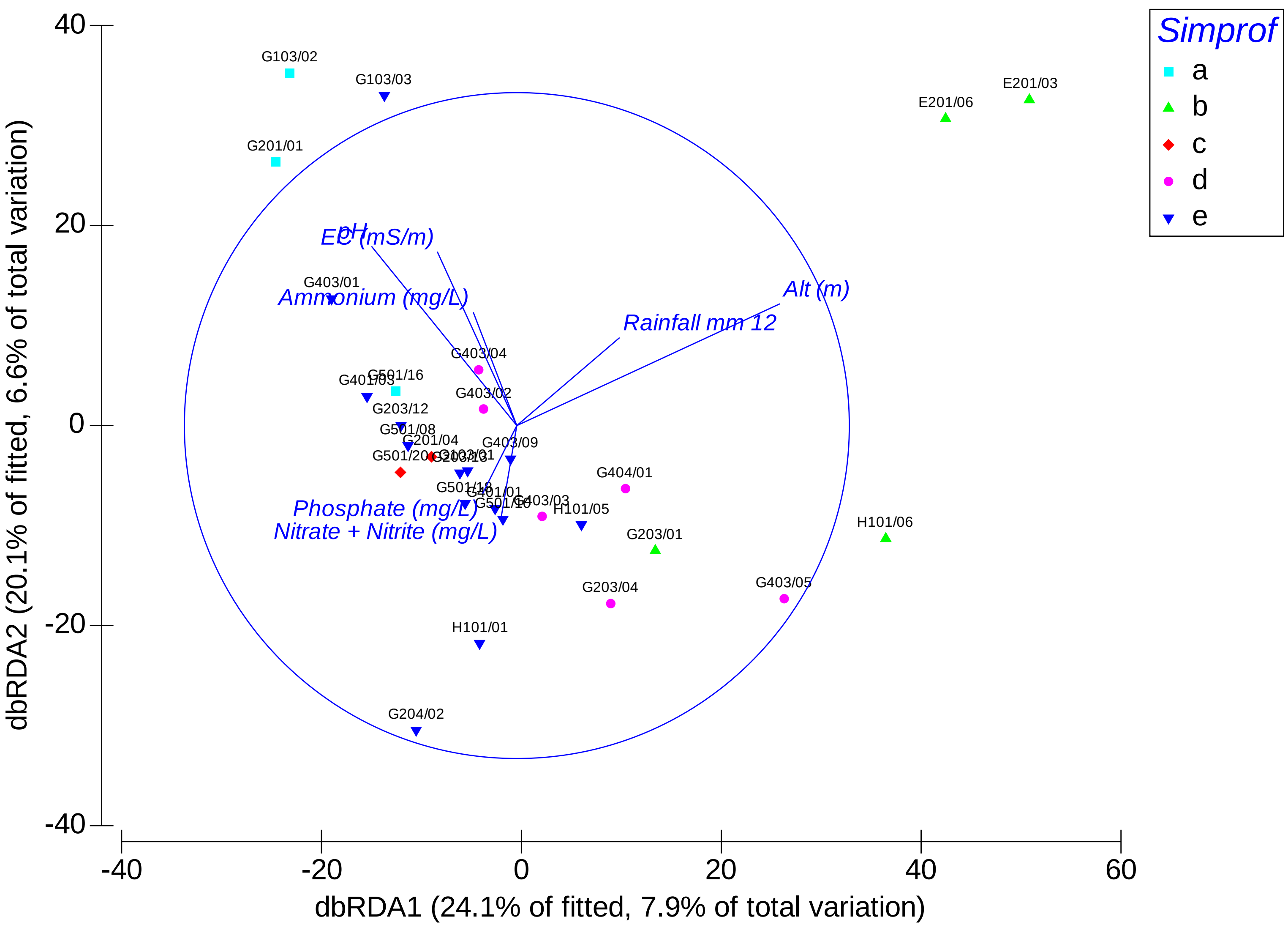

Figure 3.5 dbRDA ordination plot showing the relationship between wetland species composition and the environmental variables in a DistLM model for 2012/13 (n=30). Wetlands may be identified by their wetland site codes.

In summary, none of the environmental variables was shown to be significant ($p > 0.05$) in explaining the relationship between the plant species communities in the historic data set. Altitude was the major variable correlating to the plant species communities in present-day data set. EC and pH were significant ($p < 0.05$) but rainfall and the nutrients phosphate were insignificant.

3.3 Have the wetland plant communities changed over time and has the surrounding land use influenced these changes the wetlands?

3.3.1 Multivariate analysis of vegetation community assemblages

Historic and present plant data were combined to examine the effect of survey year (i.e. change over time) on species composition of the different plant communities and environmental variables in the wetlands (n = 30 wetlands x 2 survey years).

The hierarchical clustering (Figure 3.6) of the vegetation in the 60 wetlands identifies nine plant communities distinct at a similarity of 10% (SIMPROF, $p <0.05$). The main groups, in the dendrogram, are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The low stress value of 0.13 indicates that the two-dimensional MDS plot (Figure 3.7) is a good representation of the patterns in the data. Changes of plant community types, indicated with colour arrows are observed for eight wetland sites.

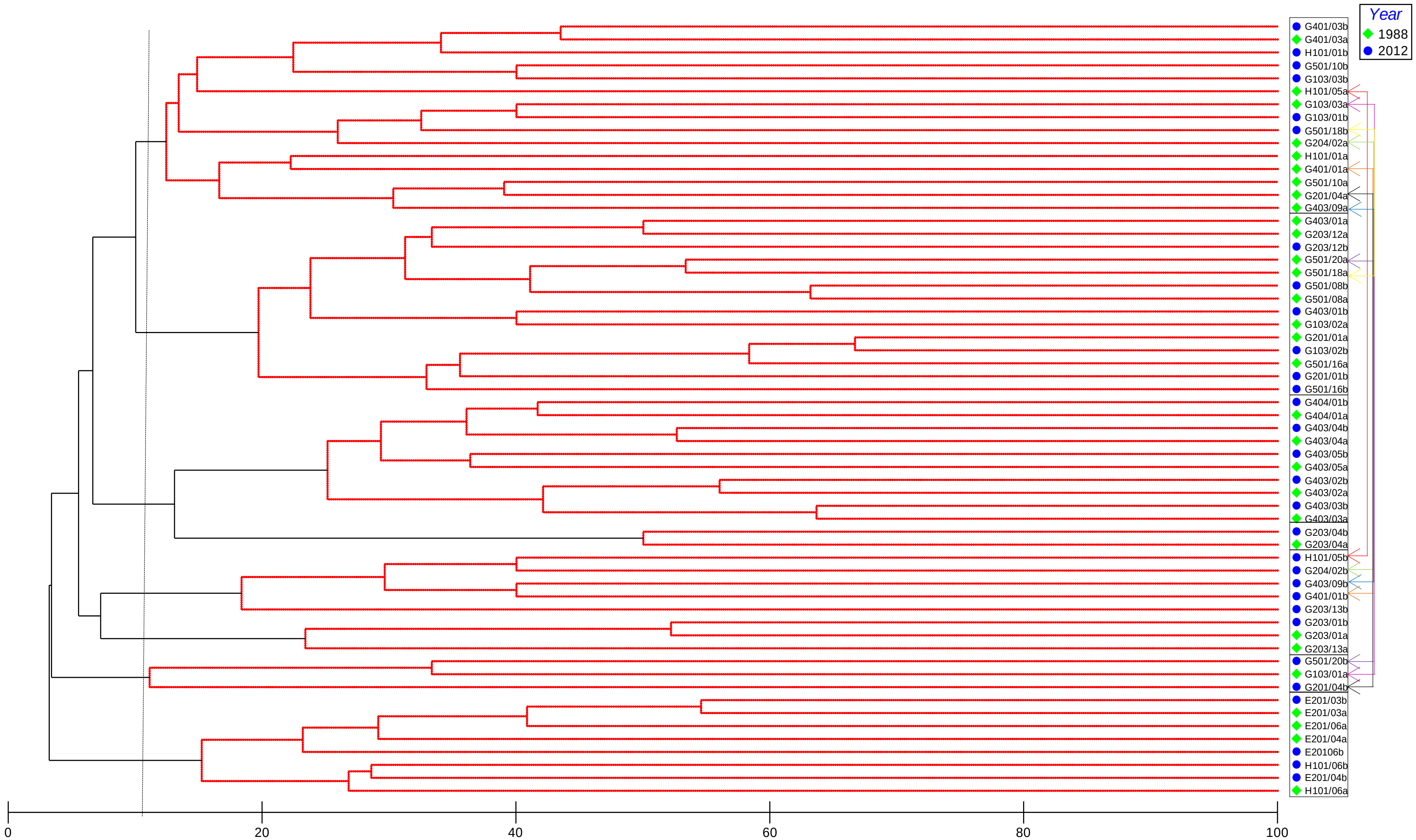

Figure 3.6 Hierarchical cluster dendrogram of the nine plant communities identified for 1988/89 ( ) and 2012/13 ( ) (n=60). The colour arrows indicate change in plant communities of wetland sites. Wetlands may be identified by their wetland site codes.

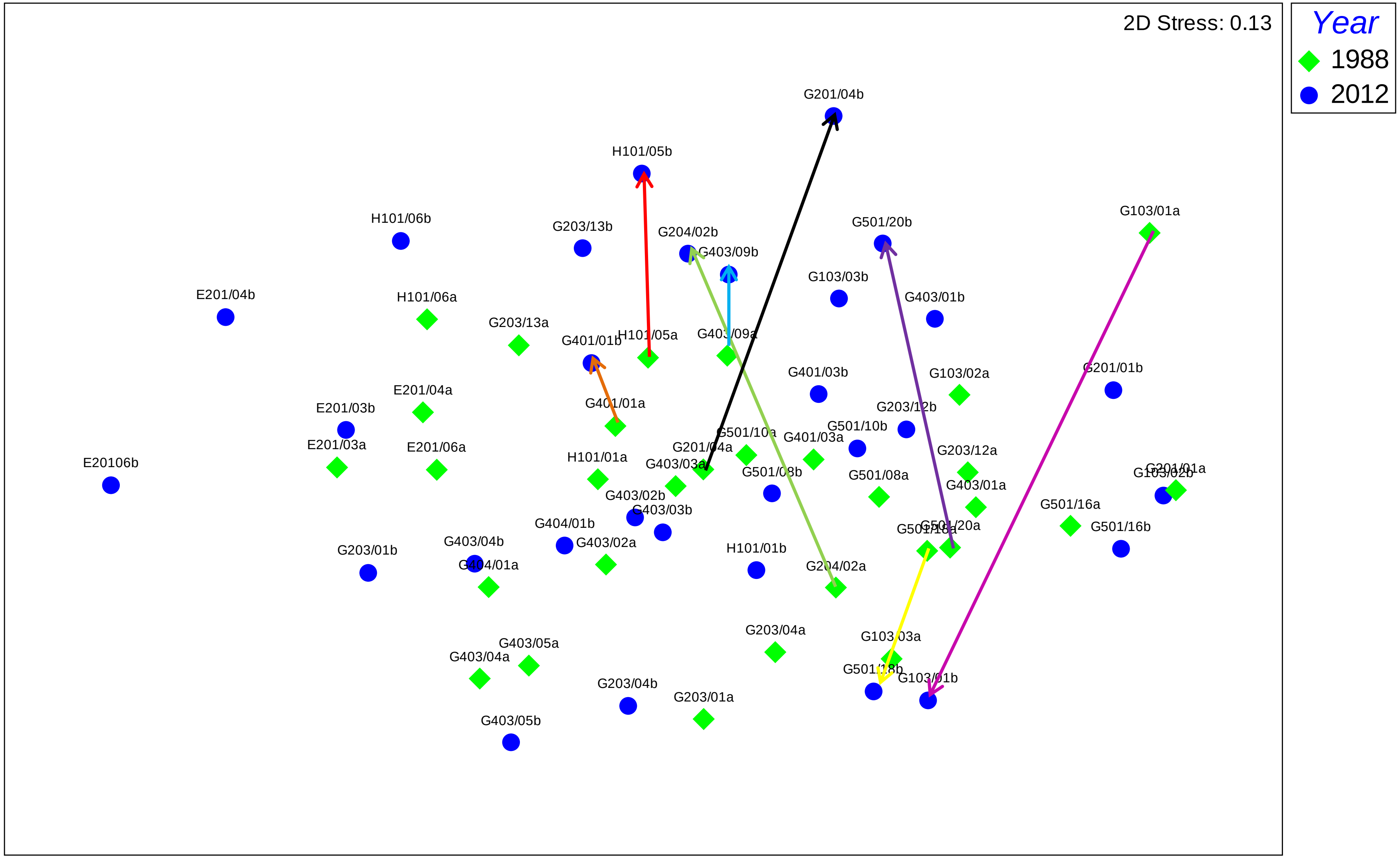

Figure 3.7 MDS plot of the species composition data of 1988/89 and 2012/13 (n=60). The colour arrows indicate change in plant communities of wetland sites, as identified in the cluster analysis (Figure 3.6). Wetlands sites may be identified by their wetland site codes

The MDS plot of the vegetation species assemblage data (Figure 3.7) illustrates the wetland sites, which reveal a shift in plant communities over time, as revealed and indicated by the cluster analysis (Figure 3.6). These wetlands with the respective colour arrows indicate the magnitude of the shifts include: G103/01 (pink arrow) – Koekeisvlei, a coastal depression located on the West Coast (SW phytogeographic centre); G201/04 (black arrow) - Rondeberg, a coastal depression located on the West Coast (SW); G204/02 (green arrow) – Khayelitsha pool, a floodplain wetlands which functions as a depression found in Khayelitsha on the Cape Peninsula (SW); G401/01 (orange arrow) - Malkopsvlei, a coastal depression in Betty's Bay (SW); G403/09 (blue arrow) – Gaansbaai, a depressional wetland in Gaansbaai (SW); G501/18 (yellow arrow) – Wiesdrif, a depressional wetland on the Agulhas plain (AP); G501/20 (purple arrow) - Varkensvlei, a depressional wetland surrounded by agriculture on the Agulhas Plain (AP) and H101/05 (red arrow) - Verrekyker, a depressional wetland in Wolseley (NW). In general the MDS plot illustrates the extent of the differences between sample sites in the two periods. The proximity of the sample points on the MDS plot (Figure 3.7) illustrates and reveals the magnitude of change in multivariate space. If plant communities have not changed one would expect sample sites from different years survey to be similar, and any dissimilarities would suggest shifts in vegetation.

Table 3.7 Historical and present-day plant communities of the eight wetland sites that has changed over the sampling period of 1988/89 to 2012/13. (h - historical, p – present-day plant community groups)

Wetland code and name	Plant communities	
	1988/89	**2012/13**
G103/01 (pink) Koekiesvlei	*Juncus kraussii – Sarcocornia natalensis* (h - group D)	*Phragmites australis – Juncus kraussii* (p - group E)
G201/04 (black) Rondeberg	*Typha capensis – Juncus kraussii* (h - group C)	*Ficinia nodosa* (p - group C)
G204/02 (green) Khayelitsha pool	*Juncus kraussii – Sarcocornia natalensis* (h - group D)	*Phragmites australis – Juncus kraussii* (p - group E)
G401/01 (orange) Malkopsvlei	*Typha capensis – Juncus kraussii* (h - group C)	*Phragmites australis – Juncus kraussii* (p - group E)
G403/09 (blue) Gaansbaai	*Typha capensis – Juncus kraussii* (h - group C)	*Phragmites australis – Juncus kraussii* (p - group E)

Wetland code and name	Plant communities	
	1988/89	2012/13
G501/18 (yellow) Wiesdrif	*Juncus kraussii – Sarcocornia natalensis* (h - group D)	*Phragmites australis – Juncus kraussii* (p - group E)
G501/20 (purple) Varkensvlei	*Juncus kraussii – Sarcocornia natalensis* (h - group D)	*Ficinia nodosa* (p - group C)
H101/05 (red) Verrekyker	*Typha capensis – Juncus kraussii* (h - group C)	*Phragmites australis – Juncus kraussii* (p - group E)

The one-way PERMANOVA confirmed the plant groupings identified in the cluster analysis (Figure 3.6), and revealed that these groupings are significantly different ($p = 0.001$). Two-way crossed ANOSIM revealed a significant difference (global $R=0.74$, $p=0.001$) between the plant community groups across the survey years. The two-factor PERMANOVA to test change over time of the plant species composition and environmental variables across the years revealed the effects of survey years to be significant ($p < 0.05$) for plant species composition, supporting the ANOSIM, and insignificant ($p > 0.05$) for the environmental variables. In general time has had no effect on environmental variables although variation in the species composition between the plant communities are significant. Furthermore, it must be noted that there may be changes in the measured environmental variables that are not impacting on species presence/absence but may impact on dominance for certain species.

3.3.2 Analysis of land-use changes

GIS mapping of aerial images of the land-use practices in and around the wetlands was used to explore potential reasons for changes in plant assemblages over time. (See Appendix 4 for aerial photographs). Table 3.8 provides estimated changes in area over the study period with the historic and present-day plant species community groups previously identified in the cluster and described by SIMPER analysis, environmental results and plant species data. It provides a summary of the results found in the statistical analysis of plant species assemblages, environmental variables and land-use and how they correlate for 23 wetland sites.

The land use analyses indicate that 48 % (11 wetlands) of the wetland sites have exhibited a change in land use. Four percent (1 wetland) have experienced an increase in surrounding agriculture and land-use around 13 % (3 wetlands) of depressional and salt pans wetlands has changed from agricultural land to natural/conserved land, many of these wetlands has shifted in term of the dominant species which describe them. Another 30 % (7 wetlands) of the sites (all depressional wetlands) have experienced an increase in urban/informal residential development. Of these three wetland sites have species indicative of nutrient enrichment, such as *Typha capensis* and *Phragmites australis*. Twelve wetlands especially depressions have experienced an introduction of or increase in alien and/or invasive species since the previous survey. Twelve known alien and/or invasive plants were recorded in the historic data, while 23 alien and/or invasive plants are recorded in the present study.

Table 3.8 Historical and present day land-use surrounding the wetland sites in the Core Cape Region were examined using aerial photographs (Appendix 4) over the years as indicated for each wetland site, providing estimated percentage of area covered by the land-use classes. Identified historical and present-day plant communities are provided for each site. Environmental data are provided for those wetlands which strongly correlated with certain variables in the DistLM or showed high concentration in Table 3.5.

Wetland name	**Wetland code**	**Plant community groups**		**Land-use**		**Description of the area within the 1 km buffer % of change, and general comments**
		1988/89	**2012/13**	**1988/89**	**2012/13**	
Blomfontein	E201/03	*Isolepis prolifera - Penniseteum macrourum* (group A)	*Pennisetum macrourum - Elegia capensis* (group B)	Conserved	Conserved	A Seep high in the Cederberg mountains has not experienced any land use changes over the past 25 years. The present plant community is explained by the high altitude (1369 m above sea level) of the wetland, which correlates with the findings of the environmental variables analysis. 1986: 100% conserved land 2010: 100% conserved land
Kleinplaats dam west	G203/01	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Pennisetum macrourum - Elegia capensis* (group B)	Open land, dam	Open land, dam	There are no indications of land-use change in this area over the past 25 years 1988: 100% natural open land 2010: 100% natural open land
De diepte gatt	G403/05	*Calopsis paniculata - Carpha glomerata – Cliffortia strobilifera*	*Calopsis paniculata - Cliffortia strobelifera* (group D)	Agriculture	Agriculture	The land-use around the wetland has not changed over the past 25 years but there has been an increase in agricultural lands. This area has become overgrown and is dominated by *Berzelia lanuginosa* which is a common native of wetlands in the region. 1989: 51% natural land, 49% agricultural land

		(group B)				2010: 44% natural land, 56% agricultural land
Varkensvlei	G501/20	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Ficinia nodosa* (group C)	Agriculture	Agriculture	From the aerial photographs it is evident that the surrounding land-use has not changed over the years. There is evidence of grazing within the wetland. This wetland has completely shifted its plant community type from 1988/89 to 2012/13. 1989: 100% agricultural land 2010: 100% agricultural land
Melkbos pan	G501/16	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Sarcocornia natalensis* (group A)	Agriculture	Conserved	Once completely surrounded by agricultural land now falls within SanParks land rehabilitated protected. 1989: 12% natural (wetland), 88% agriculture 2010: 100% Sanparks(conserved)land
Kiekoesvlei	G103/01	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Phragmites australis - Juncus kraussii* (group E)	Agriculture	Agriculture	Agricultural land use around the wetland has not changed over the past 25 years. There are indications of mowing to the water's edge. This wetland is known to hold the rare emergent species *Oxalis distichia* but agricultural weeds, such as *Cotula turbinata* and *Erodium moschantum* are dominant within the wetland. 1988: 100% agricultural land 2010: 100% agricultural land
Koekiespan	G103/02	*Juncus kraussii - Sarcocornia natalensis*	*Sarcocornia natalensis* (group A)	Agriculture	Agriculture	Agricultural land use around this salt pan has not changed over the past 25 years. Agricultural weeds *Cotula turbinata* and *Erodium moschantum* is commonly found surrounding the wetland. The analysis of the environmental variables suggests EC strongly influence the change in

		(group D)				plant community over time. From the DistLM analysis of the plant community assemblages EC and pH strongly influence the variation of the plant community of the present day study. This clearly correlates with the EC measured for this site which is the highest reading of 18 300 mS/m. This wetland also has high concentration of phosphate, nitrite + nitrate and ammonium. These high concentrations are likely to be due to runoff from the surrounding cultivated lands. 1988: 100% agricultural land 2010: 100% agricultural land
Burgerspan		*Juncus kraussii - Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Agriculture	Agriculture	Agricultural land use around the salt pan has not changed but there are signs that the inlet has been channelized. Many agricultural weeds, such as *Cotula turbinata* are now present. EC seems strongly too influence the plant community of the present-day. The second highest EC reading of 13260 mS/m is recorded for this site. 1988: 100% agricultural land 2010: 100% agricultural land
Rooipan	G201/01	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Sarcocornia natalensis* (group A)	Private land, housing	Private land, housing	This area was mined for gypsum many years ago, potentially removing wetland species and deepening the system so that currently it functions as a salt pan. The number of houses south of the pan has increased. EC strongly influence the plant community of this wetland in the present day study. This is clear from the EC reading of 4440 mS/m was measured for this Salt pan. 1988: 98% natural land, 2% developed 2010: 96% natural land 4% developed

Vermont pan	G403/01	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Phragmites australis - Juncus kraussii* (group E)	Residential	Residential	Land-use has changed in the west from natural land (wetland seep) to residential housing. Proliferation of macro-algae *Ulva cf flexulosa* in the pan has been noted. This species which tolerates a wide range of salinity, temperature and water quality is a useful, classical organism which indicates eutrophication within a wetland. The water chemistry measurements (Table 3.5) reveal that this wetland has generally high concentration of nutrients all of which contribute to eutrophication. 1989: 64% natural land, 36% developed 2010: 51% natural land, 49% developed
Driehoek	E201/06	*Isolepis prolifera - Penniseteum macrourum* (group A)	*Pennisetum macrourum - Elegia capensis* (group B)	Conserved	Conserved	This channelled valley bottom wetland in the Cederberg wilderness area indicate no change in land use over the past 25 years although there are signs in the present day aerial photographs of possible agriculture activities in the wetland downstream outside of the 1 km buffer . Declared a nature reserve in the 1960's. The present plant community is explained by the high altitude (903 m above sea level), which correlates with the findings of the environmental variables analysis. 1986: 100% conserved land 2010: 100% conserved land
Hemel en aarde	G403/02	*Calopsis paniculata - Carpha glomerata – Clifforita strobilifera* (group B)	*Calopsis paniculata – Cliffortia strobelifera* (group D)	Agriculture	Agriculture	Land use has not changed around the wetland area. Impacts however, are not just from around the wetland but also from further upstream, as a distinctive channel is starting to form within parts of the wetland. 1989: 42% natural land, 58% agricultural land 2010: 42% natural land, 58% agricultural land

Belsvlei	G403/04	*Typha capensis - Juncus kraussii* (group C)	*Calopsis paniculata - Cliffortia strobelifera* (group D)	Agriculture	Agriculture	The surrounding land use has not significantly changed from agricultural lands over the years; housing has been recently built with lawns extending into the wetland. The surrounding agriculture has led to the introduction of many alien invasive plants such as, *Pinus sp* and *Acacia sp* within the wetland. Different species are dominant in the wetland in the present-day study, thus indicated by the change in plant community. 1989: 22% natural land, 78% agricultural land 2010: 22% natural land, 78% agricultural land
Salmonsdam	G404/01	*Calopsis paniculata - Carpha glomerata – Clifforita strobilifera* (group B)	*Calopsis paniculata - Cliffortia strobelifera* (group D)	Conserved	Conserved	Largely un-impacted with no land-use change. Erosion gullies were evident within the wetland. 1989: 100% conserved land 2010: 100% conserved land
De Vlakte	H101/06	*Isolepis prolifera - Penniseteum macrourum* (group A)	*Pennisetum macrourum - Elegia capensis* (group B)	Agriculture	Agriculture	The surrounding agricultural land-use within and around the 1 km buffer has not changed over the past 25 years. There are signs of cutting, ploughing and cultivation to the water's edge of the wetland site, thus the removal of majority of the wetland plants, which has allowed for the introduction of many alien invasive species such as, *Pennisetum clandestinum*, *Rumex sp* and *Rubus sp*. The plant community is strongly influenced by nitrite + nitrate concentration 0.746 mg/L (Table 3.5). Nitrate may enter systems via fertilizers and agricultural runoff. This high concentration reading is surely effects of runoff from the surround agriculture lands, as there is no vegetation buffer between the system and the surrounding crop agriculture. 1987: 100% agricultural land 2010: 100% agricultural land

Noordhoek Soutpan	G203/12	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Phragmites australis - Juncus kraussii* (group E)	Excavated (marina)	Residential marina	Excavated in the 1970's for a marina. Housing development started in 2000 and is still increasing presently in and around the wetland. Many of the plants and trees have been planted in the wetland system to give it a natural feel however there are remnants of natural/indigenous wetland species such as *Schoenoplectus scirpoides* and *Ficinia nodosa* that can be seen in some parts of the wetland system, especially at the water's edge. 1988: 99% natural land, 1% developed 2010: 67% natural land, 33% developed
Kenilworth race course	G203/13	*Typha capensis - Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Horse race course	Horse race course/conservation area	Surrounded by a horse racing track the Kenilworth race course conservation area was declared in 2005, in an area already highly developed in the 1980's there has been a slight increase in the proportion of developed land surrounding the wetlands. The immediate area surrounding the wetland is conserved and managed well. 1988: 69% conserved land, 31% developed 2010: 60% conserved land, 40% developed
Khayelitsha pool	G204/02	*Juncus kraussii - Sarcocornia natalensis* (group D)	*Phragmites australis - Juncus kraussii* (group E)	Rural development	Residential -Rural /Urban, wetland park	Over the years there have been land-uses changes around the wetland with in the buffer zone, where land which once was agricultural land has now become developed with housing (formal and informal housing). More alien invasive and cosmopolitan species, such as *Pennisetum clandestinum*, *Foeniculum vulgare*, *Berula erecta* and *Centella asiatica* can be found within the wetland. The dominant species in this system is *Typha capensis* which is an indicator of high nutrients. 1988: 69% natural land, 18% developed, 13% agricultural land 2010: 71%, natural land, 29% developed

Malkkops vlei	G401/01	*Typha capensis - Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Residential	Residential	There has been an increase in the extent of residential houses around the wetland, many of which are known to have septic tanks. Many of the species are indigenous species such as, *Cyperus rotundus*, *Psoralea pinnata* and *Cliffortia ferruginea*. 1988: 99% natural land, 1% developed 2010: 82% natural land, 18% developed
Groot witvlei	G401/03	*Typha capensis - Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Residential	Residential	There has been a sizable increase in the extent of residential houses around the wetland, many of which are known to have septic tanks. *Typha capensis* and *Phragmites australis* are dominant with in the wetland. The 1 km buffer includes an adjacent wetland found in the area. 1988: 99% natural land, 1% developed 2010: 65% natural land, 35% developed
Gaansbaai	G403/09	*Typha capensis - Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Open natural land	Open natural land	Evidence of land use change is not evident on the aerial photographs. Open water can be seen on the historical aerial photographs, presently it cannot, the site was observed to be overgrown with *Phragmites australis, Typha capensis* and *Acacia saligna. Typha capensis* and *Phragmites australis*, not previously recorded at this site, and are indicators of increased nutrients and stabilizing of water fluctuations. 1989: 100% natural land 2010: 100% natural land
Rondeberg	G201/04	*Typha capensis - Juncus kraussii*	*Ficinia nodosa* (group C)	Grazing	Private Conserved land	King and Silberbauer made reference to grazing around the wetland, which is not very evident on the aerial photographs. Presently the land around the wetland is conserved on private land.

		(group C)				1988: grazed?, natural? (unsure about past land use) 2010: 100% conserved land
Bokkekraal	H101/01	*Typha capensis – Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Agriculture / dam	Agriculture / dam	Land-use has not changed over the years although there has been an slight increase in agriculture overall in this area; impacts to the wetland may arise from upstream effects as well as known direct impacts which cannot be seen on the aerial photographs e.g. too frequent fires, loss of water to the wetland. *Aponogeton angustifolius* a vulnerable and threatened species is found in this wetland system. *Lotus subiflora* an invasive species has become prominent within the wetland as well. 1987: 65% natural land (35% partially a dam and river) 2010: 65% natural land (35% partially a dam and river)
Verrekyker	H101/05	*Typha capensis - Juncus kraussii* (group C)	*Phragmites australis - Juncus kraussii* (group E)	Agriculture / plantations	Rehab wetland	Land-use has changed from agriculture and plantations to a rehabilitated land. Rehabilitation has largely removed alien vegetation. The high concentration of nutrients (Table 3.5) especially that of phosphorus and nitrites + nitrates indicate the system to be eutrophic. The presence and infestation of *Typha capensis*, *Lemna gibba* and *Eichhornia crassipes* are indicators which supports this. 1987: 100% agricultural land 2010: 100% conserved land

In summary, many of the wetlands that have changed in terms of land-use have species which are indicators of nutrient enrichment and stabilizing water fluctuation within the system. These species include *Typha capensis* and *Phargmites australis* which describe many of the plant communities groups as well. Inspection of the environmental data, especially those of the nutrients concentration measurements revealed that wetlands like G201/01, H101/01 are affected by runoff from the surrounding agriculture; G403/01 and G204/02 impacted by the surrounding urban and/or informal residential development.

Overall in this chapter it was revealed that for the historic data four plant community groups could be distinguished whereas five were identified for the present-day data. Indicators species describing the plant community groups in the different years were identified. Single dominant species strongly described wetland plant groups for the present-day vegetation, while no single dominant species described the historical vegetation data. The relationship between environmental variables and species composition revealed that the historical plant species composition was not statistically significant correlated to any of the environmental variables whereas the present-day species composition were significant correlated to altitude, pH and conductivity. The effect of survey years revealed to be insignificant for the environmental variables but the plant groups across years were significantly different. Community differences are apparent between the historical and present vegetation data. It is clear that one of the historic plant communities has split in the present-day data. Furthermore, *Ficinia nodosa* characterizes a plant community group in the present-day vegetation data that was not evident in the historical data. From this study a biological change in plant species communities can be distinguished, more so in depressional wetlands than any other wetland type, over the past 25 years. The biological change was not supported by the environmental variables that were examined but was linked to the analysis of the surrounding land-use.

CHAPTER 4

Discussion, Conclusion and Recommendations

This chapter discusses the wetland plant communities identified in 1988/89 and 2012/13; the relationship between the distribution of the plant communities' and the underlying environmental variables; how plant community composition has changed over time and its relation to changes in the surrounding land-use.

4.1 Sampling wetlands of the Core Cape region

Different approaches can be used to examine and detect changes over time in wetland vegetation. Numerous studies have examined and recorded changes in plant communities, plant community distribution, characterization of wetland plant communities, species cover and distribution, and many more other factors, utilizing satellite images and aerial photography which involves visually assessing images of wetlands and wetland vegetation (e.g. Williams and Lyon, 1991; Lee and Lunetta, 1996; Rebelo *et al*., 2009). The use of permanent quadrat sampling plots is another repeated sampling method which records wetland species composition, visually or by the relevé method (listing of species), through field data collection across a number of years (Odland and del Moral, 2002; Childer *et al*., 2003; Pyšek *et al*. 2004; Rolon and Maltchik, 2006; Johnston and Brown, 2013). Using aerial photography and field observations through ground-truthing, Russell (2002) produced distribution maps and evaluated changes in the distribution of emergent aquatic plants in the Wilderness Lakes, a brackish South African estuarine- lake system, between 1975 and 1997.

ssessing change over time in this project was constrained by the previous sampling procedure. Replicating the sampling protocol of King and Silberbauer was a difficult task, as they did not provide a detailed description of their procedures for collecting the floral data. The present-day sampling procedure – the how, when and where was always kept as close as possible on par with the historical data collection. In the current study vegetation sampling was therefore conducted with the help of the previous plant collection book, field notes and map drawings and visual observation of the presence/absence of dominant wetland plants. Potential source of error in the environemtal data collection could possibly be found due to 1) the sampling technique, 2) the precision of the different sampling equipment used in the historical and present-day data collection (technology improvement over the years) and 3) operator use. Previous studies (e.g. Griffiths and Wiesberg, 2011) have demonstrated that the underlying technology or challenges with technology transfer are not the biggeset problems when implementing new technology in water quality analysis. A few wetlands were difficult to assess, in terms of vegetation sampling and were therefore not included in the study. Most of the wetlands in the previous study were visited during the winter rainfall months of 1988/89, so for accuracy and comparative purposes they were sampled in the same months during the current study. This made identification of many of the plants difficult as many of them do not flower or fruit during the winter months. The limitations of the previous study cannot be ignored because they have probably resulted in some inaccuracy in sampling and therefore in analysis of the results. Intensive sampling within homogenous and 'representative' stands of wetland vegetation during spring and/or early summer months would have been a more appropriate procedure of sampling. Within each relevé the vegetation could be recorded using the Braun Blanquette method (Westhoff and van der Maarel, 1978). The results of such a sampling regime would provide a more accurate picture of the plant communities. Depending on the purpose and the objectives of a vegetation research study the most appropriate and applicable sampling procedure should be adapted.

4.2 Characterization of plant communities and wetland types

Cluster analysis and MDS plots of the plant species data identified four main plant community groups historically and five in the present-day study (Figures 3.1 and 3.3). PERMANOVA confirmed the plant community groups identified by the cluster analysis to be significantly different from each other ($p < 0.05$). Multivariate techniques can be used to summarise the basic attributes of wetland vegetation in terms of plant communities (Little, 2013). The MDS plots, (Figure 3.2 and 3.4) indicates a pattern of an altitude gradient across the plots, together with water chemistry, appear to be shaping the plant communities especially those in the present-day study. Historic plant community groups A and B and present-day groups B and D, are characterized by freshwater, high altitude seeps and valley-bottom wetlands. Historic plant groups C and D and present-day plant groups E, C and A are described and located in low to moderate altitudes and vary from fresh to saline habitats. A split of historic plant community group D can be seen between the two sampling periods, where two wetlands is creating a new separate group (group C). The reasons for this group has separating in the present-day vegetation data is unclear. Even though significant differences are observed between the representative plant community groups there is an overlap and sharing of species between groups (Tables 3.1 and 3.3). In other words, some of the groups share the same diagnostic species.

Where a species is exclusive to a group, such diagnostic/indicator species can be used to describe plant communities (Ronney and Bayley, 2011), differentiate wetlands, and associate plant species with different wetland conditions (Johnston *et al*., 2007). Characteristic or indicator species for each wetland group, from the SIMPER analysis, can be used to describe and identify the plant communities (Little, 2013). The SIMPER analysis identified the characteristic species describing the plant communities historically and currently. The first two species with the greatest percentage contribution were used to describe the plant community in each group (Tables 3.3 & 3.6). Nine plant communities (four from the first sampling period and five from the second) were identified and shown to be characterized by various obligate wetland species, mostly dominated by species which are indigenous in and a few which are endemic to, the CFR. In cases of single species, such as *Sarcocornia natalensis* and *Ficinia nodosa* are strongly dominant and describe plant community groups observed in the present-day vegetation data. A general pattern is that saline salt pans to brackish depression wetland communities are characterized by *Sarcocornia natalensis* - *Juncus kraussii, Sarcocornia natalensis* and *Ficinia nodosa*. *Sarcocornia natalensis* also characterizes the *Sarcocornia natalensis* community type describing hypersaline wetlands of Seiben (2011). *Juncus kraussii* a saltpan macrophyte is widely distributed in southern Africa. This species is commonly found brackish to saline environments, such as in salt pans or marshes, bordering lagoons and near the sea (Naidoo and Kift, 2005, Seiben, 2011). The *Ficinia nodosa* community exclusively associated with two wetland sites, G501/20 and G 201/04 while the *Sarcocornia natalensis* community exclusively characterized three wetland site G103/02, G201/01 and G501/16 in the present-day study. *Calopsis paniculata* - *Carpha glomerata* – *Cliffortia strobilifera* and *Calopsis paniculata* - *Cliffortia strobilifera* communities characterize permanent freshwater, high altitude valley-bottom wetlands. *Calopsis paniculata*, *Carpha glomerata* and *Cliffortia strobilifera* are obligate wetland species that inhabit and characterize lotic wetlands, such as channelled valley-bottoms. These species are common dominant species in riparian vegetation communities (Clever *et al*., 2004; Hugo *et al*., 2012; Meek *et al*., 2013). *Typha capenis* -*Juncus kraussii* and *Phragmites* *australis - Juncus kraussii* communities characterizing low-lying semi-permanent to permanent, freshwater to brackish depressional wetlands, high in nutrients with stabilizing water levels, indicating these wetlands over time has become more permanent with less fluctuating water levels. *Typha capensis* is a common wetland emergent mainly distributed within shallow standing or slow-flowing habitats of the Western Cape, but is commonly known to occur in the rest of South Africa (Wyk *et al*., 1997). *Phragmites,* an emergent species found in aquatic habitats is one of the most widely distributed plants in the world (Marks *et al*., 1999). Kotze and O'Connor (2000) found *Phragmites australis* and *Typha capensis* to be dominant in semi-permanently wet wetlands below 800 m. *Isolepis prolifera - Pennisetum macrourum* and *Pennisetum macrourum – Elegia capensis communities* characterize high-altitude freshwater wetlands, most of which are seeps. *Pennisetum macrourum* was not found in wetlands below 800 m (Kotze and O'Connor, 2000).

Underlying environmental characteristics such as geomorphology and hydrology affect biotic and chemical processes in wetlands. These characteristics shape and define the functions of wetlands and their water holding capacity within the environment (Brinson, 1993; Maltby *et al*., 1994). Therefore wetlands of different types can be expected to provide different habitats for the plants. Ollis *et al*. (2013) proposed that dominant vegetation forms (e.g. aquatic, herbaceous, shrub/thicket and forested) and vegetation status (i.e. indigenous or alien) of wetlands should further describe wetland type and developed a classification of wetlands and other aquatic ecosystems in South Africa. Considering these factors in the current study, wetland sites from both study periods, were classified using the HGM (hydrogeomorphic) approach Ollis *et al*. (2013) in order to ascertain whether similar HGM units (i.e. similar wetland types) hold similar plant communities. From the cluster analyses (Figures 3.1 and 3.3) and MDS plots (Figures 3.2 and 3.4) show that plant community groups do not consistently group wetlands of the same wetland HGM type, which suggests that the plant species data alone cannot be reliably used to identify different types of wetlands. Wetland vegetation can, however be used to improve classification systems. Furthermore, aquatic forms are good indicators of wetland condition (Goslee *et al*. 1997; US EPA, 2002) while *Sarcocornia* indicative of saline conditions and emergent plants, such as *Typha capensis* and *Phragmites australis*, can be used to identify permanently inundated wetlands. For many wetland types a few species tend to dominate in terms of the number of individuals and in the percentage of aerial cover. The existence of these species indicates that the wetland meets the habitat requirements for these plants. It is best therefore to use plant species composition to describe wetland type rather than to define it (Cowardin *et al*., 1979; Jones, 2002; Ollis *et al*. 2013).

4.3 The relationship between plant communities and the environmental variables

Several studies have analysed environmental variables affecting species diversity and richness in riparian wetland vegetation (e.g. Ssegwa *et al*., 2004; Rolon and Maltchik, 2005; Johnston and Brown 2013). Analysis of environmental variables can be explored by direct gradient analysis the position of samples along axes determined by environmental variables (Kenkel, 2006). Data on water chemistry rather than sediment chemistry was available for the current study, a situation that is not uncommon especially in aquatic botany field studies. Soil chemistry data would have been preferable because emergent vegetation takes up nutrients from the soil, and water chemistry data may not mirror those found in the soil (Johnston *et al*., 2001).

Distance-based Liner Modelling (DistLM) was used to characterize the plant communities in terms of the biotic and environmental variables with which they are associated. The DistLM for the historical data found none of the four variables examined (pH, altitude, rainfall and EC) to be statistically significant in explaining the relationship between the plant communities and the measured environmental variables, although 8.9 % of the variation within the model can be best explained by pH. Examining the relationship between the plant communities and the environmental variables for the 2012/13 study period using DistLM, altitude, pH and EC were shown to be significant variables in explaining the relationship between the plant community groups and the environmental variables. Altitude, furthermore, is the main predictor of plant communities explaining 8.0% of the variation in species composition in the 30 wetlands. Wetlands ranging from 903 – 1369 m above sea level, which include seeps and valley-bottom wetlands, strongly correlates with the attitude axis in the dbRDA plot (Figure 3.5). Similarly, altitude was identified as one of the important predictors of macrophyte richness in southern Brazil (Rolon and Malchik, 2006) and to strongly influence wetland plant species composition and diversity of 66 wetlands in KwaZulu-Natal, South Africa (Kotze and O' Connor, 2000). Furthermore, Johnston and Brown (2013) report that certain water chemistry variables such as pH and electrical conductivity (EC) should be considered when setting standards to support wetland vegetation. They also suggest that interactions in wetlands should not be oversimplified, as multiple interactions such as present and historical land use, water fluctuations and many other factors are influential as well.

pH is defined as the concentration of hydrogen ions in water (Dallas and Day, 2004). Vestergaard and Sand-Jensen (2002) demonstrated that vegetation species composition of Danish lakes, strongly correlated with alkalinity and pH. A case study (Bird *et al.,* 2013) within the current study area investigated the effects of alien vegetation invasion on temporary wetlands in the Kenilworth Racecourse Conservation Area (G203/13). They found pH, to be the strongest response variable and that pH increased linearly as indigenous fynbos vegetation around the wetlands was replaced by alien species, thus indicating that a low pH values are natural for the fynbos wetlands in their study. In the present-day study, the lack of correlations of the environmental variables and plant communities for the historical data could possibly be attributed to the small number of samples sites or the environmental variables considered in the analysis.

Plant assemblages of saline wetlands G103/03, G201/01 and G103/02 were strongly correlated with high EC (Figure 3.5 and Table 3.5). Electrical conductivity has shown to distinguish wetland plant community types in comparative studies in North and South America and Europe (Vitt and Chee, 1990; Rey Benayas and Scheiner, 1993; Thomaz *et al*., 2003; Rolon and Maltchik; 2006; Sass *et al*., 2010). The significantly high conductivity values in wetlands G103/03, G201/01 and G103/02 maybe due to the underlying geological substrate, as other wetlands in the vicinity (Darling, West Coast) are mined for gypsum, as G201/01 has been previously.

Nutrient concentrations in the present-day study were not significantly correlated with the plant assemblages in the 2012/13 DistLM (Table 3.6), but for a few wetlands, such as H101/01, G204/02, G403/01, and H101/06 with phosphorus, nitrite + nitrate and ammonium axes showed a strong correlation with their plant communities (dbRDA, Figure3.5). The lack of the relationship between the nutrients and plant communities was unexpected, based on the significant relationship findings reported some previous studies (Craft et al., 2007, Croft and Chow-Fraser, 2007). However, a non-significant relationship between water nutrient concentrations aquatic plant diversity have been reported from studies on other wetlands by Jones *et al*. (2003), Rolon and Malchik (2006) and, Johnston and Brown, 2013).

4.4 Change over time of wetland plant communities and the influence of land-use the plant species composition of plant communities.

Many studies have searched for patterns in response of plant communities to biotic and abiotic, including natural and anthropogenic, alterations to the environment (Adamus *et al*., 2001). Studying changes in vegetation requires monitoring the same location a number of times over a period of years (Kent, 2012). The most frequently asked question in monitoring is: how variable are plant communities among sites and over time? Little (2003) recognizes that considerable change in wetland vegetation can be tracked using random sampling of the same sites at different times and that statistical power and assurance that change has occurred comes with sampling exactly the same place at different times. Depending on the study objectives, permanent sample plots could be placed randomly or representative, of particular communities. In this study changes in plant communities between 1988/89 and 2012/13 were examined.

After comparing the plant communities (Table 3.7) identified by cluster analyses, a change or addition of a plant community group is apparent from the historic to the present-day plant communities. A split in one of the historic plant communities appears to have occurred. Plant community group D (*Juncus kraussii– Sarcocornia natalensis*) of the historic data has split and is shared in two groups of plant community group A (*Sarcocornia natalensis*) and plant community group E (*Phragmites australis – Juncus kraussii*) in the present-day data. A dominant diagnostic species, *Ficinia nodosa*, now characterizes wetlands G201/04-Rondeberg and G501/20-Varkensvlei in the present-day vegetation data. Furthermore, the cluster analysis reveals that the *Ficinia nodosa* community type is new and is believed to have arisen from the *Typha capensis – Juncus kraussi* community (historical group C). Dominant species of the plant communities of wetland sites G103/01, G204/02, G403/09, G401/01, H101/05 and G501/18 have also shifted (Table 3.7). The majority of these wetland sites have experienced a shift in species composition from *Typha capensis – Juncus kraussii* to *Phragmites australis – Juncus kraussii*. *Phragmites* is more common in permanent wetlands with stable water levels, whereas *Typha* more commonly occupies wetlands with fluctuating water levels. This current study thus indicates that wetlands in this study have become more permanent, with water levels stabilizing over time. A case study done in Long Point, Ontario, Canada found that *Phragmites australis* was common in and invade aquatic habitats that have experienced disturbances, such as altered hydrologic regimes, dredging or increase nutrient availability (Wilcox *et al*., 1999). Other plant communities have remained the same and are still present from 1988/89 to 2012/13 except for changes in the diagnostic species which describe them: *Calopsis paniculata – Carpha glomerata – Cliffortia strobilifera* to *Calopsis paniculata – Cliffortia strobilifera* and *Isolepis prolifera – Pennisetum macrourum* to *Pennisetum macrourum – Elegia capensis*.

A change in species composition over time can indicate environmental change (Cronk and Fennesey, 2001). Mitch and Gosselink (2000) noted that some shifts in plant community composition can be attributed to an increase in nutrients levels in the soils. Sediment nutrients were not examined in this study, but others (e.g. Vitt and Chee, 1990; Craft *et al*., 2007 and Croft and Chow-Fraser, 2007) have shown relationships between wetland vegetation and surface water nutrients. The ANOSIM reveals differences within plant communities to be significant across years, suggesting change over time in species composition of the plant communities. The PERMANOVA indicated no significant change in environmental variables and supported the significant effect of survey year on plant community composition. This indicates that there are no apparent significant differences in environmental variables selected between sampling periods and that the main source of variation is therefore in plant species composition. The majority of wetlands whose plant communities have changes are depressions. They include G103/01, G201/04, G204/02, G401/01, G403/09, G501/20, G501/18 and H101/05 (Figure 3.7). The results are supported by similar studies by ter Braak and Wiertz (1994) and Childers *et al*. (2003). ter Braak and Wiertz (1994) found changes over time in wetland vegetation from 1977 to 1988 due to changes in pH and water depth in the Netherlands and Childers *et al*. (2003) found dramatic changes in species composition in

Everglade wetlands from 1989 to 1999. De Steven and Toner (2004) recognize that even without changes in measured environmental variables, biological changes may arise due to additional factors such as hydrological regime, soil type, wetland size and disturbance history, all of which may directly influence the vegetation of depression wetlands.

4.4.1 Analysis of land-use changes

Since the changes in species composition were not correlated with change in the environmental variables measured in this study, the land-use dynamics were investigated, since disturbance is known to influence vegetation of wetlands (De Steven and Toner, 2004). Walters *et al*. (2006) found that land cover and use have had noticeable effects on wetland plant composition, diversity, structure and wetland functioning.

GIS together with field studies and historical aerial photography, provide an opportunity to investigate temporal changes in land-use (Johnston and Naiman, 1990). Aerial photographs from 1987 to 2010 were used in this study to assess the changes in land-use to infer changes in wetland plant species composition. Table 3.9 shows that 48% of the wetlands experienced a change in land use, either as an increase in human use of the land or as a change from one type of land cover to another. Four percent of wetland sites have experienced an increase in surrounding agriculture; 13% of wetland sites, all of which are depression and salt pans, such as H101/05, G501/16 and G201/04 have reverted from agricultural to conserved land. Phosphorus, nitrate, nitrite and ammonium, which enter surface water *via* runoff, are major nutrients which contribute to nutrient enrichment in standing waters. Water quality has been shown to be significantly correlated to land-use activities (Berka *et al*., 2001; Alam *et al*., 2011). The presence of alien and/or invasive species such as *Typha capensis*, *Lemna gibba* and *Eichhornia crassipes* in H101/05 are indicators of nutrient enrichment. Species like *Typha* can also be used to infer high nutrient load in the wetland system because *Typha* is efficient at the taking up nutrients during periods of abundance (Quick, 1987). Thirty percent of the wetlands, all of which are depressions, have experienced an increase in the surrounding urban/informal residential development. Furthermore, the surrounding agriculture of G403/01, H101/06 and H101/05 correlates with the high nutrient concentration readings (Table 3.7). Without the historical nutrient data, exploring whether there has been a change over time is impossible. Depressional wetland experienced and exhibited the most change in the surrounding land use over the past 25 years, in term of land use, supporting the idea that land-use dynamics have had an apparent effect of the plant species composition over the past 25 years as exhibited by the statistically biological changes.

4.5 Conclusion

- This research provides baseline data on the plant communities of various wetlands of the Core Cape region.
- Differences in sampling intensity and procedure (and thus sampling area) between the 1988/89 and 2012/13 surveys may have resulted in some inconsistency in sampling and may therefore have complicated and affected the interpretation of the results. I understand that the failure in finding no single dominant species describing the historical vegetation data could possibly be attributed to the short comings of the historical sampling protocol used in data collection It can be concluded for the study wetlands, however, that although HMG types cannot be identified by plant communities, plant communities can be used to describe HGM units. Several HMG units are recognized, each with characteristic plant communities and indicator species.
- Differences in species composition over time were found to describe present-day plant communities of depressional wetland sites.

- Differences in species composition over time seem to be tied to changes in land-use despite few or no changes over time in the measured environmental variables. As such, the trajectories of change are not readily predictable. Shifts in species dominance may alter the aspect and ecology of these wetlands.

4.6 Recommendations

4.6.1 Recommendations for further wetland vegetation studies

Lessons learnt from this study for future projects involve recommendations on how, when and what should be sampled in the field for wetland vegetation studies. Vegetation surveys for reference site data should be based on more than presence/absence data. At the very least, once-off intensive sampling of wetland vegetation should be done. The use of permanent quadrat sampling allows for representative field data collection across subsequent years, and for monitoring process. The relevé method (listing of species) with cover, abundance and vegetation structure provides a comprehensive plant species list and it especially identifies and provides records for rare, vulnerable and threatened species. Thereafter it is appropriate to collect presence/absence data within the same quadrat plot. Monitoring data could then be compared to determine if changes/shifts in plant communities have occurred over the years. Sampling should be planned to coincide with spring and/or early summer months as it makes identification is much easier for a non-specialist. Soil samples for emergent vegetation and water samples for floating and submerged vegetation should be collected at each plot and/or site for analysis of associated environmental variables. Site descriptions of land-use should also be noted.

4.6.2 General recommendations

Vegetation surveys and descriptions provide baseline information that allows similar surveys to be conducted in the future. They should therefore include all necessary information that will aid in the proper monitoring, management and conservation of wetlands. Keeping on par with ongoing studies, it is concluded from this study that future wetland vegetation research should be conducted as described above in section 4.6.1 and results should be fed into projects such as the National Wetlands Monitoring Programme and the National Wetland Database (Sieben, 2011). Such an objective will contribute to and increase the knowledge of wetland vegetation not just in the Western Cape, but nationally. The National Wetland Vegetation Database can then be a useful tool for recognizing wetlands that should be included into the National Wetlands Monitoring Programme to ensure better understanding of how these wetlands function, and provide and support different habitats for the management and conservation of South African ecosystems holistically.

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Appendix 1

Plant species identified, sampled and collected per wetland sites for 2012-2013

Sample no.	Species	Authors	Family	GPS coordinates	Locality details	Wetland code	Life Cycle	Life Form
C - L R 750	*Hypochaeris radicata**	L.	*Asteraceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Herb
C - L R 731	*Pteridium aquilinum*	(L.) Kuhn	*Dennstaedtiaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Herb/Geophyte
C - L R 736	*Psoralea aphylla*	L.	*Fabaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Tree/Shrub
C - L R 732	*Dipogon lignosus*	(L.) Verdc.	*Fabaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Herb
C - L R 729	*Wachendorfia thyrsiflora*	Burm.	*Haemodoraceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Geophyte
C - L R 744	*Pennisetum clandestinum**	Chiov.	*Poaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Graminoid
C - L R 747	*Rumex acetosello* ssp. *Acetoselliodes**	L.	*Polygonaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Herb
C - L R 735	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Shrub/Restiod
C - L R 730	*Cliffortia strobilifera*	Murray	*Rosaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Shrub
C - L R 443	*Asteraceae* sp 2		*Asteraceae*	-32.43487 19.21802	Blomfontein	E201/03		
C - L R 445	*Ficinia indica*	(Lam.) Pfeiff.	*Cyperaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Herb/Cyperoid

C - L R 448	*Cyperus thunbergii*	Vahl	*Cyperaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Herb/Cyperoid
C - L R 449	*Isolepis prolifera*	R.Br.	*Cyperaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Herb/Cyperoid
C - L R 450	*Isolepis prolifera*	R.Br.	*Cyperaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Herb/Cyperoid
C - L R 438	*Psoralea oligophylla*	Eckl. & Zeyh.	*Fabaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Tree/Shrub
C - L R 446	*Pennisetum macrourum*	Trin.	*Poaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Graminoid
C - L R 437	*Elegia capensis*	(Burm.f.) Schelpe	*Restionacaceae*	-32.43487 19.21802	Blomfontein	E201/03	Perennial	Shrub/Restiod
C - L R 441	Unknown sp 1			-32.43487 19.21802	Blomfontein	E201/03		
C - L R 568	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb
C - L R 583	*Aponogeton angustifolius*	Aiton	*Aponogetonacea e*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb/Geophyte
C - L R 582	*Isolepis fluitans*	(L.) R.Br.	*Cyperaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb/Cyperoid
C - L R 584	*Isolepis* sp		*Cyperaceae*	-33.66648 19.397121	Bokkekraal	H101/01		
C - L R 571	*Lotus subbiflora* *	Lag.	*Fabaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb
C - L R 572	*Juncus kraussii*	Hochst.	*Juncaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb
C - L R 570	*Mentha aquatic**	L.	*Lamiaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb
C - L R 581	*Eragrostis curvula*	(Schard.) Nees	*Poaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Graminoid
C - L R	*Persicaria* sp		*Polygonaceae*	-33.66648	Bokkekraal	H101/01		

580				19.397121				
C - L R 826	*Prionium serratum*	(L.f.) Drège ex E. Mey.	*Prioniaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Herb/Hydrophyte
C - L R 577	*Leucodendron bruniodes* var *bruniodes*	Meisn.	*Proteaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Shrub
C - L R 574	*Elegia tectorum*	(L.f.) Moline & H.P. Linder	*Restionacaeae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Dwarf shrub/Restioid
C - L R 575	*Cliffortia strobilifera*	Murray	*Rosaceae*	-33.66648 19.397121	Bokkekraal	H101/01	Perennial	Shrub
C - L R 569	Unknown sp 2			-33.66648 19.397121	Bokkekraal	H101/01		
C-L R 251	*Juncus kraussii*	Hochst.	*Juncaceae*	-33.268797 18.343378	Burgerspan	G103/03	Perennial	Herb
C - L R 768	*Berzelia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.344131 19.326265	De Diepte Gat	G403/05	Perennial	Shrub
C - L R 770	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.344131 19.326265	De Diepte Gat	G403/05	Perennial	Herb/Cyperoid
C - L R 769	*Pteridium aquilinum*	(L.) Kuhn	*Dennstaedtiaceae*	-34.344131 19.326265	De Diepte Gat	G403/05	Perennial	Herb/Geophyte
C - L R 771	*Prionium serratum*	(L.f.) Drège ex E. Mey.	*Prioniaceae*	-34.344131 19.326265	De Diepte Gat	G403/05	Perennial	Herb/Hydrophyte
C - L R 608	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-34.742969 19.752034	Die Pan	G501/17	Perennial	Herb
C - L R 606	*Sarcocornia natalensis*	(Bunge ex Ung.-Sternb.)	*Chenopodiaceae*	-34.742969 19.752034	Die Pan	G501/17		
C - L R 609	*Plantago* sp 1		*Plantaginaceae*	-34.742969 19.752034	Die Pan	G501/17		
C - L R	*Sporobolus*	(L.) Kunth	*Poaceae*	-34.742969	Die Pan	G501/17	Perennial	Graminoid

607	*virginicus**			19.752034				
C - L R 524	*Pennisetum clandestinum**	Chiov.	*Poacaeae*	-33.243237 19.276012	Die Vlakte	H101/06	Perennial	Graminoid
C - L R 525	*Stenotaphrum secundatum**	(H. Walter) Kuntze	*Poacaeae*	-33.243237 19.276012	Die Vlakte	H101/06	Perennial	Graminoid
C - L R 528	*Pennisetum marcrourum*	Trin.	*Poacaeae*	-33.243237 19.276012	Die Vlakte	H101/06		
C - L R 460	*Othonna parviflora*	P.J Bergius	*Asteraceae*	-32.431429 19.148417	Driehoek	E201/06	Perennial	Shrub
C - L R 457	*Erica* sp 1		*Ericaceae*	-32.431429 19.148417	Driehoek	E201/06		
C - L R 453	*Calopsis paniculata*	(Rottb.) Desv.	*Restionaceae*	-32.431429 19.148417	Driehoek	E201/06	Perennial	Shrub/Restiod
C - L R 454	*Elegia capensis*	(Burm.f.) Schelpe	*Restionaceae*	-32.431429 19.148417	Driehoek	E201/06	Perennial	Shrub/Restiod
C - L R 466	*Restio* sp 5		*Restionaceae*	-32.431429 19.148417	Driehoek	E201/06		
C - L R 467	*Restio* sp 6		*Restionaceae*	-32.431429 19.148417	Driehoek	E201/06		
C - L R 468	*Restio* sp 7		*Restionaceae*	-32.431429 19.148417	Driehoek	E201/06		
C - L R 753	*Aponogeton distachyos*	L. f.	*Aponogetonacea e*	-34.344649 19.457385	Elias Gat	G403/03	Perennial	Herb/Geophyte
C - L R 756	*Cotula coronopifolia*	L.	*Asteraceae*	-34.344649 19.457385	Elias Gat	G403/03	Annual	Herb
C - L R 752	*Isolepis proliferaa*	R.Br.	*Cyperaceae*	-34.344649 19.457385	Elias Gat	G403/03	Perennial	Herb/Cyperoid
C - L R 759	*Acacia saligna**	H. L Wendl	*Fabaceae*	-34.344649 19.457385	Elias Gat	G403/03	Perennial	Shrub
C - L R 751	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.344649 19.457385	Elias Gat	G403/03	Perennial	Graminoid

C - L R 755	*Cliffortia strobilifera*	Murray	*Rosaceae*	-34.344649 19.457385	Elias Gat	G403/03	Perennial	Shrub
C - L R 760	*Rubus* sp		*Rosaceae*	-34.344649 19.457385	Elias Gat	G403/03		
C - L R 765	*Acacia saligna**	H. L Wendl	*Fabaceae*	-34.348115 19.482339	Elias Gat	G403/03	Perennial	Tree/Shrub
C - L R 767	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.348115 19.482339	Elias Gat	G403/03	Perennial	Graminoid
C - L R 761	*Prionium serratum*	(L.f.) Drège ex E. Mey.	*Prioniaceae*	-34.348115 19.482339	Elias Gat	G403/03	Perennial	Herb/Hydroph yte
C - L R 762	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.348115 19.482339	Elias Gat	G403/03	Perennial	Shrub/Restiod
C - L R 683	*Searsia lucida*	(L.) F.A. Barkley	*Anacardiaceae*	-34.576939 19.375242	Gaansbaai	G403/09	Annual	Shrub
C - L R 682	*Cotula filifolia*	Thunb.	*Asteraceae*	-34.576939 19.375242	Gaansbaai	G403/09	Annual	Herb
C - L R 685	*Acacia saligna*	H. L Wendl	*Fabaceae*	-34.576939 19.375242	Gaansbaai	G403/09	Perennial	Tree/Shrub
C - L R 680	*Pennisetum clandestinum**	Chiov.	*Poaceae*	-34.576939 19.375242	Gaansbaai	G403/09	Perennial	Graminoid
C - L R 681	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.576939 19.375242	Gaansbaai	G403/09	Perennial	Graminoid
C - L R 684	*Typha capensis*	(Rohrb.) N.E.Br.	*Typhaceae*	-34.576939 19.375242	Gaansbaai	G403/09	Perennial	Herb
C - L R 845	*Nymphoides indica**	(L.) Kuntz	*Menyanthaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Hydrophyte
C - L R 831	*Isolepis proliferaa*	R.Br.	*Cyperaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Herb/Cyperoid
C - L R 659	*Erica coccinea* subsp *coccinea*	L.	*Ericaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Shrub

C - L R 654	*Juncus lomatophyllus*	Spreng.	*Juncaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Herb
C - L R 651	*Nymphaea nouchali**	Burm.f.	*Nymphaeaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Herb/Hydroph yte
C - L R 658	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Graminoid
C - L R 652	*Potamogeton schweinfurthii*	A.W. Benn	*Potamogetonace ae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Herb/Hydroph yte
C - L R 657	*Prionium serratum*	(L.f.) Drège ex E. Mey.	*Prioniaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Herb/Hydroph yte
C - L R 650	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Shrub/Restiod
C - L R 656	*Cliffortia graminea*	L.f.	*Rosaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Shrub
C - L R 660	*Cliffortia ferruginea*	L.f.	*Rosaceae*	-34.671843 19.599275	Groot hagelkraal 2mnt	G501/14	Perennial	Shrub
C - L R 663	*Nidorella foetida*	(L.) DC.	*Asteraceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Suffrutex
C - L R 670	*Berzelia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Shrub
C - L R 671	*Cuscuta* sp	L.	*Convolvulaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09		
C - L R 674	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Herb/Cyperoid
C - L R 675	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Herb/Cyperoid
C - L R 679	*Carex acutiformis**	Ehrh.	*Cyperaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Herb/Cyperoid

C - L R 664	*Psoralea* sp 3		*Fabaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09		
C - L R 829	*Psoralea oligophylla*	Eckl. & Zeyh.	*Fabaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Tree/Shrub
C - L R 669	*Pennisetum clandestinum**	Chiov.	*Poaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Graminoid
C - L R 665	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Shrub/Restiod
C - L R 668	*Cliffortia graminea*	L.f.	*Rosaceae*	-34.682985 19.573451	Groot Hagelkraal farm	G501/09	Perennial	Shrub
C - L R 631	*Berzilia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Perennial	Shrub
C - L R 635	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Perennial	Herb/Cyperoid
C - L R 827	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Perennial	Herb/Cyperoid
C - L R 630	*Psoralea aphylla*	L.	*Fabaceae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Perennial	Shrub
C - L R 636	*Laurembergia repens*	(Hiern) Oberm.	*Haloragaceae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Annual	Herb
C - L R 632	*Platycoulas compressus*	(Rottb.) H.P. Linder	*Restionacaeae*	-34.238923 18.382338	Groot Rondevlei CP	G203/04	Perennial	Shrub/Restiod
C - L R 634	Unknown sp 3			-34.238923 18.382338	Groot Rondevlei CP	G203/04		
C - L R 420	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb
C - L R 837	*Bolboschoenus maritimus*	(L.) Palla	*Cyperaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb/Cyperoid
C - L R 838	*Rhynchospora brownie*	Roem. & Schult.	*Cyperaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb

C - L R 416	*Psorelea pinnata*	L.	*Fabaceae*	-34.361941 18.891045	Groot Witvlei	G401/03		
C - L R 419	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb
C - L R 418	*Mentha aquatica**	L.	*Lamiaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb
C - L R 409	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Graminoid
C - L R 836	*Eragrostis curvula*	(Schard.) Nees	*Poaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Graminoid
C - L R 422	*Persicaria decipiens*	(R. Br.) Wilson	*Polygonaceae*	-34.361941 18.891045	Groot Witvlei	G401/03		
C - L R 412	*Elegia tectorum*	(L.f.) Moline & H.P. Linder	*Restionaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Dwarf shrub/Restiod
C - L R 414	*Cliffortia graminea*	L.f.	*Rosaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Shrub
C - L R 408	*Typha capensis*	(Rohrb.) N.E.Br.	*Typhaceae*	-34.361941 18.891045	Groot Witvlei	G401/03	Perennial	Herb
C - L R 723	*Cuscuta* sp	L.	*Convolvulaceae*	-34.388369 19.229227	Hemel en aarde	G403/02		
C - L R 720	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb/Cyperoid
C - L R 725	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb/Cyperoid
C - L R 728	*Isolepis proliferaa*	R.Br.	*Cyperaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb/Cyperoid
C - L R 726	*Laurembergia repens*	(Hiern) Oberm.	*Haloragaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Annual	Herb

C - L R 721	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb
C - L R 722	*Juncus lomatophyllus*	Spreng.	*Juncaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb
C - L R 724	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Graminoid
C - L R 727	*Prionium serratum*	(L.f.) Drège ex E. Mey.	*Prioniaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Herb/Hydroph yte
C - L R 718	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Shrub/Restiod
C - L R 719	*Cliffortia strobilifera*	Murray	*Rosaceae*	-34.388369 19.229227	Hemel en aarde	G403/02	Perennial	Shrub
C - L R 714	*Psoralea pinnata*	L.	*Fabaceae*	-34.383843 19.234312	Hemel en aarde	G403/02	Perennial	Tree/Shrub
C - L R 710	*Pinus* sp*	L.	*Pinaceae*	-34.383843 19.234312	Hemel en aarde	G403/02		
C - L R 707	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.383843 19.234312	Hemel en aarde	G403/02	Perennial	Graminoid
C - L R 716	*Pennisetum clandestinum**	Chiov.	*Poaceae*	-34.383843 19.234312	Hemel en aarde	G403/02	Perennial	Graminoid
C-L R 178	*Searsia lucida*	(L.) F.A. Barkley	*Anacardiaceae*	-33.998567 18.488071	Kenilworth	G203/13	Annual	Shrub
C-L R 179	*Gomphocarpus physocarpus**	E. Mey.	*Apocynaceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Shrub
C-L R 184	*Zantedeschia aethiopica*	(L.) Spreng	*Araceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Herb
C-L R 183	*Helichrysum petiolare. microphyllum*	Hillard & B.L Burtt	*Asteraceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Shrub

C-L R 185	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Herb/Cyperoid
C-L R 186	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Herb/Cyperoid
C-L R 181	*Oxalis versicolor*	L.	*Oxalidaceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Geophyte
C-L R 187	*Stenotaphrum secundatum*	(H. Walter) Kuntze	*Poaceae*	-33.998567 18.488071	Kenilworth	G203/13	Perennial	Graminoid
C-L R 177	*Persicaria decipiens*	(R. Br.) Wilson	*Polygonaceae*	-33.998567 18.488071	Kenilworth	G203/13	Annual	Herb
C - L R 551	*Berula erecta**	(Hundson) Cov.	*Apiaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Annual	Herb
C - L R 553	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Herb
C - L R 550	*Gomphocarpus physocarpus**	E. Mey.	*Apocynaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03		
C - L R 557	*Schoenoplectus scirpoides*	(Schrad.) J. Browning	*Cyperaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Herb/Cyperoid
C - L R 563	*Schoenoplectus triqueter*	(L.) Palla	*Cyperaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03		
C - L R 560	*Mentha aquatic**	L.	*Lamiaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Herb
C - L R 561	*Mentha aquatic**	L.	*Lamiaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Herb
C - L R 549	*Pennisetum clandestinum**	Chiov.	*Poacaeae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Graminoid
C - L R 559	*Persicaria decipiens*	(R. Br.) Wilson	*Polygonaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Annual	Herb

C - L R 548	*Typha capensis*	(Rohrb.) N.E.Br.	*Typhaceae*	-34.039136 18.686666	Khayelitsha pool/East	G204/03	Perennial	Herb
C-L R 257	*Cotula turbinanta*	L.	*Asteraceae*	-33.263346 18.388672	Kiekosvlei	G103/01	Annual	Herb
C-L R 258	*Erodium moschantum*	(L.) L' Hér	*Geraniaceae*	-33.263346 18.388672	Kiekosvlei	G103/01	Annual	Herb
C-L R 256	*Oxalis disticha*	Jacq.	*Oxalidaceae*	-33.263346 18.388672	Kiekosvlei	G103/01	Perennial	Geophyte
C - L R 843	*Berzelia abrotanoides*	(L.) Brongn.	*Bruniaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Shrub
C - L R 847	*Drosera aliciae*	Raym.-Hamet	*Droseraceae*	-34.177136 18.388042	Kleinplaats West	G203/01		
C - L R 844	*Erica laeta*	Bartl.	*Ericaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Shrub
C - L R 427	*Psoralea pinnata*	L.	*Fabaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Tree/Shrub
C - L R 431	*Laurembergia repens*	(Hiern) Oberm.	*Haloragaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Annual	Herb
C - L R 426	*Polygonum* sp		*Malvaceae*	-34.177136 18.388042	Kleinplaats West	G203/01		
C - L R 840	*Pennisetum macrourum*	Trin.	*Poaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Graminoid
C - L R 425	*Leucondendron laureolum*	(Lam.) Fourc.	*Proteaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Shrub
C - L R 839	*Leucodendron* sp		*Proteaceae*	-34.177136 18.388042	Kleinplaats West	G203/01		
C - L R 842	*Serruria glomerata*	(L.) R.Br.	*Proteaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Shrub
C - L R 841	*Elegia cuspidata*	Mast.	*Restionaceae*	-34.177136 18.388042	Kleinplaats West	G203/01	Perennial	Dwarf shrub/Restiod

C-L R 263	*Sarcocornia natalensis*	(Bunge ex Ung.-Sternb.)	*Chenopodiaceae*	-33.263346 18.343378	Koekiespan	G103/02	Perennial	Dwarf shrub
C-L R 259	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-33.263346 18.343378	Koekiespan	G103/02	Perennial	Graminoid
C-L R 261	*Sporobolus virginicus**	(L.) Kunth	*Poaceae*	-33.263346 18.343378	Koekiespan	G103/02	Perennial	Graminoid
C - L R 382	*Searsia lucida*	(L.) F.A. Barkley	*Anacardiaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Annual	Shrub
C - L R 390	*Hydrocotyle verticillata*	Thunb.	*Apiaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb/Hydrophyte
C - L R 380	*Blechnum capense*	Burm.f.	*Blechnaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb/Geophyte
C - L R 834	*Crassula pellucida* subsp *pellucida*	L.	*Crassulaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb/Succulent
C - L R 385	*Cyperus congestus*	Vahl	*Cyperaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb/Cyperoid
C - L R 832	*Pteridium aquilinum*	(L.) Kuhn	*Dennstaedtiaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb/Geophyte
C - L R 387	*Psoralea* sp		*Fababceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01		
C - L R 388	*Pennisetum clandestinum**	Chiov.	*Poacaeae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Graminoid
C - L R 378	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Graminoid
C - L R 389	*Persicaria decipiens*	(R. Br.) Wilson	*Polygonaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Annual	Herb
C - L R 386	*Platycoulas compressus*	(Rottb.) H.P. Linder	*Restionacaeae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Shrub/Restiod

C - L R 391	*Cliffotia graminea*	L.f.	*Rosaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Shrub
C - L R 393	*Cliffortia odorata*	L.f.	*Rosaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Shrub
C - L R 379	*Typha capensis*	(Rohrb.) N.E.Br.	*Typhaceae*	-34.356007 18.9070761	Malkopsvlei/Bass lake	G401/01	Perennial	Herb
C - L R 820	*Cotula coronopifolia*	L.	*Asteraceae*	-34.718951 19.752137	Melkbos pan	G501/16	Annual	Herb
C - L R 605	*Sarcocornia natalensis*	(Bunge ex Ung.-Sternb.)	*Chenopodiaceae*	-34.718951 19.752137	Melkbos pan	G501/16	Perennial	Dwarf shrub
C - L R 602	*Plantago* sp 1		*Plantaginaceae*	-34.718951 19.752137	Melkbos pan	G501/16		
C - L R 604	*Limonium kraussianum**	(Buchinger ex Boiss.) Kuntze	*Plumbaginaceae*	-34.718951 19.752137	Melkbos pan	G501/16	Perennial	Dwarf shrub
C - L R 603	*Sporobolus virginicus**	(L.) Kunth	*Poaceae*	-34.718951 19.752137	Melkbos pan	G501/16	Perennial	Graminoid
C - L R 646	*Mentha aquatica**	L.	*Lamiaceae*	-34.67011 19.527988	Pearly Beach	G501/10	Perennial	Herb
C - L R 645	*Lemna gibba**	L.	*Lemnaceae*	-34.67011 19.527988	Pearly Beach	G501/10	Perennial	Herb/Hydrophyte
C - L R 647	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.67011 19.527988	Pearly Beach	G501/10	Perennial	Graminoid
C - L R 612	*Aponogeton distachyos*	L. f.	*Aponogetonaceae*	-34.753027 19.763123	Ratel River	G501/15	Perennial	Herb/Geophyte
C - L R 613	*Isolepis striata*	(Nees) Kunth	*Cyperaceae*	-34.753027 19.763123	Ratel River	G501/15	Perennial	Herb/Cyperoid
C - L R 618	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.753027 19.763123	Ratel River	G501/15	Perennial	Herb
C - L R	*Oxalis versicolor*	L.	*Oxalidaceae*	-34.753027	Ratel River	G501/15	Perennial	Geophyte

614				19.763123				
C - L R 616	*Stenotaphrum secundatum**	(H. Walter) Kuntze	*Poaceae*	-34.753027 19.763123	Ratel River	G501/15	Perennial	Graminoid
C - L R 615	*Elegia tectorum*	(L.f.) Moline & H.P. Linder	*Restionacaeae*	-34.753027 19.763123	Ratel River	G501/15	Perennial	Dwarf shrub/Restiod
C-L R 267	*Ficinia nodosa*	(Rottb.) Goetgh., Muasya & D.A. Simpson	*Cyperaceae*	-33.442746 18.274639	Rondeberg	G201/04	Perennial	Herb/Cyperoid
C-L R 275	*Lemna gibba**	L.	*Lemnaceae*	-33.442746 18.274639	Rondeberg	G201/04	Perennial	Herb/Hydroph yte
C-L R 276	*Wolffia arrhiza**	(L.) Horkel ex Wimm.	*Lemnaceae*	-33.442746 18.274639	Rondeberg	G201/04	Perennial	Herb
C-L R 191	*Cotula filifolia*	Thunb.	*Asteraceae*	-33.33108 18.163746	Rooipan	G201/01	Annual	Herb
C-L R 192	*Asteraceae* sp 1		*Asteraceae*	-33.33108 18.163746	Rooipan	G201/01		
C-L R 190	*Sarcocornia natalensis*	(Bunge ex Ung.-Sternb.)	*Chenopodiaceae*	-33.33108 18.163746	Rooipan	G201/01	Perennial	Dwarf shrub
C-L R 193	*Limonium scabrum*	(Thunb.) Kuntze	*Plumbaginaceae*	-33.33108 18.163746	Rooipan	G201/01	Perennial	Dwarf shrub
C - L R 787	*Nidorella foetida*	(L.) DC.	*Asteraceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Suffrutex
C - L R 783	*Berzelia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Shrub
C - L R 776	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R	*Isolepis natans*	(Thunb) A.	*Cyperaceae*	-34.429853	Salmonsdam	G404/01	Annual	Herb/Cyperoid

789		Dieter		19.630989				
C - L R 790	*Isolepis levynslana*	Muasya & D.A. Simposon	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Annual	Herb/Cyperoid
C - L R 846	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 792	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 794	*Ficinia capillifolia*	(Schrad.) C.B. Clarke	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 795	*Isolepis proliferaa*	R.Br.	*Cyperaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 784	*Pteridium aquilinum*	(L.) Kuhn	*Dennstaedtiacea e*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb/Geophyte
C - L R 777	*Virgillia* sp		*Fabaceae*	-34.429853 19.630989	Salmonsdam	G404/01		
C - L R 788	*Psoralea* sp 4		*Fabaceae*	-34.429853 19.630989	Salmonsdam	G404/01		
C - L R 779	*Wachendorfia thyrsiflora*	Burm.	*Haemodoraceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Geophyte
C - L R 793	*Watsonia* sp		*Iridaceae*	-34.429853 19.630989	Salmonsdam	G404/01		
C - L R 791	*Juncus lomatophyllus*	Spreng.	*Juncaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Herb
C - L R 775	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Graminoid
C - L R 778	*Pennisetum macrourum*	Trin.	*Poaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Graminoid
C - L R 786	*Calopsis paniculata*	(Rottb.) Desv.	*Restionacaeae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Shrub/Restiod

C - L R 780	*Cliffortia strobilifera*	Murray	*Rosaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Shrub
C - L R 781	*Cliffortia graminea*	L.f.	*Rosaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Shrub
C - L R 782	*Cliffortia ferruginea*	L.f.	*Rosaceae*	-34.429853 19.630989	Salmonsdam	G404/01	Perennial	Shrub
C - L R 839	*Blechnum capense*	Burm.f.	*Blechnaceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Herb/Geophyte
C - L R 797	*Berzelia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Shrub
C - L R 801	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 802	*Isolepis* sp		*Cyperaceae*	-34.440064 19.620113	Salomonsdam	G404/01		Herb/Cyperoid
C - L R 804	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Herb/Cyperoid
C - L R 838	*Isolepis* sp		*Cyperaceae*	-34.440064 19.620113	Salomonsdam	G404/01		Herb/Cyperoid
C - L R 799	*Pteridium aquilinum*	(L.) Kuhn	*Dennstaedtiacea e*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Herb/Geophyte
C - L R 803	*Wachendorfia thyrsiflora*	Burm.	*Haemodoraceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Geophyte
C - L R 798	*Pennisetum macrourum*	Trin.	*Poaceae*	-34.440064 19.620113	Salomonsdam	G404/01	Perennial	Graminoid
C-L R 210	*Osmitopsis asteroids*	(P.J. Berggius) Less.	*Asteraceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb
C-L R 208	*Berzilia lanuginosa*	(L.) Brongn.	*Bruniaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Shrub

C-L R 307	*Carpha glomerata*	(Thunb.) Nees	*Cyperaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb/Cyperoid
C-L R 311	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb/Cyperoid
C-L R 207	*Isolepis prolifera*	R.Br.	*Cyperaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb/Cyperoid
C-L R 206	*Fuirena hirsuta*	(P.J. Berggius) P.L. Forbes	*Cyperaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb/Cyperoid
C-L R 312	*Erica curviflora*	Salisb.	*Ericaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Shrub
C-L R 306	*Virgilia divericata*	Adamson	*Fabaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Tree
C-L R 310	*Gleichenia polypodioides*	(L.) Sm.	*Gleicheniaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb
C-L R 309	*Nymphae nouchali**	Burm.f.	*Nymphaeaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Herb
C-L R 209	*Elegia fistulosa*	Kunth	*Restionaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Dwarf shrub/Restiod
C-L R 313	*Cliffortia graminea*	L.f.	*Rosaceae*	-34.074198 18.39558	Silvermine Inflow	G203/18	Perennial	Shrub
C-L R 340	*Berula erecta**	(Hundson) Cov.	*Apiaceae*	-34.117678 18.383351	Noordhoek	G203/13	Annual	Herb
C-L R 339	*Sarcocornia natalensis*	(Bunge ex Ung.-Sternb.)	*Chenopodiaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Dwarf shrub
C-L R 341	*Wolffia arrhiza**	(L.) Horkel ex Wimm.	*Lemnaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Herb
C-L R 342	*Myoporum tenuifolium**	G. Forst.	*Myoporaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Tree/Shrub

C-L R 343	*Syzygium cordatum*	Hochst. Ex C. Krauss.	*Myrtaceae*	-34.117678 18.383351	Noordhoek	G203/14	Perennial	Tree/Shrub
C-L R 338	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Graminoid
C-L R 345	*Cyperus textilis*	Thunb.	*Cyperaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Herb/Cyperoid
C-L R 346	*Ficinia nodosa*	(Rottb.) Goetgh., Muasya & D.A. Simpson	*Cyperaceae*	-34.117678 18.383351	Noordhoek	G203/15	Perennial	Herb/Cyperoid
C-L R 347	*Schoenoplectus scirpoides*	(Schrad.) J. Browning	*Cyperaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Herb/Cyperoid
C-L R 344	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.117678 18.383351	Noordhoek	G201/12	Perennial	Herb
C - L R 470	*Brunia alopecuroides*	Thunb.	*Bruniaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04	Perennial	Shrub
C - L R 481	*Bruniaceae* sp		*Bruniaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04		
C - L R 477	*Drosera* sp		*Droseraceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04		
C - L R 475	*Pelargonium englerianum*	R. Kunth	*Geraniaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04		
C - L R 476	*Oxalis* sp		*Oxalidaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04	Perennial	Geophyte
C - L R 471	*Ehrharta ramosa*	(Thunb.) Thunb.	*Poaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04	Perennial	Graminoid
C - L R 480	*Pennisetum macrourum*	Trin.	*Poaceae*	-32.478053 19.164371	Sneeuberg hut stream	E201/04	Perennial	Graminoid
C - L R	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-34.726928	Soetendalsvlei	G501/08	Perennial	Herb

597				19.984579				
C - L R 594	*Schoenoplectus scirpoides*	(Schrad.) J. Browning	*Cyperaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb/Cyperoid
C - L R 598	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb/Cyperoid
C - L R 599	*Isolepis prolifera*	R.Br.	*Cyperaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb/Cyperoid
C - L R 821	*Isolepis rubicunda*	Kunth	*Cyperaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb/Cyperoid
C - L R 822	*Isolepis prolifera*	R.Br.	*Cyperaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb/Cyperoid
C - L R 593	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb
C - L R 600	*Triglochin striata*	Ruiz & Pav.	*Juncaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Herb
C - L R 595	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Graminoid
C - L R 596	*Sporobolus virginicus**	(L.) Kunth	*Poaceae*	-34.726928 19.984579	Soetendalsvlei	G501/08	Perennial	Graminoid
C - L R 811	*Centella asiatica*	(L.) Urb.	*Apiaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb
C - L R 842	*Aponogeton distachyos*	L.f.	*Aponogetonaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb/Geophyte
C - L R 805	*Ficinia nodosa*	(Rottb.) Goetgh., Muasya & D.A. Simpson	*Cyperaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb/Cyperoid
C - L R 808	*Cyperus congestus*	Vahl	*Cyperaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb/Cyperoid
C - L R 809	*Bolboschoenus maritimus*	(L.) Palla	*Cyperaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb/Cyperoid

C - L R 810	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.645037 20.021475	Varkensvlei	G501/20	Perennial	Herb
C - L R 698	*Cotula filifolia*	Thunb.	*Asteraceae*	-34.412113 19.159634	Vermont pan	G403/01	Annual	Herb
C - L R 700	*Bolboschoenus maritimus*	(L.) Palla	*Cyperaceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Herb/Cyperoid
C - L R 701	*Pycreus polystachos*	(Rottb.) P. Beauv.	*Cyperaceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Herb/Cyperoid
C - L R 704	*Epilobium tetragonum* *	L.	*Onagraceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Herb
C - L R 705	*Epilobium hirsutum**	L.	*Onagraceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Herb
C - L R 695	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Graminoid
C - L R 703	*Sporobolus virginicus**	(L.) Kunth	*Poaceae*	-34.412113 19.159634	Vermont pan	G403/01	Perennial	Graminoid
C - L R 697	*Ulva cf flexulosa*	Wulfen	*Ulvaceae*	-34.412113 19.159634	Vermont pan	G403/01		
C - L R 537	*Azolla filiculoides**	Lam.	*Azollaceae*	-33.43415 19.1774	Verrekyker	H101/05	Perennial	Herb/Hydroph yte
C - L R 539	*Cyperus textilis*	Thunb.	*Cyperaceae*	-33.43415 19.1774	Verrekyker	H101/05	Perennial	Herb/Cyperoid
C - L R 535	*Pennisetum clandestinum**	Chiov.	*Poacaeae*	-33.43415 19.1774	Verrekyker	H101/05	Perennial	Graminoid
C - L R 534	*Phragmites australis*	(Cav.)Trin. Ex Steud.	*Poaceae*	-33.43415 19.1774	Verrekyker	H101/05	Perennial	Graminoid
C - L R 536	*Persicaria decipiens*	(R. Br.) Wilson	*Polygonaceae*	-33.43415 19.1774	Verrekyker	H101/05	Annual	Herb
C - L R 538	*Eichhornia crassipes**	(Mart.) Solms	*Pontederiaceae*	-33.43415 19.1774	Verrekyker	H101/05	Perennial	Herb/Hydroph yte
C - L R	*Typha capensis*	(Rohrb.)	*Typhaceae*	-33.43415	Verrekyker	H101/05	Perennial	Herb

533		N.E.Br.		19.1774				
C - L R 693	*Cyperus thunbergii*	Vahl	*Cyperaceae*	-34.670436 19.878101	Voelvlei	G501/18	Perennial	Herb/Cyperoid
C - L R 692	*Gladiolus tritis*	L.	*Iridaceae*	-34.670436 19.878101	Voelvlei	G501/18	Perennial	Herb/Geophyte
C - L R 689	*Cotula coronopifolia*	L.	*Asteraceae*	-34.669606 19.912607	Wiesdrif	G501/18	Annual	Herb
C - L R 691	*Juncus kraussii*	Hochst.	*Juncaceae*	-34.669606 19.912607	Wiesdrif	G501/18	Perennial	Herb
C - L R 690	*Eleocharis limosa*	(Schard.) Schult.	*Poaceae*	-34.669606 19.912607	Wiesdrif	G501/18	Perennial	Graminoid
C - L R 840	*Gleichenia polypodioides*	(L.) Sm.	*Gleicheniaceae*	-34.351257 19.275621	Belsvlei	G403/04	Perennial	Herb

Appendix 2

King and Silberbauer 1988/89 wetland plant species list

Family	Species	New/changed sp name or Family	Catalog no.	wetland code	wetland name
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		205	G403/04	Belsvlei
ERICACEAE	*Erica curviflora* L.		206	G403/04	Belsvlei
FABACEAE	*Psoralea aphylla* L.		207	G403/04	Belsvlei
FABACEAE	*Dolichos hastaeformis* E. Mey.		208	G403/04	Belsvlei
HAEODORACEAE	*Wachendorfia thurisflora* Burm.		203	G403/04	Belsvlei
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		204	G403/04	Belsvlei
ROSACEAE	*Cliffortia strobilifera* Murray.		210	G403/04	Belsvlei
DENNSTAEDTIACEAE	*Pteridium aquilinum (*L.) Kuhn	*Pteridium aquilinum subsp aquilinum* (L.) Kunth	209	G403/04	Belsvlei
ASTERACEAE	*Helichrysum foetidum* (L.) Maoench		593	E201/03	Blomfontein
ASTERACEAE	*Othonna parviflora* Berg.		601	E201/03	Blomfontein
CYPERACEAE	*Carpha capitellata (*Nees) Boeck.		600	E201/03	Blomfontein
CYPERACEAE	*Mariscus thunbergii* (Vahl) Schrad.	*Cyperus thunbergii* Vahl	599	E201/03	Blomfontein

CYPERACEAE	*Isolepis proliferaa* R. Br.		591	E201/03	Blomfontein
ERICACEAE	*Erica curviflora* L.		596	E201/03	Blomfontein
ERICACEAE	*Erica mammosa* L.		597	E201/03	Blomfontein
FABACEAE	*Psoralea oligophylla* Eckl. & Zeyh.		594	E201/03	Blomfontein
HALORAGIDACEAE	*Gunnera perpensa* L.	***GUNNERACEAE***	602	E201/03	Blomfontein
JUNCACEAE	*Juncus punctorius* L. f.		598	E201/03	Blomfontein
LILIACEAE	*Kniphofia uvaria* (L.) Oken		592	E201/03	Blomfontein
POACEAE	*Setria sphacelata* (Schmumach.) Moss		595	E201/03	Blomfontein
RESTIONACEAE	*Elegia capensis* (Burm. F.) Schelpe.		590	E201/03	Blomfontein
CYPERACEAE	*Pycreus polystachos* (Rottb.) Beauv. *var polystachyos*		141	H101/01C	Bokke Kraal
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		133	H101/01	Bokke Kraal
JUNCACEAE	*Prionium serratum* (L.f.) Drege ex E. Mey.		136	H101/01	Bokke Kraal
JUNCACEAE	*Juncus sp*		137	H101/01	Bokke Kraal
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	138	H101/01C	Bokke Kraal
JUNCACEAE	Juncus lomatophyllus Spreng.		140	H101/01C	Bokke Kraal
POACEAE	*Pennisetum macrourum* Trin.		139	H101/01C	Bokke Kraal
POACEAE	*Eragrotis cf. curvula*		126	H101/01	Bokke Kraal
POLYGONACEAE	*Polygonum sp C*		134	H101/01	Bokke Kraal
PROTEACEAE	*Leucondendron linifolium* (Jacq.) R Br.		135	H101/01	Bokke Kraal
RESTIONACEAE	*Elegia fistulosa* Kunth		127	H101/01	Bokke Kraal

RESTIONACEAE	*Willdenowia incurvata (*Thunb.) Linder		142	H101/01C	Bokke Kraal
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	304	G103/03	Burgerspan
APIACEA	*Berula erecta (*Hudson) Cov.		65	G204/01	Cape Corps
ASTERACEAE	*Rorippanasturium-aquaticum** (L.) Hayek	*Nasturtium officinale** W.T. Aiton	63	G204/01	Cape Corps
CYPERACEAE	*Cyperus longus* L.		66&38	G204/01	Cape Corps
CYPERACEAE	*Scirpus maritimus* L.	*Bolboschoenus maritimus (*L.) Palla	64	G204/01	Cape Corps
CYPERACEAE	*Scirpus nodosus* Rottb.	*Ficinia nodosa* (Rottb.) Goetgh., Muasya & D.A. Simpson	67	G204/01	Cape Corps
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	69	G204/01	Cape Corps
POACEAE	*Paspalum vaginatum* Swartz		71-73	G204/01	Cape Corps
POACEAE	*Polypogon monspeliensis** (L.) Desf.		70	G204/01	Cape Corps
ANACARDIACEAE	*Searsia angustifolia (*L.) F.A. Barkely		223	G403/05	De Diepte Gatt
ASTERACEAE	*Conyza scabrida* DC.		224	G403/05	De Diepte Gatt
ASTERACEAE	*Osmitopsis asteriscoides* (Berg.) Less.		215	G403/05	De Diepte Gatt
BRUNIACEAE	*Berzelia lanuginosa* (L.) Brongn.		214	G403/05	De Diepte Gatt
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		228	G403/05	De Diepte Gatt
CYPERACEAE	*Epischoenus gracilis* Levyns		230	G403/05	De Diepte Gatt
FABACEAE	*Psoralea aphylla* L.		225	G403/05	De Diepte Gatt

JUNCACEAE	*Prionium serratum* (L.f.) Drege ex E. Mey.		226	G403/05	De Diepte Gatt
LAURACEAE	*Cassytha ciliolata* Nees		221	G403/05	De Diepte Gatt
PROTEACEAE	*Leucodendron xanthaconus* (Kuntze) K. Schum		213	G403/05	De Diepte Gatt
RESTIONACEAE	*Elegia fistulosa* Kunth		219	G403/05	De Diepte Gatt
RESTIONACEAE	*Platycaulos callistachyus* (Kunth) Linder		222	G403/05	De Diepte Gatt
RESTIONACEAE	*Platycaulos major* (Mast.) Linder		220	G403/05	De Diepte Gatt
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		229	G403/05	De Diepte Gatt
ROSACEAE	*Cliffortia strobilifera* Murray.		227	G403/05	De Diepte Gatt
BLECHNACEAE	*Blechum capense* Burm. f.		217	G403/05	De Diepte Gatt
BLECHNACEAE	*Blechum tabulare* (Thunb.) Kuhn		218	G403/05	De Diepte Gatt
DENNSTAEDTIACEAE	*Pteridium apuilinum subsp aquilinum* (L.) Kunth		216	G403/05	De Diepte Gatt
APONOGETONACEAE	*Aponogeton distachyos* L. f.		168	H101/06	Die Vlakte
CYPERACEAE	*Isolepis prolifera* R. Br.		167	H101/06	Die Vlakte
POACEAE	*Hermarthria altissima* (Poir.) Stapf & C. Hubb.		166	H101/06	Die Vlakte
POACEAE	*Pennisetum macrourum* Trin.		169	H101/06	Die Vlakte
CYPERACEAE	*Mariscus thunbergii* (Vahl) Schrad.	*Cyperus thunbergii* Vahl	620	E201/06	Driehoek
CYPERACEAE	*Isolepis fluitans* (L.) R. Br.		625	E201/06	Driehoek
CYPERACEAE	*Isolepis prolifera* R. Br.		617	E201/06	Driehoek

HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		619	E201/06	Driehoek
JUNCACEAE	*Juncus lomatophyllus* Spreng.		626	E201/06D	Driehoek
LILIACEAE	*Kniphofia uvaria (*L.) Oken		618	E201/06	Driehoek
POACEAE	*Setria sphacelata* (Schmumach.) Moss		615	E201/06	Driehoek
POACEAE	*Setria sphacelata (Schmumach.) Moss*		616	E201/06	Driehoek
RESTIONACEAE	*Restionaceae sp A*		623	E201/06	Driehoek
RESTIONACEAE	*Elegia capensis* (Burm. F.) Schelpe.		621	E201/06	Driehoek
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		622	E201/06	Driehoek
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		195	G403/03B	Elias Gat
ROSACEAE	*Cliffortia strobilifera* Murray.		193	G403/03B	Elias Gat
APIACEA	*Centella asiatica* (L.) Urb.		192	G403/03A	Elias Gat
APONOGETONACEAE	*Aponogeton distachyos* L. f.		201	G403/03A	Elias Gat
ASTERACEAE	*Conyza scabrida* DC.		196	G403/03B	Elias Gat
CYPERACEAE	*Cyperus textilis* Thunb.		197	G403/03B	Elias Gat
CYPERACEAE	*Isolepis prolifera* R. Br.		202	G403/03A	Elias Gat
FABACEAE	*Psoralea pinnata* L.		194	G403/03B	Elias Gat

JUNCACEAE	*Prionium serratum* (L.f.) Drege ex E. Mey.		200	G403/03B	Elias Gat
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	198&199	G403/03B	Elias Gat
POACEAE	*Phragmites australis* (Cav.) Steud.		212	G403/03A	Elias Gat
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		211	G403/03A	Elias Gat
ASTERACEAE	*Cotula coronopifolia* L.		401	G403/09	Gaansbaai
ASTERACEAE	*Cotula coronopifolia* L.		404	G403/09	Gaansbaai
ASTERACEAE	*Cotula filifolia* Thunb.		402	G403/09	Gaansbaai
ASTERACEAE	*Senecio sp A*		395	G403/09	Gaansbaai
CELASTRACEAE	*Pterocelastrus tricuspidatus* (Lam.) Sond		397	G403/09	Gaansbaai
CRASSULACEAE	*Crassula natans* Thunb.		408	G403/09	Gaansbaai
CYPERACEAE	*Ficinia gracillis (*Poir.) Schard.		407	G403/09	Gaansbaai
GENTIANACEAE	*Nymphoides indica (*L.) Kuntze subsp occidentalis A. Raynal	***MENYANTHACEAE***	403	G403/09	Gaansbaai
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda (*Hiern) Oberm.		398	G403/09	Gaansbaai
LEMNACEAE	*Lemna gibba* L.		409	G403/09	Gaansbaai
POTAMOGETONACEAE	*Potamogeton pectinatus L.*		405	G403/09	Gaansbaai
POTAMOGETONACEAE	*Potamogeton pectinatus* L.		406	G403/09	Gaansbaai
RANUNCALACEAE	*Ranunculus trichophyllus Chaix subsp drouetii* (Schultz Clapham	*Ranunculus rionii* Lagger	399	G403/09	Gaansbaai

RESTIONACEAE	*Elegia fistulosa* Kunth		410	G403/09	Gaansbaai
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia* tectorum (L.f.) Moline & H.P. Linder	411&412	G403/09	Gaansbaai
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		413	G403/09	Gaansbaai
CHARACEAE	*Chara globularis*	*Chara globularis* J.L. Thuiller	400	G403/09	Gaansbaai
ASTERACEAE	*Othonna parviflora* Berg.		462	G501/14B	Groot Hagelkraal
BRUNIACEAE	*Berzelia sp*		459	G501/14B	Groot Hagelkraal
BRUNIACEAE	*Berzelia lanuginosa* (L.) Brongn.		449	G501/14	Groot Hagelkraal
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		457	G501/14	Groot Hagelkraal
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		468	G501/14B	Groot Hagelkraal
CYPERACEAE	*Scirpus nodosus* Rottb.	*Ficinia nodosa* (Rottb.) Goetgh., Muasya & D.A. Simpson	466	G501/14B	Groot Hagelkraal
CYPERACEAE	*Isolepis rubicunda* Kunth		450&451	G501/14	Groot Hagelkraal
CYPERACEAE	*Neesenbecki punctoria* (Vahl) Levyns		446	G501/14	Groot Hagelkraal
ERICACEAE	*Erica parviflora* L.		465	G501/14B	Groot Hagelkraal
FABACEAE	*Psoralea aphylla* L.		461	G501/14B	Groot Hagelkraal
FABACEAE	*Psorlea aff. Trullata*		453	G501/14	Groot Hagelkraal
HAEODORACEAE	*Wachendorfia sp*		469	G501/14B	Groot Hagelkraal
JUNCACEAE	*Prionium serratum (*L.f.) Drege ex E. Mey.		470	G501/14B	Groot Hagelkraal
LENTIBULARIACEAE	*Utricularia sp*		456	G501/14	Groot Hagelkraal
POACEAE	*Merxmuellera cincta* (Nees)		448	G501/14	Groot Hagelkraal

	Conert				
POACEAE	*Phragmites australis* (Cav.) Steud.		458	G501/14B	Groot Hagelkraal
PROTEACEAE	*Leucodendron xanthaconus* (Kuntze) K. Schum		452	G501/14	Groot Hagelkraal
PROTEACEAE	*Leucodendron xanthaconus* (Kuntze) K. Schum		460	G501/14B	Groot Hagelkraal
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	Elegia tectorum (L.f.) Moline & H.P. Linder	454	G501/14	Groot Hagelkraal
RESTIONACEAE	*Platycaulos compressus* (Rottb.) Linder		467	G501/14B	Groot Hagelkraal
RESTIONACEAE	*Platycaulos major* (Mast.) Linnder		447	G501/14	Groot Hagelkraal
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		464	G501/14B	Groot Hagelkraal
ROSACEAE	*Cliffortia strobilifera* Murray.		463	G501/14B	Groot Hagelkraal
APIACEA	*Hydrocotyle veticillata* Thunb.		51	G203/04	Groot Rondevlei
BRUNIACEAE	*Berzelia lanuginosa* (L.) Brongn.		50	G203/04	Groot Rondevlei
CYPERACEAE	*Isolepis rubicunda* Kunth		45	G203/04	Groot Rondevlei
FABACEAE	*Psoralea aphylla* L.		47	G203/04	Groot Rondevlei
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	49	G203/04	Groot Rondevlei
RESTIONACEAE	*Chondropetalum tectorum (*L. f.) Raf	*Elegia tectorum* (L.f.) Moline & H.P. Linder	46	G203/04	Groot Rondevlei
RESTIONACEAE	*Platycaulos major (Mast.) Linnder*		48	G203/04	Groot Rondevlei

APIACEA	*Centella asiatica (*L.) Urb.		513	G401/03	Groot Witvlei
ASTERACEAE	*Elytropappus rhinocerotis* (L.f.) Less	*Dicerothamnus rhinocerotis* (L.f.) Koekemoer	96	G401/03	Groot Witvlei
ASTERACEAE	*Senecio lanceus*		511	G401/03	Groot Witvlei
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	515	G401/03	Groot Witvlei
JUNCAGINACEAE	*Triglochin striata* Ruiz & Pav.		509	G401/03	Groot Witvlei
LAMIACEAE	*Mentha aquatica* L.		512	G401/03	Groot Witvlei
LOBELIACEAE	*Lobeliacea sp A*		508	G401/03	Groot Witvlei
POACEAE	*Paspalum vaginatum* Swartz		514	G401/03	Groot Witvlei
POACEAE	*Phragmites australis* (Cav.) Steud.		506	G401/03	Groot Witvlei
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum*(L.f.) Moline & H.P. Linder	516	G401/03	Groot Witvlei
TYPHACEAE	*Typha capensis (*Rohrb.) N.E. Br.		507	G401/03	Groot Witvlei
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		191	G403/02B	Hemel en Aarde
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda (Hiern) Oberm.*		188	G403/02B	Hemel en Aarde
JUNCACEAE	*Prionium serratum (*L.f.) Drege ex E. Mey.		187	G403/02A	Hemel en Aarde
JUNCACEAE	*Juncus lomatophyllus* Spreng.		186	G403/02A	Hemel en Aarde
MYRICACEAE	*Myrica serrata* Lam.	*Morella serrata (Lam.) Killick.*	182	G403/02A	Hemel en Aarde
POACEAE	*Paspalum urvillei** Steud.		190	G403/02B	Hemel en Aarde
POACEAE	*Phragmites australis* (Cav.)		189	G403/02B	Hemel en Aarde

	Steud.				
RESTIONACEAE	*Platycaulos major (*Mast.) Linnder		179	G403/02A	Hemel en Aarde
RESTIONACEAE	*Calopsis paniculata (*Rottb.) Desv		180&181	G403/02A	Hemel en Aarde
RESTIONACEAE	*Calopsis paniculata (*Rottb.) Desv		182	G403/02A	Hemel en Aarde
ROSACEAE	*Cliffortia strobilifera* Murray.		185	G403/02A	Hemel en Aarde
THELYPTERIDACEAE	*Thelypteris confluens (*Thunb.) Morton		184	G403/02A	Hemel en Aarde
ANACARDIACEAE	*Rhus lucida* L.	*Searsia lucida* (L.) F.A. Barkely	271	G203/13	Kenilworth Race Course
ASTERACEAE	*Plecostachys serpyllifolia* L.		273	G203/13	Kenilworth Race Course
BRUNIACEAE	*Berzelia abrotanoides* (L.) *Brongn.*		274	G203/13	Kenilworth Race Course
CYPERACEAE	*Chrysithrix capensis* L. Var.		272	G203/13	Kenilworth Race Course
FABACEAE	*Psoralea pinnata* L.		267	G203/13	Kenilworth Race Course
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		268	G203/13	Kenilworth Race Course
OXALIDACEAE	*Oxalis sp.*		266	G203/13	Kenilworth Race Course
POACEAE	*Stenotaphrum secundatum* (Walt.) Kuntze		275	G203/13	Kenilworth Race Course

RESTIONACEAE	*Elegia fistulosa* Kunth		270	G203/13	Kenilworth Race Course
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		276	G203/13	Kenilworth Race Course
CYPERACEAE	*Cyperus longus* L.		81	G204/03	Khayelitsha East
CYPERACEAE	*Bolboschoenus maritimus* (L.) Palla		79&82	G204/03	Khayelitsha East
CYPERACEAE	*Scirpoides thunbergii* (Shard.)		80	G204/03	Khayelitsha East
POACEAE	*Paspalum vaginatum* Swartz		83	G204/03	Khayelitsha East
APIACEA	*Centella asiatica* (L.) Urb.		77	G204/02	Khayelitsha Pool
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	78	G204/02	Khayelitsha Pool
POACEAE	*Cynodon dactylon* (L.) Pers.		76	G204/02	Khayelitsha Pool
POLYGONACEAE	*Polygonum sp C*		75	G204/02	Khayelitsha Pool
POTAMOGETONACEAE	*Potamogeton pectinatus* L.		74	G204/02	Khayelitsha Pool
CYPERACEAE	*Bolboschoenus maritimus* (L.) Palla		294	G103/01	Kiekoesvlei
CYPERACEAE	*Cyperus textilis Thunb.*		232	G403/07	Klein Vlakte
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	233	G403/07	Klein Vlakte
POACEAE	*Phragmites australis* (Cav.) Steud.		231	G403/07	Klein Vlakte
FABACEAE	*Psoralea aphylla* L.		14	G203/02	Kleinplaats east
IRIDACEAE	*Watsonia zeyheri* Bol.		21	G203/02	Kleinplaats east
POACEAE	*Aundo donax** L.		20	G203/02	Kleinplaats east
RESTIONACEAE	*Platycaulos major* (Mast.) Linnder		18	G203/02	Kleinplaats East
	*Restio ambiguus (*Mast.)		15	G203/02	Kleinplaats East

RESTIONACEAE	*Restio bolusii* Pillans		19	G203/02	Kleinplaats East
BRUNIACEAE	*Berzelia abrotanoides* (L.) Brongn.		11	G203/01	Kleinplaats West
DROSERACEAE	*Drosera aliciae* R. Hamet		8	G203/01	Kleinplaats West
ERICACEAE	*Erica laeta* Bartl.		6	G203/01	Kleinplaats West
FABACEAE	*Psoralea pinnata L.*		9	G203/01	Kleinplaats West
IRIDACEAE	*Watsonia zeyheri* Bol.		13	G203/01	Kleinplaats West
JUNCACEAE	*Juncus cf. kraussii*		2	G203/01	Kleinplaats West
JUNCACEAE	*Juncus oxycarpus* E. Mey. Ex Kunth		1	G203/01	Kleinplaats West
PROTEACEAE	*Serruria glomerata* (L.) R. Br.		10	G203/01	Kleinplaats West
RESTIONACEAE	*Staberoha sp.*		5a	G203/01	Kleinplaats West
RESTIONACEAE	*Elegia cuspidata* Mast.		3	G203/01	Kleinplaats West
RESTIONACEAE	*Elegia filacea* Mast.		4	G203/01	Kleinplaats West
RESTIONACEAE	*Restio quinquefarius* Nees		5b	G203/01	Kleinplaats West
RESTIONACEAE	*Elegia fistulosa* Kunth		16&17	G203/02	Klienplaats East
ASTERACEAE	*Cotula pusilla* Thunb.		302	G103/02	Koekiespan
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		299	G103/02	Koekiespan

CYPERACEAE	*Scirpus maritimus* L.	*Bolboschoenus maritimus (L.) Palla*	297	G103/02	Koekiespan
JUNCACEAE	*Juncus acutus* L. supsp leopoldii (Parl.) Snog.		296&303	G103/02	Koekiespan
JUNCAGINACEAE	*Triglochin striata* Ruiz & Pav.		298	G103/02	Koekiespan
MESEMBRYANTHEMACEAE	*Dorotheanthus* apetalus (L.f.) N.E. Br.		300	G103/02	Koekiespan
POACEAE	*Phragmites australis* (Cav.) Steud.		295	G103/02	Koekiespan
POACEAE	*Sporobolus virginicus (*L.) Kunth		301	G103/02	Koekiespan
ASTERACEAE	*Conyza scabrida* DC.		518	G401/01	Malkopsvlei (Bass Lake)
ASTERACEAE	*Osmitopsis asteriscoides* (Berg.) Less.		525	G401/01	Malkopsvlei (Bass Lake)
CRASSULACEAE	*Crassula pellucida* L.		519	G401/01	Malkopsvlei (Bass Lake)
CYPERACEAE	*Mariscus congestus* (Vahl) C.B. Cl.	*Cyperus congestus* Vahl	527	G401/01	Malkopsvlei (Bass Lake)
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda (*Hiern) Oberm.		522	G401/01	Malkopsvlei (Bass Lake)
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	531	G401/01	Malkopsvlei (Bass Lake)
LOBELIACEAE	*Grammatotheca bergiana* (Cham.) Presl		524	G401/01	Malkopsvlei (Bass Lake)
POACEAE	*Poaceae sp A*		533	G401/01	Malkopsvlei (Bass Lake)
POLYGONACEAE	*Polygonum salicifolium* Willd.	*Persicaria decipiens* (R.Br.) K.L.Wilson	517	G401/01	Malkopsvlei (Bass Lake)

RESTIONACEAE	*Elegia thysifera (*Rottb.) Pers.		529&530	G401/01	Malkopsvlei (Bass Lake)
RESTIONACEAE	*Platycaulos compressus* (Rottb.) Linder		528	G401/01	Malkopsvlei (Bass Lake)
ROSACEAE	*Cliffortia graminea* L. f.		526	G401/01	Malkopsvlei (Bass Lake)
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		521	G401/01	Malkopsvlei (Bass Lake)
THELYPTERIDACEAE	*Thelypteris confluens* (Thunb.) Morton		520	G401/01	Malkopsvlei (Bass Lake)
CHENOPODIACEAE	*Sarcocornia natalensis (*Burge ex Urg.-Sternb.) A.J. Scott		546	G501/16	Melkbospan 1
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum (L.f.) Moline & H.P. Linder*	547	G501/16	Melkbospan 1
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		263	G203/12	Noordhoek Soutpan
CYPERACEAE	*Scirpus maritimus* L.	*Bolboschoenus maritimus (L.) Palla*	261	G203/12	Noordhoek Soutpan
CYPERACEAE	*Schoenoplectus littoralis* (Schrad.) Palla	*Schoenoplectus scirpoideus (Schard.) J.Browning*	260	G203/12	Noordhoek Soutpan
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	262	G203/12	Noordhoek Soutpan
POTAMOGETONACEAE	*Potamogeton pectinatus* L.		264	G203/12	Noordhoek Soutpan
APIACEA	*Centella asiatica (*L.) Urb.		430	G501/10A	Pearly Beach
APIACEA	*Berula erecta (*Hudson) Cov.		442	G501/10C	Pearly Beach

ASTERACEAE	*Cotula filifolia* Thunb.		427	G501/10A	Pearly Beach
ASTERACEAE	*Senecio sp A*		421	G501/10A	Pearly Beach
ASTERACEAE	*Senecio laevigatus*		425	G501/10A	Pearly Beach
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		428	G501/10A	Pearly Beach
CYPERACEAE	*Mariscus thunbergii (*Vahl) Schrad.	*Cyperus thunbergii* Vahl	420	G501/10B	Pearly Beach
CYPERACEAE	*Scirpus nodosus Rottb.*	*Ficinia nodosa* (Rottb.) Goetgh., Muasya & D.A. Simpson	435	G501/10A	Pearly Beach
CYPERACEAE	*Schoenoplectus triqueter** (L.) Palla		431	G501/10A	Pearly Beach
CYPERACEAE	*Isolepis cf. cernua*		423	G501/10A	Pearly Beach
CYPERACEAE	*Isolepis prolifera* R. Br.		440	G501/10C	Pearly Beach
FABACEAE	*Psoralea pinnata* L.		443	G501/10C	Pearly Beach
GENTIANACEAE	*Sebaea ambigua* Cham.		426	G501/10A	Pearly Beach
JUNCACEAE	*Juncus kraussii* Hochst.		436	G501/10A	Pearly Beach
JUNCACEAE	*Juncus cf. kraussii*		437	G501/10A	Pearly Beach
JUNCACEAE	*Juncus lomatophyllus* Spreng.		441	G501/10C	Pearly Beach
POACEAE	*Phragmites australis (*Cav.) Steud.		432	G501/10A	Pearly Beach

POACEAE	*Sporobolus virginicus* (L.) *Kunth*		424	G501/10A	Pearly Beach
RESTIONACEAE	*Elegia fenestrata Pillans*		444	G501/10C	Pearly Beach
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum* (L.f.) Moline & H.P. Linder	434	G501/10A	Pearly Beach
ROSACEAE	*Cliffortia strobilifera* Murray.		419	G501/10B	Pearly Beach
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		433	G501/10A	Pearly Beach
TYPHACEAE	*Typha capensis (*Rohrb.) N.E. Br.		445	G501/10C	Pearly Beach
CHARACEAE	*Chara globularis*	*Chara globularis* J.L. Thuiller	439	G501/10A	Pearly Beach
APIACEA	*Apium graveolens* L.*		311	G201/04B	Rondeberg
ASTERACEAE	*Cotula coronopifolia* L.		312	G201/04B	Rondeberg
ASTERACEAE	*Hippia frutescens* (L.) L.		321	G201/04B	Rondeberg
ASTERACEAE	*Senecio sp A*		308	G201/04B	Rondeberg
CRASSULACEAE	*Crassula natans* Thunb.		316	G201/04B	Rondeberg
CRASSULACEAE	*Crassula pellucida* L.		323	G201/04C	Rondeberg
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		320	G201/04C	Rondeberg
CYPERACEAE	*Mariscus thunbergii (*Vahl) Schrad.	*Cyperus thunbergii Vahl*	305	G201/04B	Rondeberg
CYPERACEAE	*Scirpus nodosus* Rottb.	*Ficinia nodosa* (Rottb.) Goetgh., Muasya & D.A. Simpson	307	G201/04B	Rondeberg
CYPERACEAE	*Isolepis prolifera* R. Br.		322	G201/04C	Rondeberg
HAEODORACEAE	*Wachendorfia brachyandra* W.F. Barker		324	G201/04C	Rondeberg

HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		313	G201/04B	Rondeberg
JUNCACEAE	*Juncus cf. kraussii*		306	G201/04B	Rondeberg
JUNCACEAE	*Juncus lomatophyllus* Spreng.		318	G201/04C	Rondeberg
POACEAE	*Merxmuellera cincta (*Nees) Conert		319	G201/04C	Rondeberg
POACEAE	*Cynodon sp*		317	G201/04B	Rondeberg
RESTIONACEAE	*Chondropetalum tectorum*	*Elegia tectorum* (L.f.) Moline & H.P. Linder	309	G201/04B	Rondeberg
TYPHACEAE	*Typha capensis (*Rohrb.) N.E. Br.		325	G201/04C	Rondeberg
CHENOPODIACEAE	*Halopeplis nodulosa* (Delile) Bunge ex Ung.-Sternb.		286	G201/01	Rooipan
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		285	G201/01	Rooipan
ASTERACEAE	*Plecostachys serpyllifolia* L.		248	G404/01A	Salmonsdam
ASTERACEAE	*Helichrysum odoratissimum* (L.) Sweet		251	G404/01A	Salmonsdam
BRUNIACEAE	*Berzelia lanuginosa* ***(L.) Brongn.***		135	G404/01A	Salmonsdam
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		238	G404/01A	Salmonsdam
CYPERACEAE	*Isolepis prolifera* R. Br.		255	G404/01A	Salmonsdam
ERICACEAE	*Erica curviflora* L.		257	G404/01B	Salmonsdam
FABACEAE	*Psoralea aphylla* L.		241	G404/01A	Salmonsdam

FABACEAE	*Psoralea pinnata L.*		236	G404/01A	Salmonsdam
HAEODORACEAE	*Wachendorfia thurisflora* Burm.		239	G404/01A	Salmonsdam
JUNCACEAE	*Prionium serratum* (L.f.) Drege ex E. Mey.		237	G404/01A	Salmonsdam
JUNCACEAE	*Juncus lomatophyllus* Spreng.		254	G404/01A	Salmonsdam
JUNCACEAE	*Juncus lomatophyllus* Spreng.		259	G404/01E	Salmonsdam
LAMIACEAE	*Leonotis leonurus (*L.) R. Br.		253	G404/01A	Salmonsdam
MYRICACEAE	*Myrica serrata* Lam.		247	G404/01A	Salmonsdam
POACEAE	*Pennisetum macrourum* Trin.		240	G404/01A	Salmonsdam
POLYGONACEAE	*Polygonum sp A*		252	G404/01A	Salmonsdam
PROTEACEAE	*Leucondendron salicifolium* (Salisb) I. Williams		250	G404/01A	Salmonsdam
RESTIONACEAE	*Elegia capensis (*Burm. F.) Schelpe.		244&245	G404/01A	Salmonsdam
RESTIONACEAE	*Elegia equisetecea* (Mast.) Mast.		242	G404/01A	Salmonsdam
RESTIONACEAE	*Platycaulos major* (Mast.) Linder		243	G404/01A	Salmonsdam
RESTIONACEAE	*Calopsis paniculata* (Rottb.) Desv		246	G404/01A	Salmonsdam
ROSACEAE	*Cliffortia strobilifera* Murray.		234	G404/01A	Salmonsdam

THYMELAEACEAE	*Gnidia oppositifolia* L.		256	G404/01B	Salmonsdam
DENNSTAEDTIACEAE	*Pteridium aquilinum* (L.) Kuhn	*Pteridium apuilinum subsp aquilinum (*L.) Kunth	249	G404/01A	Salmonsdam
ASTERACEAE	*Osmitopsis asteriscoides (*Berg.) Less.		375	G203/18	Silvermine Dam inflow
ASTERACEAE	*Senecio sp A*		371	G203/18	Silvermine Dam inflow
BRUNIACEAE	*Berzelia lanuginosa* (L.) Brongn.		376	G203/18	Silvermine Dam inflow
CYPERACEAE	*Carpha glomerata* (Thunb.) Nees		378	G203/18	Silvermine Dam inflow
CYPERACEAE	*Isolepis prolifera* R. Br.		374	G203/18	Silvermine Dam inflow
CYPERACEAE	*Isolepis rubicunda* Kunth		373	G203/18	Silvermine Dam inflow
CYPERACEAE	*Epischoenus gracilis* Levyns		382	G203/18	Silvermine Dam inflow
CYPERACEAE	*Macrochaetium* hexandrum (Nees)	*Cyathocoma hexandra* (Nees) J. Browning	366	G203/18	Silvermine Dam inflow
ERICACEAE	*Erica curviflora* L.		377	G203/18	Silvermine Dam inflow
FABACEAE	*Psoralea pinnata* L.		369	G203/18	Silvermine Dam inflow
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		372	G203/18	Silvermine Dam inflow
JUNCACEAE	*Prionium serratum (*L.f.) Drege ex E. Mey.		379	G203/18	Silvermine Dam inflow

LILIACEAE	*Agapanthus africanus* (L.) Hoffmg.	***AGAPANTHACEAE***	368	G203/18	Silvermine Dam inflow
POACEAE	*Merxmuellera cincta* (Nees) Conert		380	G203/18	Silvermine Dam inflow
RESTIONACEAE	*Elegia fistulosa* Kunth		365&367	G203/18	Silvermine Dam inflow
RESTIONACEAE	*Elegia fistulosa* Kunth		370	G203/18	Silvermine Dam inflow
RESTIONACEAE	*Restio ambiguus* (Mast.)		383	G203/18	Silvermine Dam inflow
ROSACEAE	*Cliffortia graminea* L. f.		381	G203/18	Silvermine Dam inflow
ASTERACEAE	*Senecio sp B*		614	E201/04	Sneeuberg Hut Stream
BRUNIACEAE	*Brunia alopecuroides* Thubnb.		605	E201/04	Sneeuberg Hut Stream
CYPERACEAE	*Isolepis prolifera* R. Br.		612	E201/04	Sneeuberg Hut Stream
CYPERACEAE	*Epischoenus gracilis* Levyns		609	E201/04	Sneeuberg Hut Stream
FABACEAE	*Psoralea oligophylla* Eckl. & Zeyh.		603	E201/04	Sneeuberg Hut Stream
GERANIACEAE	*Pelargonium sp A*		606	E201/04	Sneeuberg Hut Stream
HALORAGIDACEAE	*Laurembergia repens* Berg. *subsp brachypoda* (Hiern) Oberm.		611	E201/04	Sneeuberg Hut Stream
JUNCACEAE	*Juncus lomatophyllus* Spreng.		613	E201/04	Sneeuberg Hut Stream

POACEAE	*Setria sphacelata* (Schmumach.) Moss		610	E201/04	Sneeuberg Hut Stream
POACEAE	*Ehrharta ramosa* (Thunb.) Thunb.		607	E201/04	Sneeuberg Hut Stream
POACEAE	*Merxmuellera sp*		608	E201/04	Sneeuberg Hut Stream
RESTIONACEAE	*Cannomis virgata* (Rottb.) Steud.		604	E201/E04	Sneeuberg Hut Stream
APIACEA	*Centella asiatica* (L.) Urb.		537	G501/08	Soetendalsvlei
ASTERACEAE	*Cotula coronopifolia* L.		544	G501/08	Soetendalsvlei
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		538	G501/08	Soetendalsvlei
CYPERACEAE	*Scirpus thunbergianus* (Nees) Levyns	*Scirpoides thunbergii (*Shard.)	543	G501/08	Soetendalsvlei
CYPERACEAE	*Schoenoplectus littoralis (*Schrad.) Palla	*Schoenoplectus scirpoideus (*Schard.) J.Browning	535	G501/08	Soetendalsvlei
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	542	G501/08	Soetendalsvlei
	Delosperma sp		539	G501/08	Soetendalsvlei
POACEAE	*Phragmites australis* (Cav.) Steud.		534	G501/08	Soetendalsvlei
POACEAE	*Sporobolus virginicus* (L.) Kunth		540	G501/08	Soetendalsvlei
ASTERACEAE	*Nidorella foetita (*L.) DC.		569	G501/20	Varkensvlei
CHENOPODIACEAE	*Chenopodium murale** L.		573	G501/20	Varkensvlei
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		567	G501/20	Varkensvlei
JUNCACEAE	*Juncus kraussii* Hochst.	*subsp kraussii*	566	G501/20	Varkensvlei
JUNCAGINACEAE	*Triglochin striata* Ruiz & Pav.		572	G501/20	Varkensvlei

POACEAE	*Sporobolus virginicus* (L.) Kunth		570	G501/20	Varkensvlei
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum* (L.f.) Moline & H.P. Linder	565	G501/20	Varkensvlei
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		170	G403/01	Vermont Pan
CYPERACEAE	*Fuirena coerulescens* Steud.		171	G403/01	Vermont Pan
CYPERACEAE	*Scirpus maritimus* L.	*Bolboschoenus maritimus* (L.) Palla	172	G403/01	Vermont Pan
JUNCACEAE	*Juncus kraussii* Hochst.		174&176	G403/01	Vermont Pan
JUNCACEAE	*Juncus cf. kraussii*		173&175	G403/01	Vermont Pan
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum* (L.f.) Moline & H.P. Linder	178	G403/01	Vermont Pan
APONOGETONACEAE	*Aponogeton distachyos* L. f.		161	H101/05	Verrekyker
CYPERACEAE	*Cyperus fastigiatus* Rottb.		156	H101/05	Verrekyker
CYPERACEAE	*Schoenoplectus sp.*		155	H101/05	Verrekyker
JUNCACEAE	*Prionium serratum* (L.f.) Drege ex E. Mey.		165	H101/05	Verrekyker
JUNCACEAE	*Juncus effusus* L.		157	H101/05	Verrekyker
NYMPHAECEAE	*Nymphaea capensis* Thunb.		159	H101/05	Verrekyker
POACEAE	*Phragmites australis* (Cav.) Steud.		154	H101/05	Verrekyker
POLYGONACEAE	*Polygonum sp C*		160	H101/05	Verrekyker
POLYGONACEAE	*Polygonum sp D*		163	H101/05	Verrekyker
TYPHACEAE	*Typha capensis* (Rohrb.) N.E. Br.		164	H101/05	Verrekyker

APONOGETONACEAE	*Aponogeton angustifolius* Ait.		563	G501/18	Wiesdrif
CHENOPODIACEAE	*Sarcocornia natalensis* (Burge ex Urg.-Sternb.) A.J. Scott		559	G501/18	Wiesdrif
JUNCACEAE	*Juncus kraussii* Hochst.		558	G501/18	Wiesdrif
JUNCAGINACEAE	*Triglochin bulbosa* L.		560	G501/18	Wiesdrif
POACEAE	*Sporobolus virginicus* (L.) Kunth		561	G501/18	Wiesdrif
RESTIONACEAE	*Chondropetalum tectorum* (L. f.) Raf	*Elegia tectorum* (L.f.) Moline & H.P. Linder	557	G501/18	Wiesdrif
ANACARDIACEAE	*Rhus lucida* L.	*Searsia lucida (*L.) F.A. Barkely	271	G203/13	Kenilworth Race Course

Appendix 3

Statistical analysis results of environmental variables for 1988/89 and 2012/13

Table : Test statistics of the DistLM, based on “Best” procedure and adjusted R^2 selection criterion of transformed environmental variables for wetland species composition for 1988/89 data.

DistLM ANOVA table of results

Variable	**SS**	**Pseudo-F**	***P*-value**	**Prop (%)**	**Res *df***
Cond (mS/m)	2659.5	0.732	0.763	4.97	14
Rainfall (mm)	2690.2	0.741	0.760	5.03	14
Alt (m)	3693.8	1.038	0.401	6.90	14
pH	4766.6	1.369	0.164	8.91	14

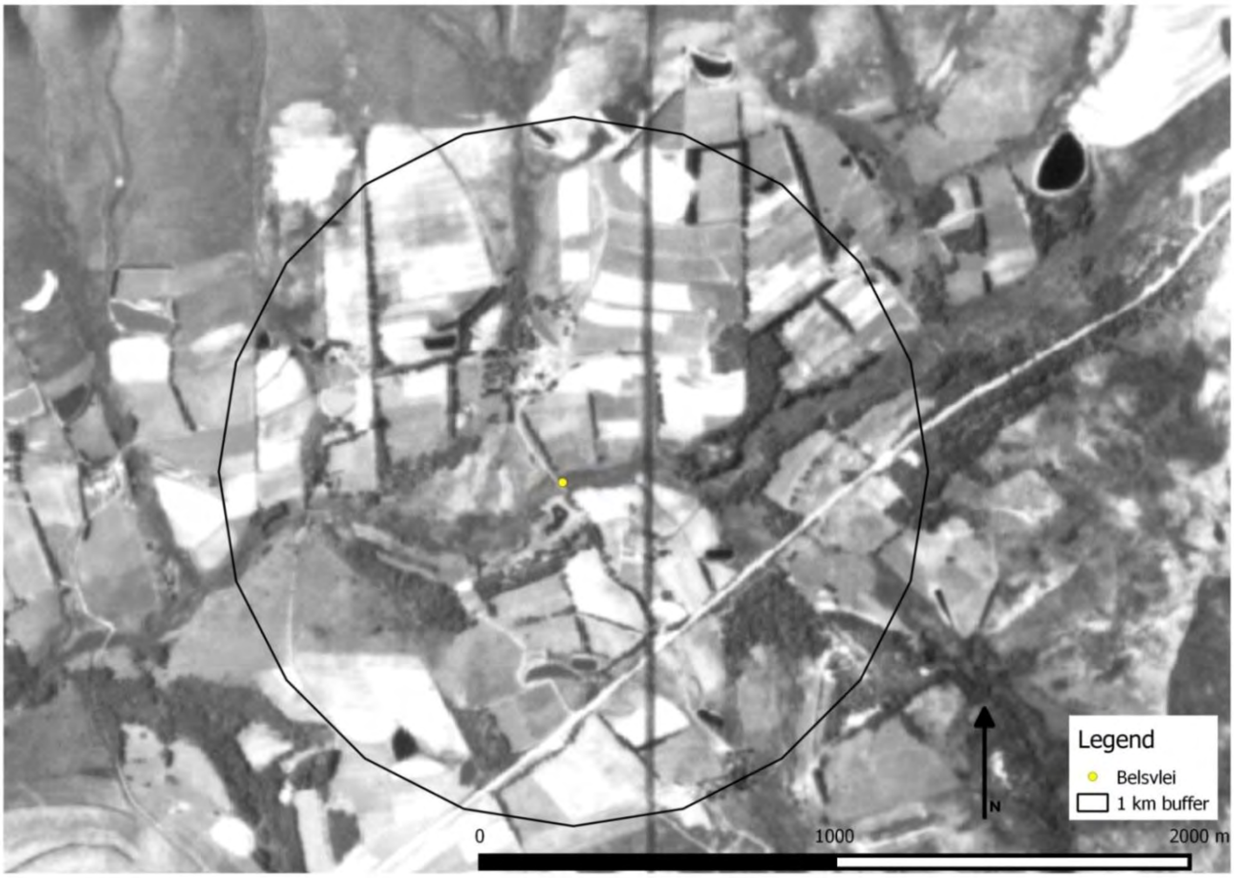
Table : Test statistics of the DistLM, based on “Best” procedure and and adjusted R^2 selection criterion of transformed environmental variables for wetland species composition for 2012/13 data.

DistLM ANOVA table of results

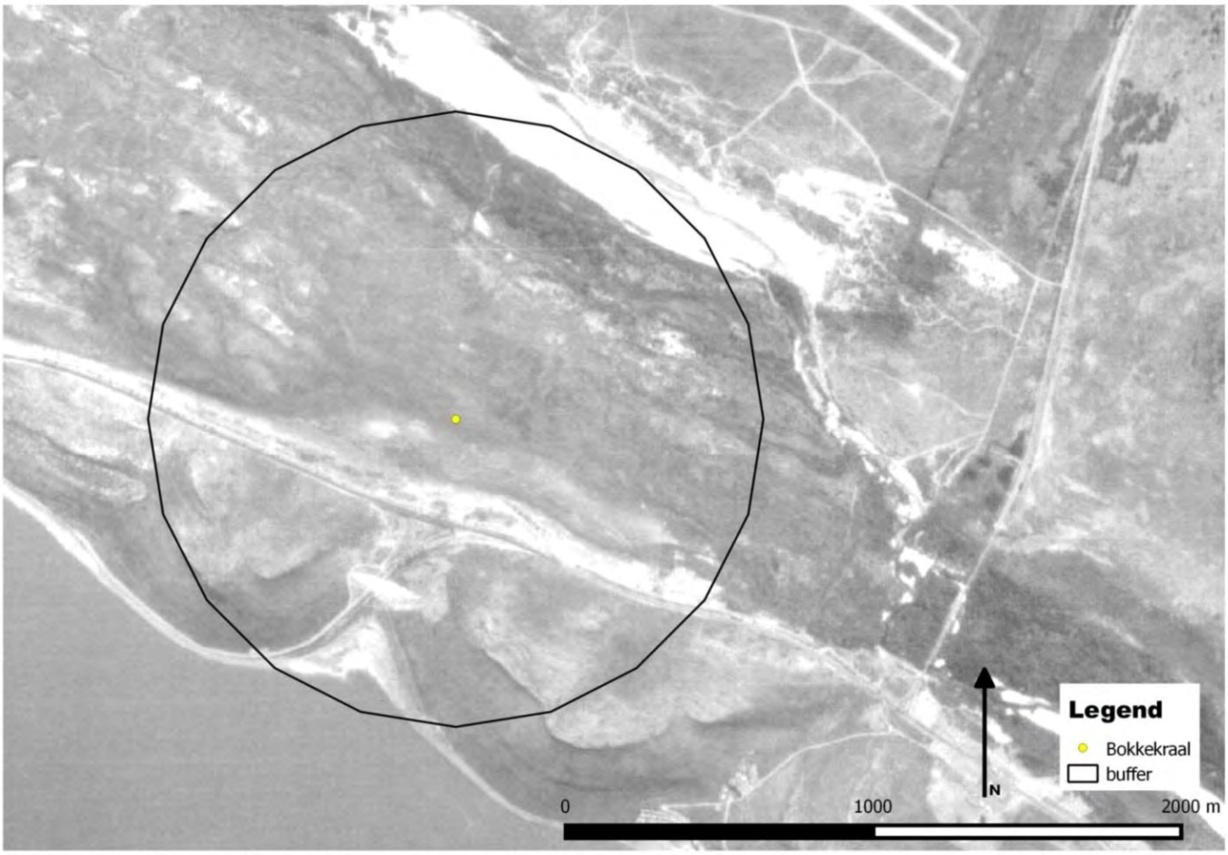
Variables	**SS**	**Pseudo-F**	***P*-value**	**Prop (%)**	**Res *df***
Alt (m)	3035.9	0.726	0.812	4.93	14
Cond (mS/m)	5256.9	1.306	0.108	8.53	14
pH	5403.1	1.346	0.142	8.77	14
Rainfall (mm)	5655.8	1.415	0.108	9.18	14

Appendix 4

Belsvlei



Bokkekraal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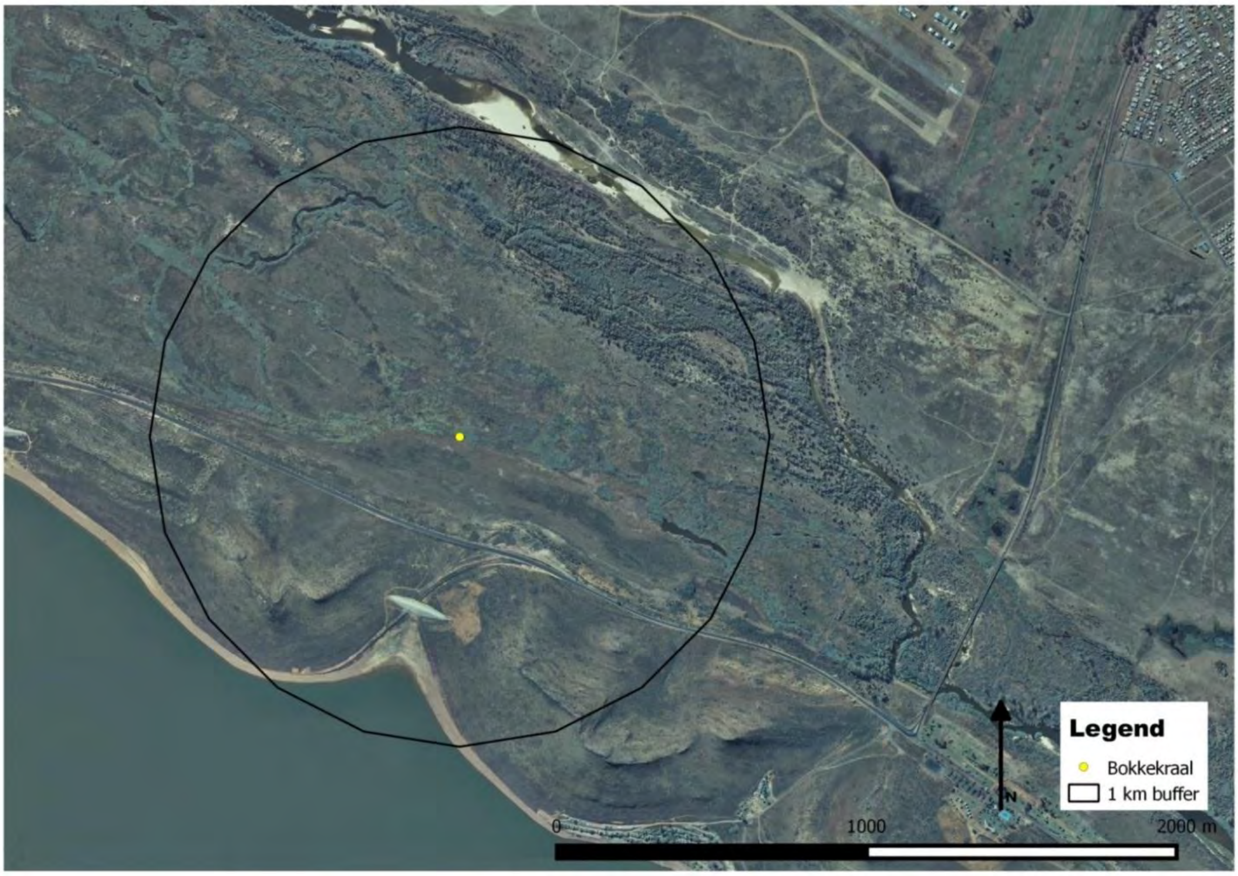
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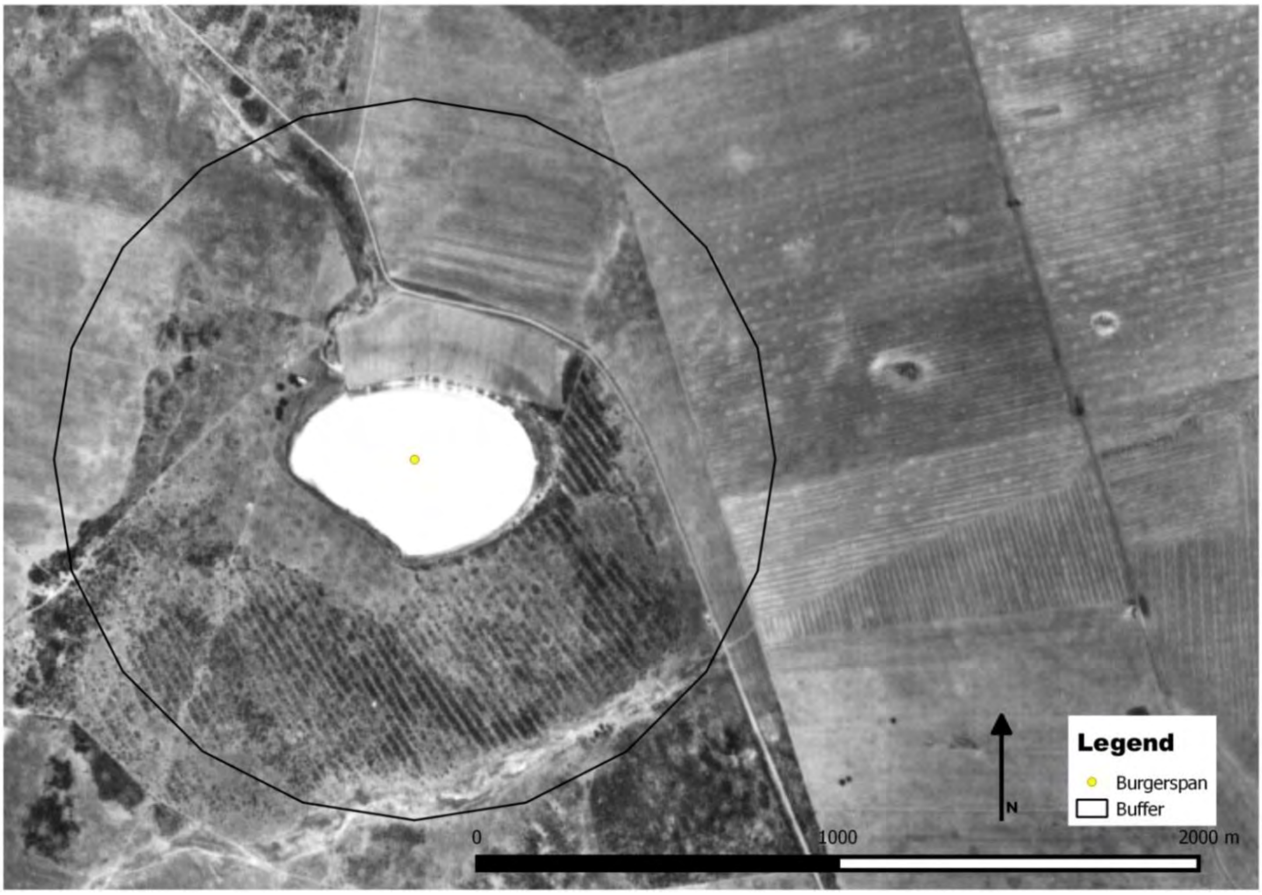
Burgerspan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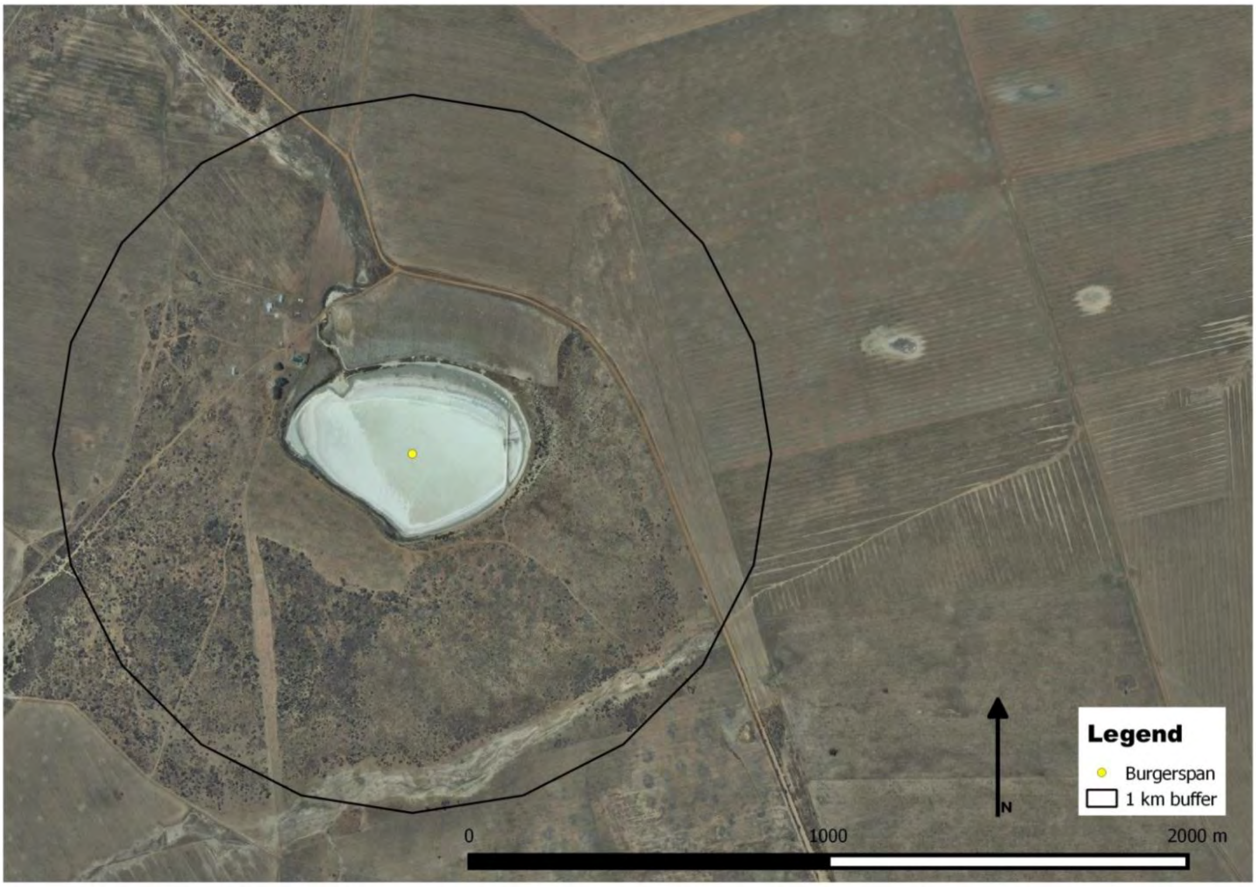
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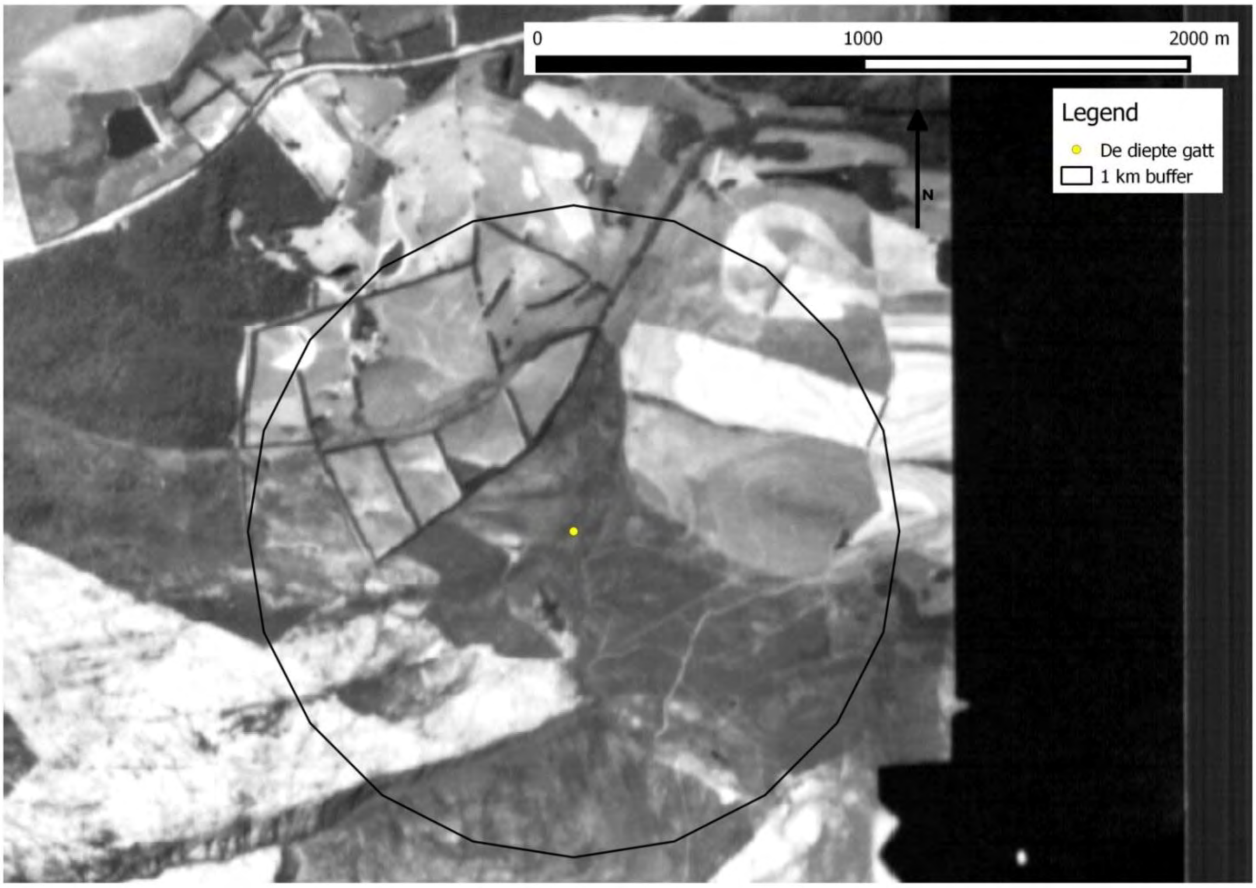
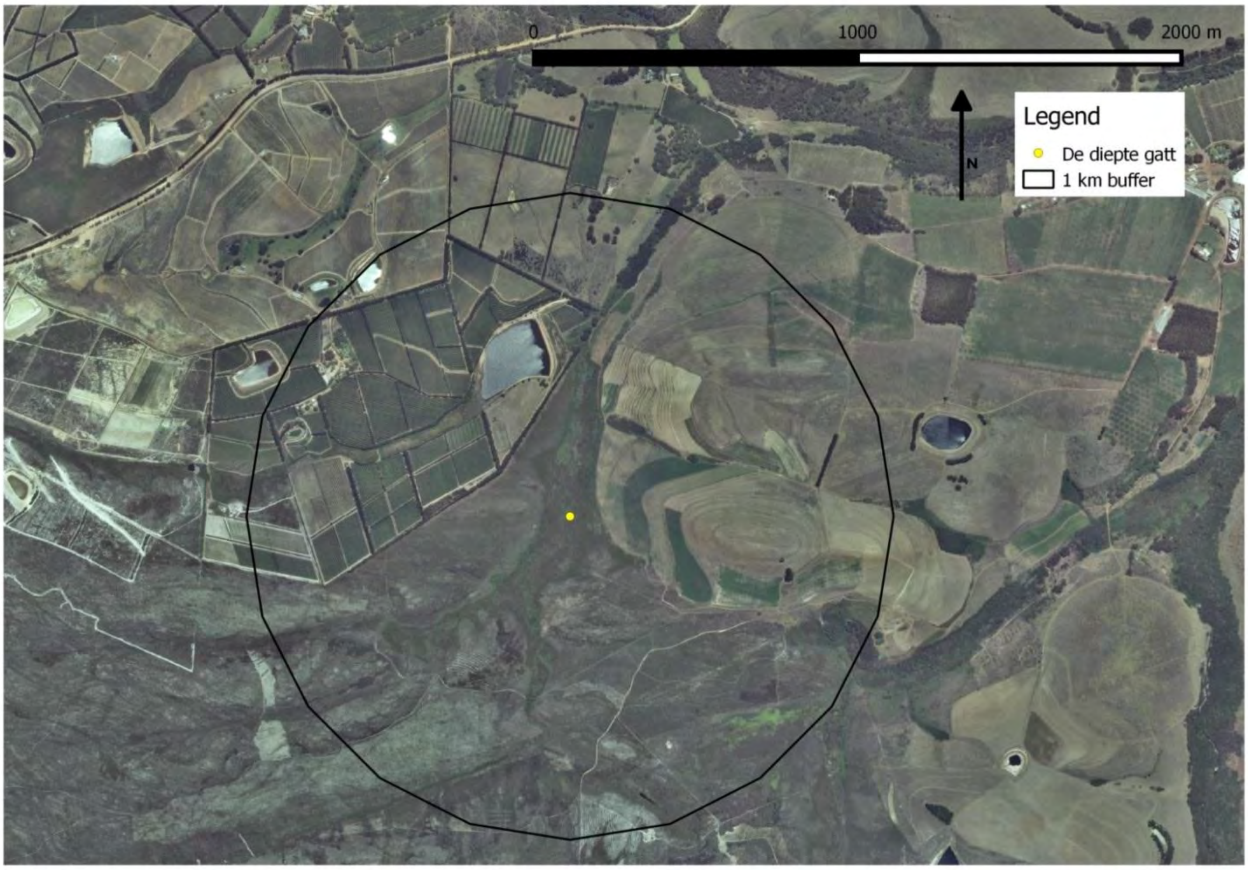
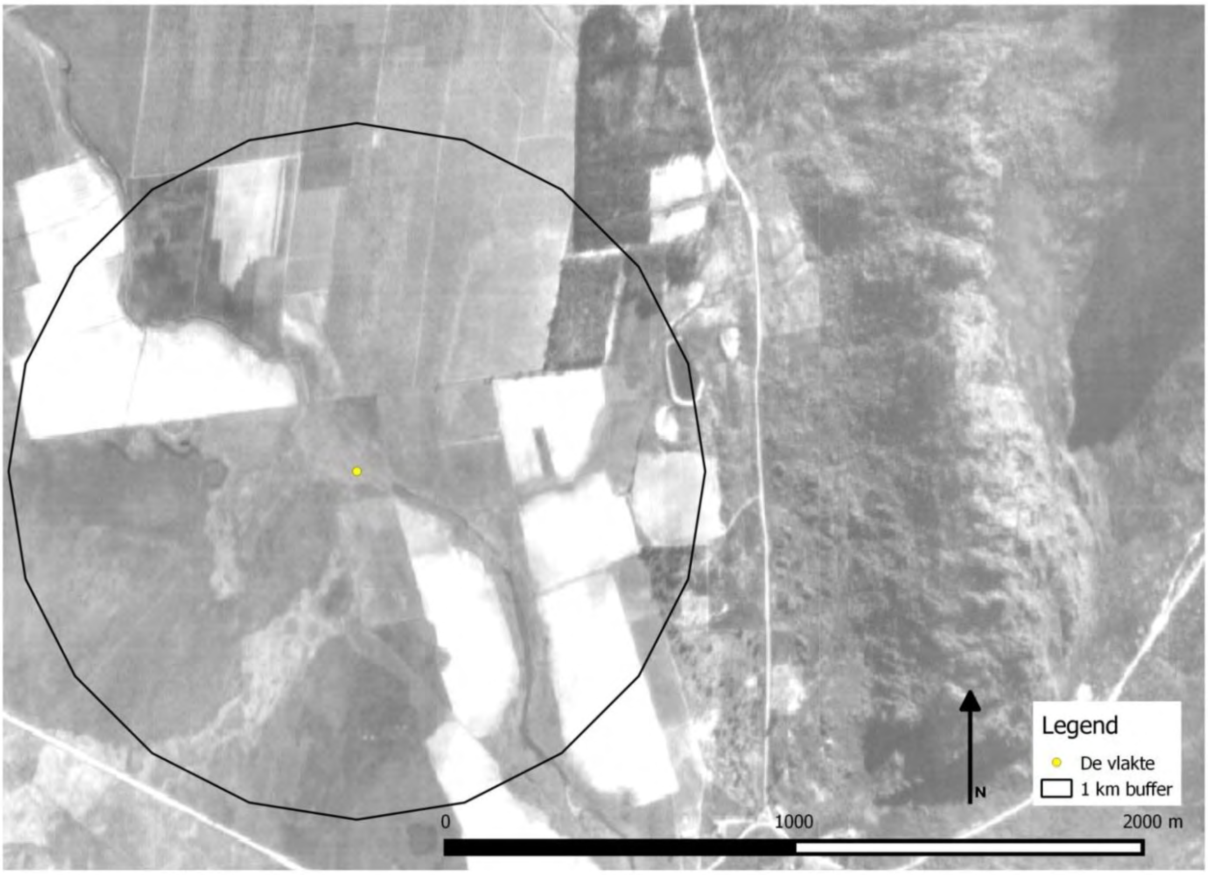
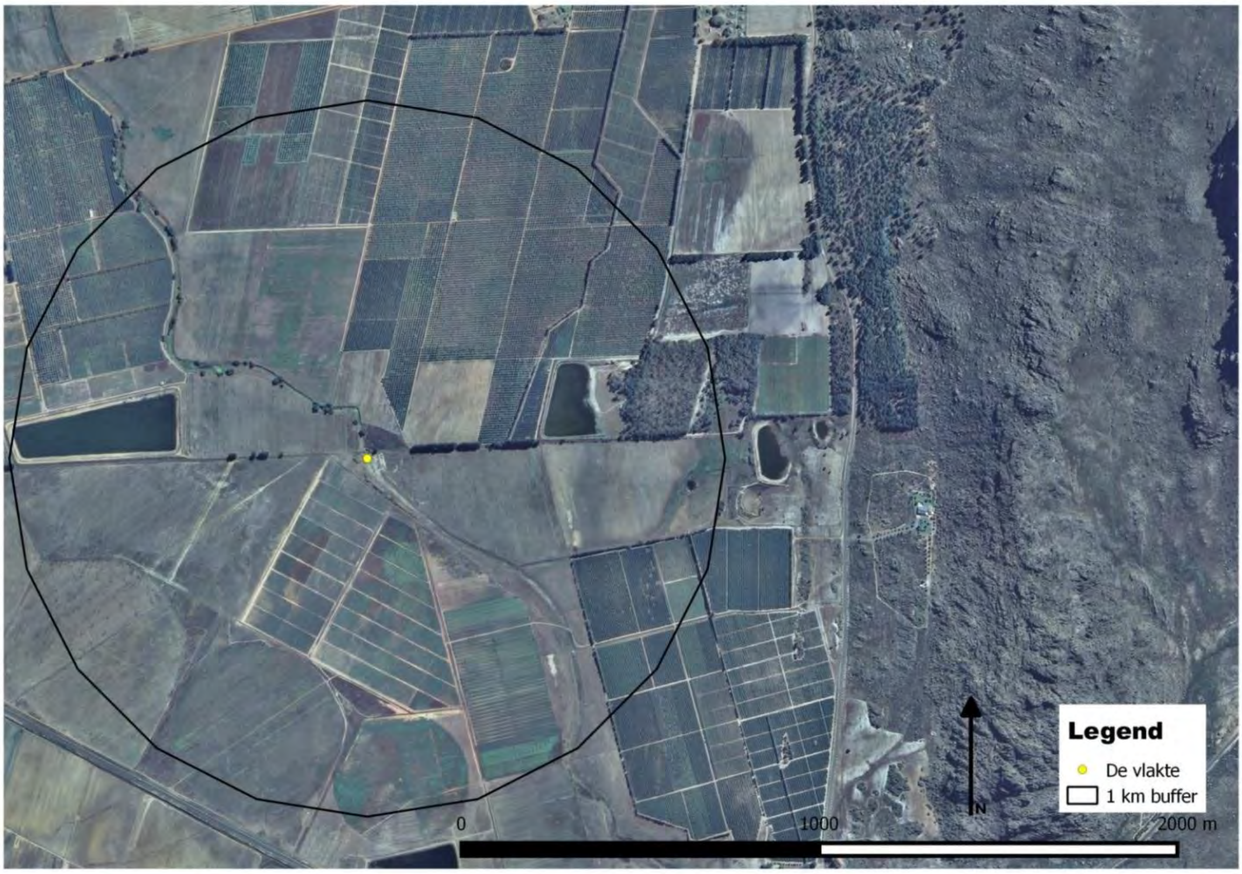
De diepte gatt



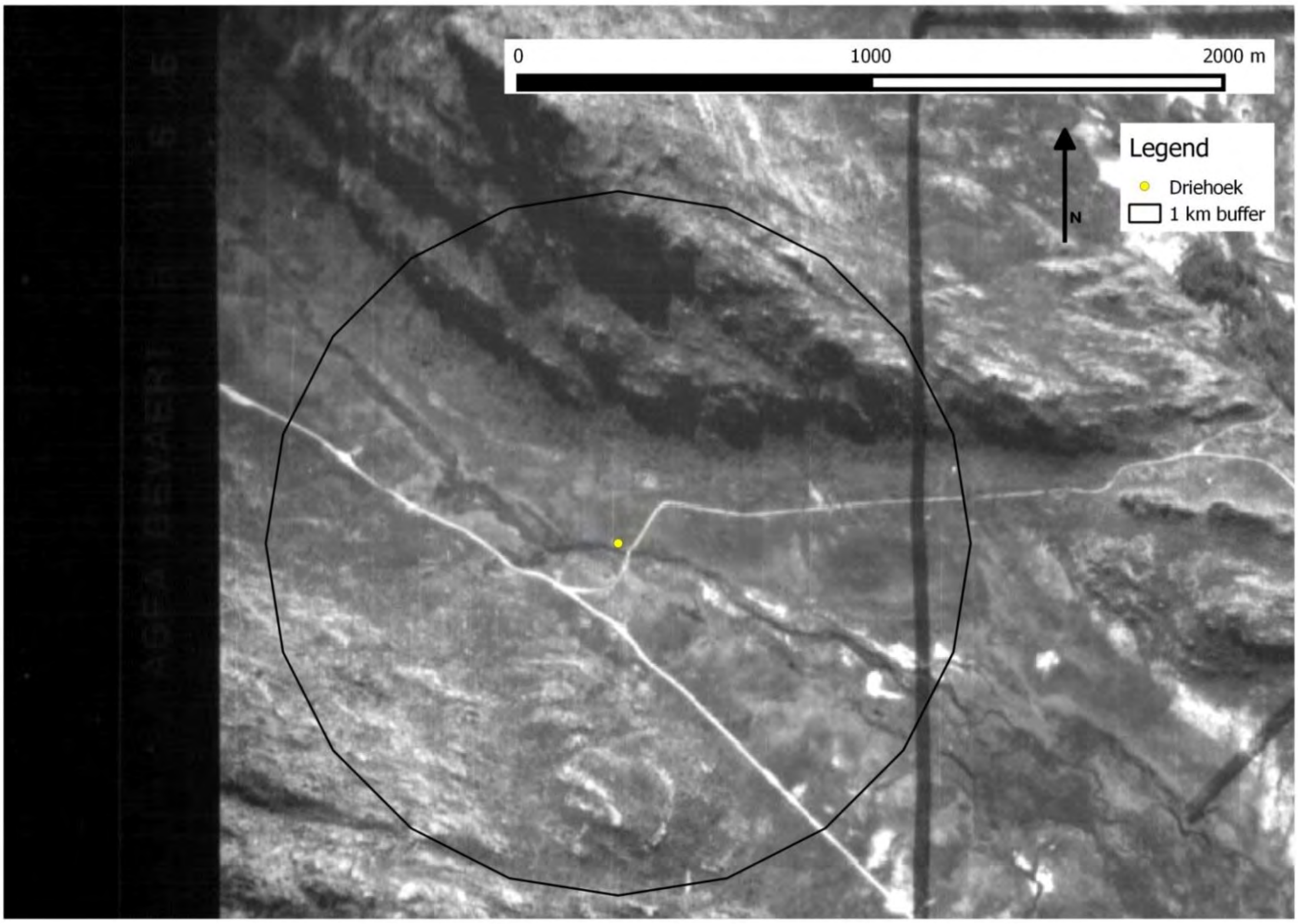


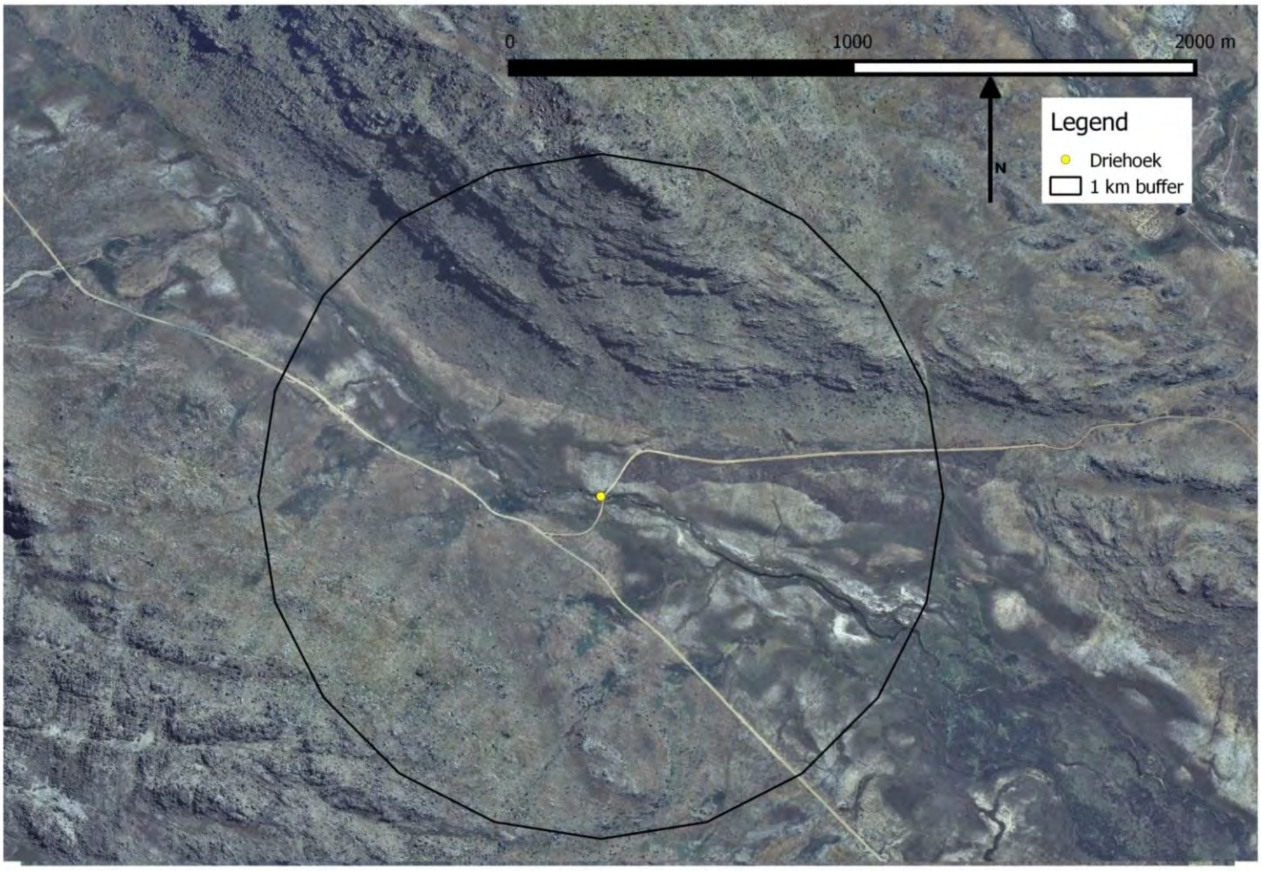
De valkte


Legend
De vlakte
1 km buffer
N
0
1000
2000 m

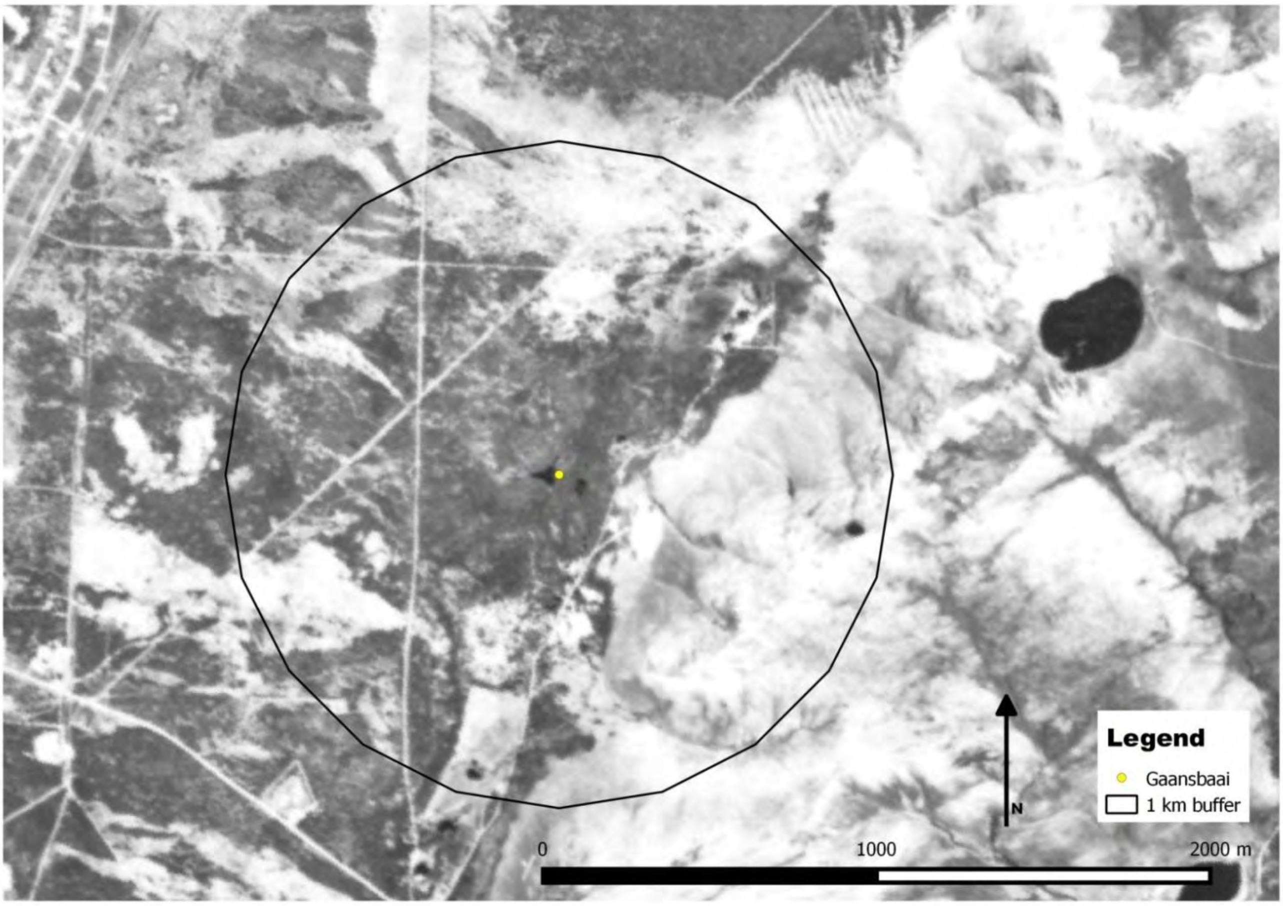

Legend
De vlakte
1 km buffer
N
0
1000
2000 m

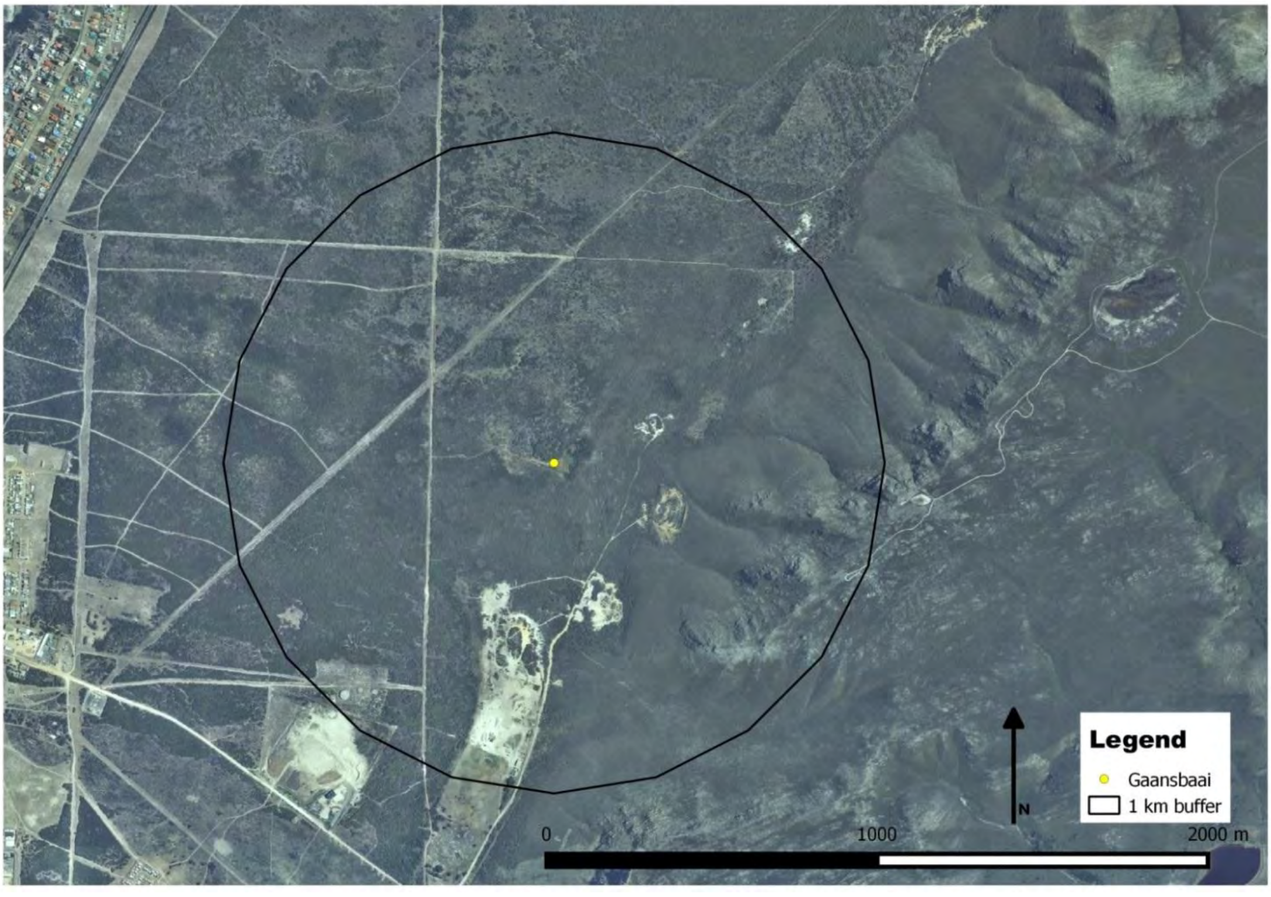
Driehoek


0
1000
2000 m
N
Legend
Driehoek
1 km buffer

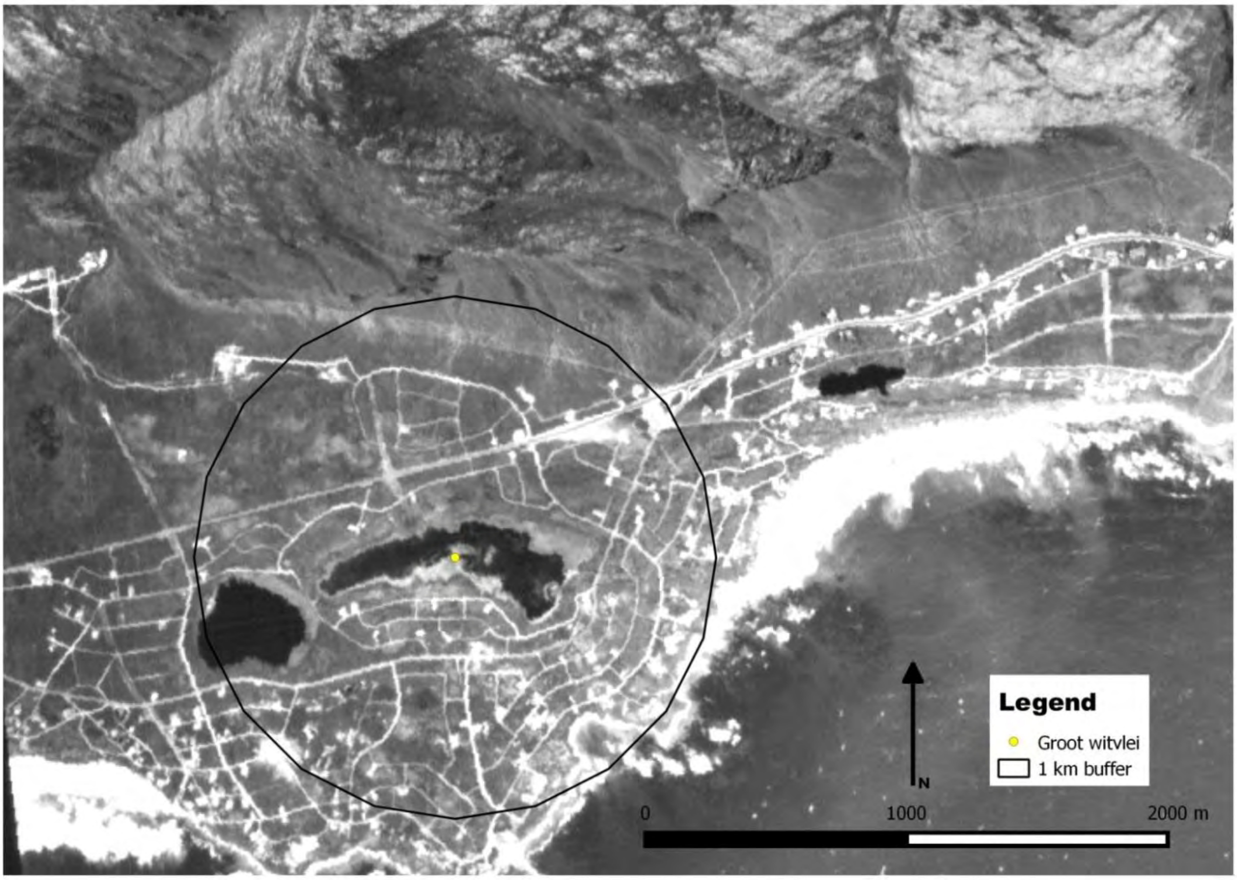

0
1000
2000 m
N
Legend
Driehoek
1 km buffer

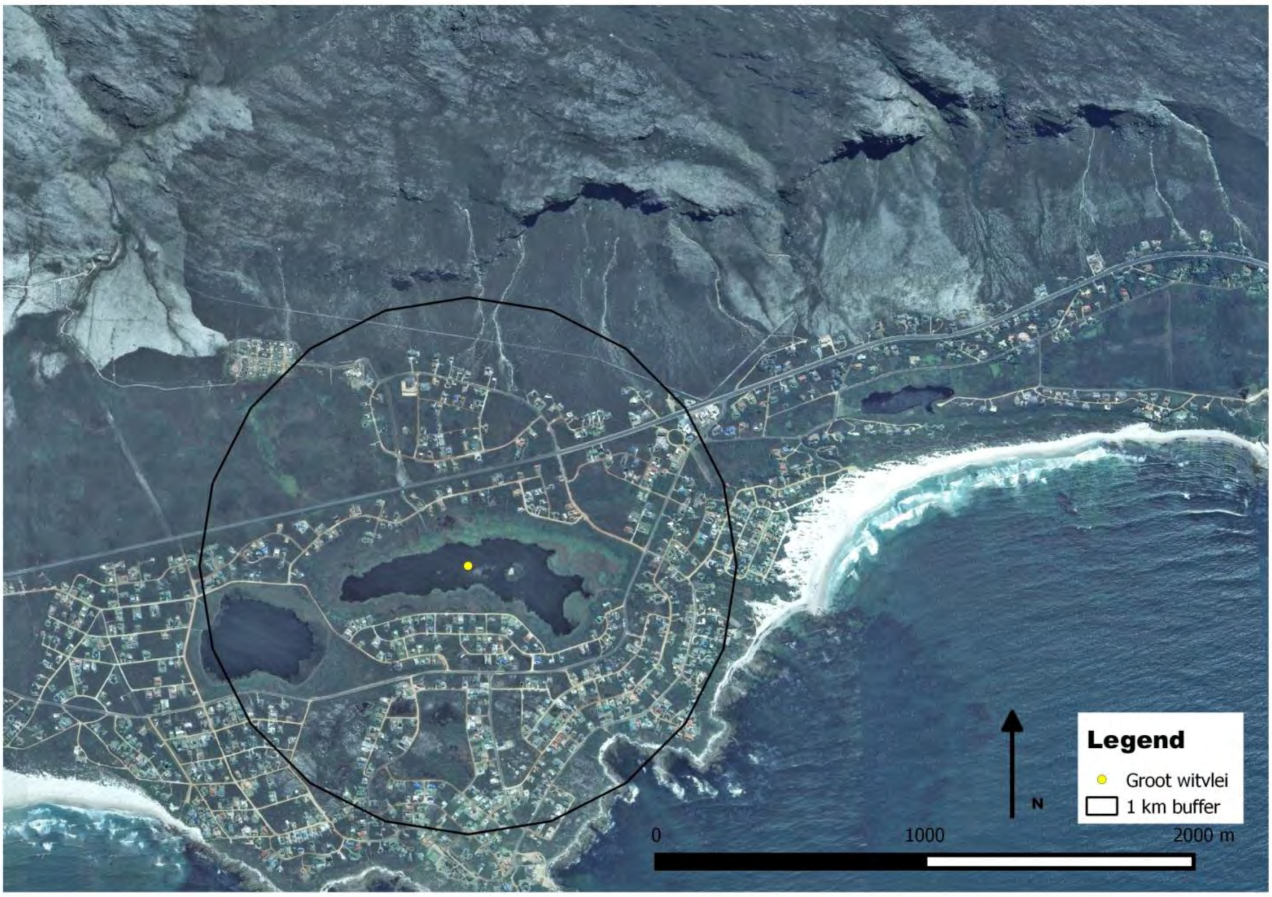
Gaansbaai


Legend
Gaansbaai
1 km buffer
N
0
1000
2000 m

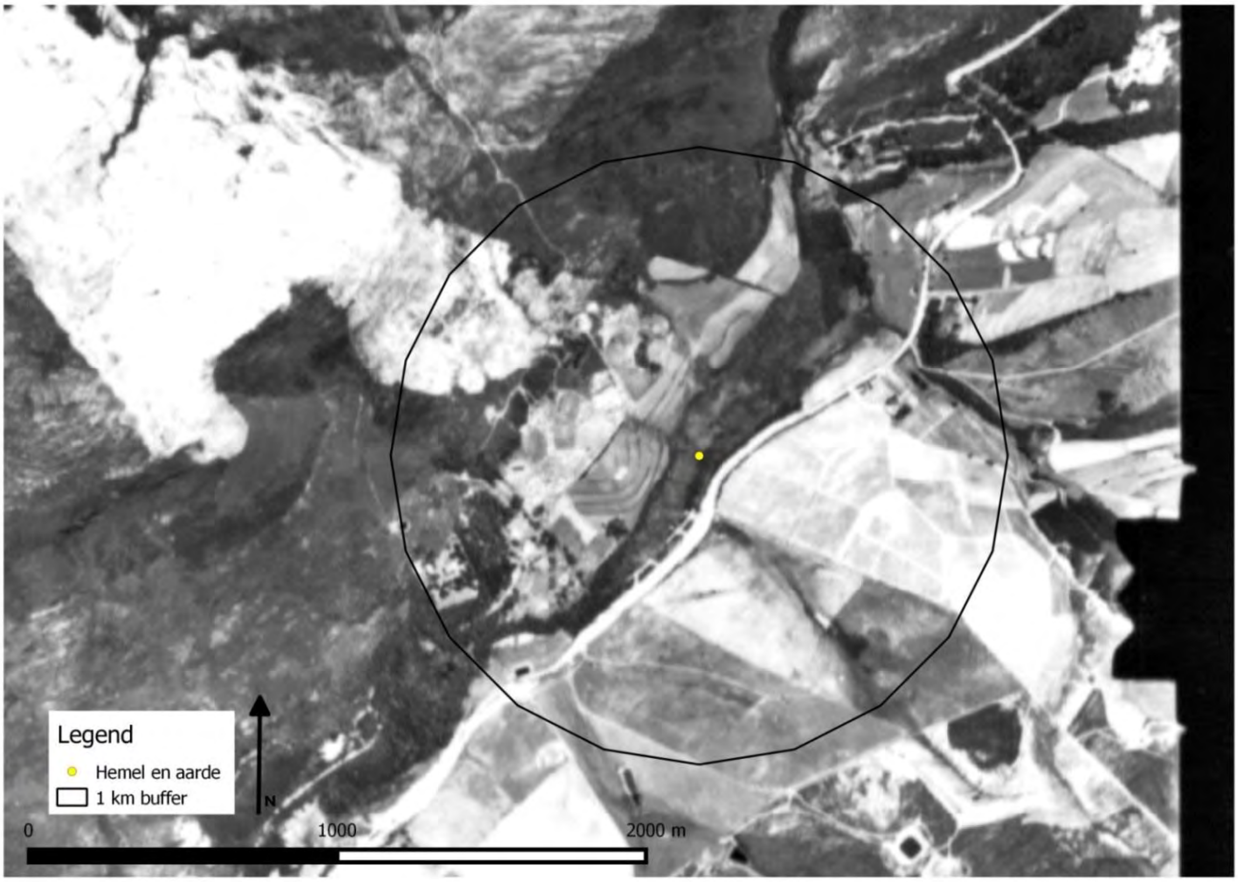

Legend
Gaansbaai
1 km buffer
N
0
1000
2000 m

Groot witvlei

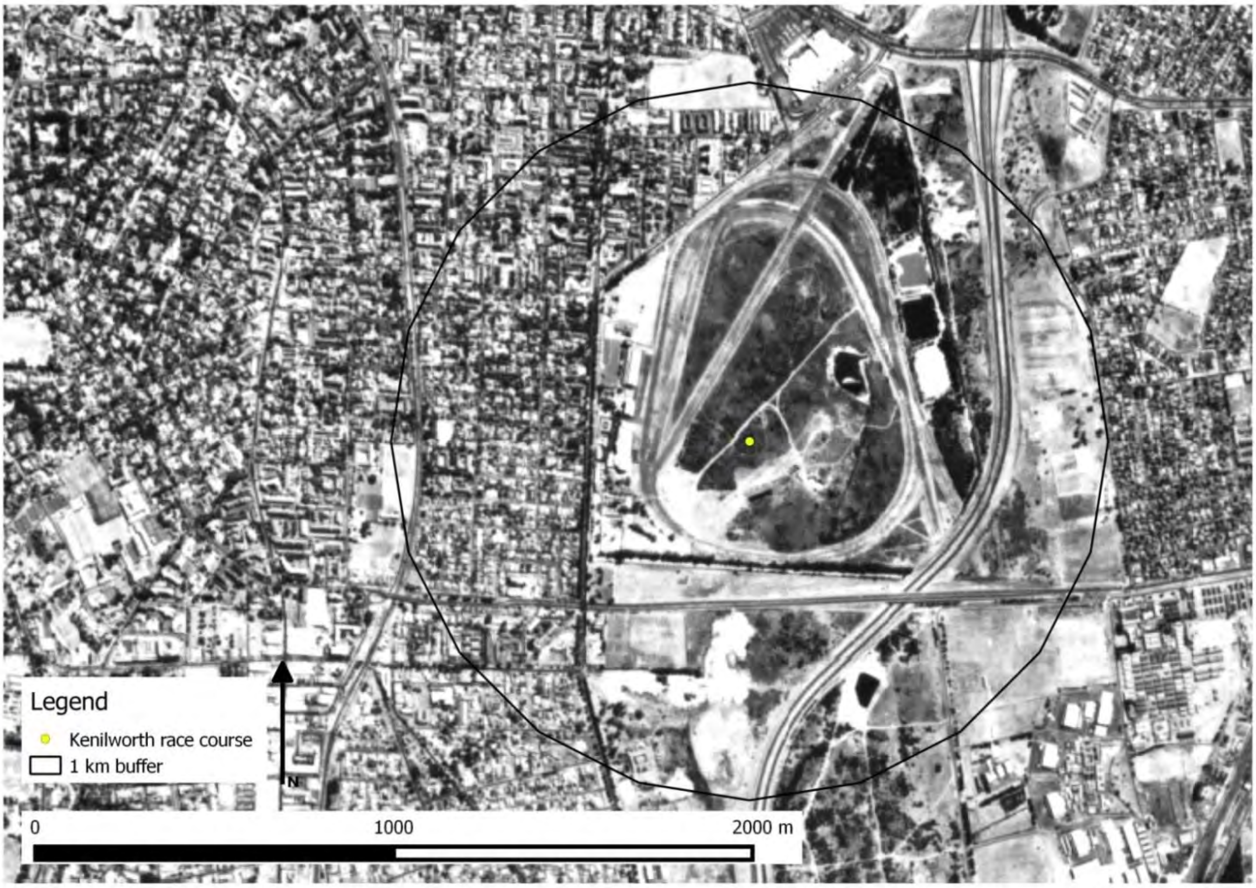




Hemel en aarde

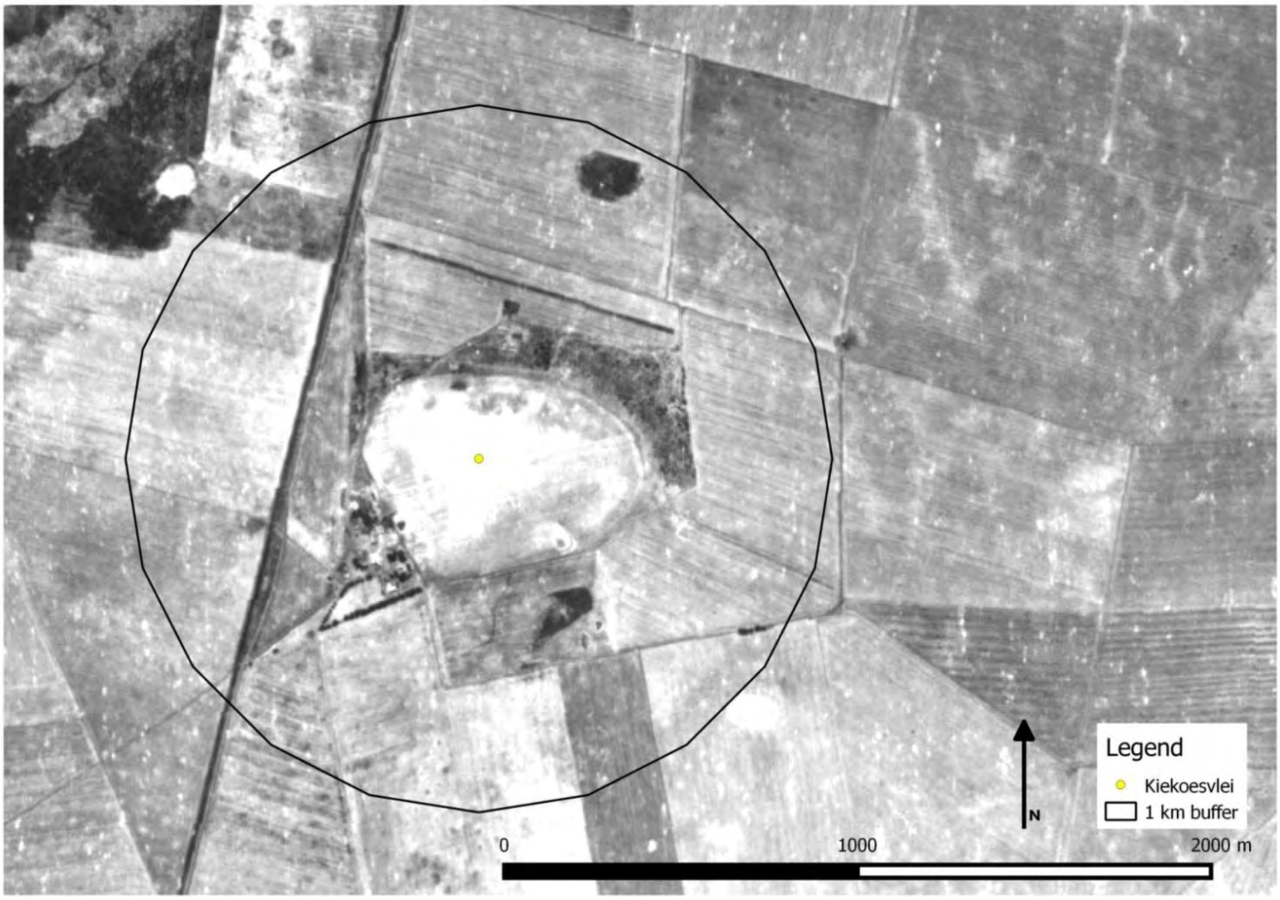


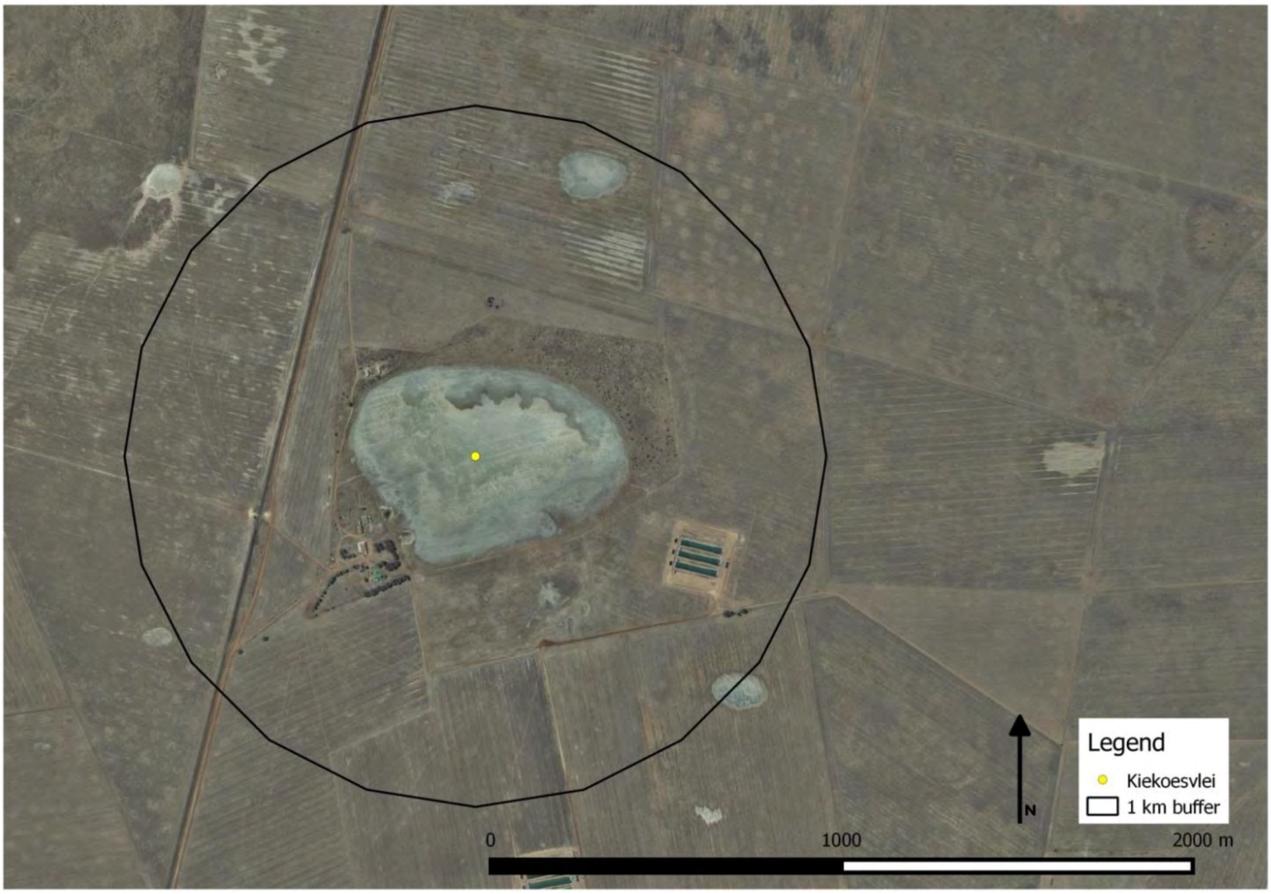
Kenilworth race course



Khayelitsha

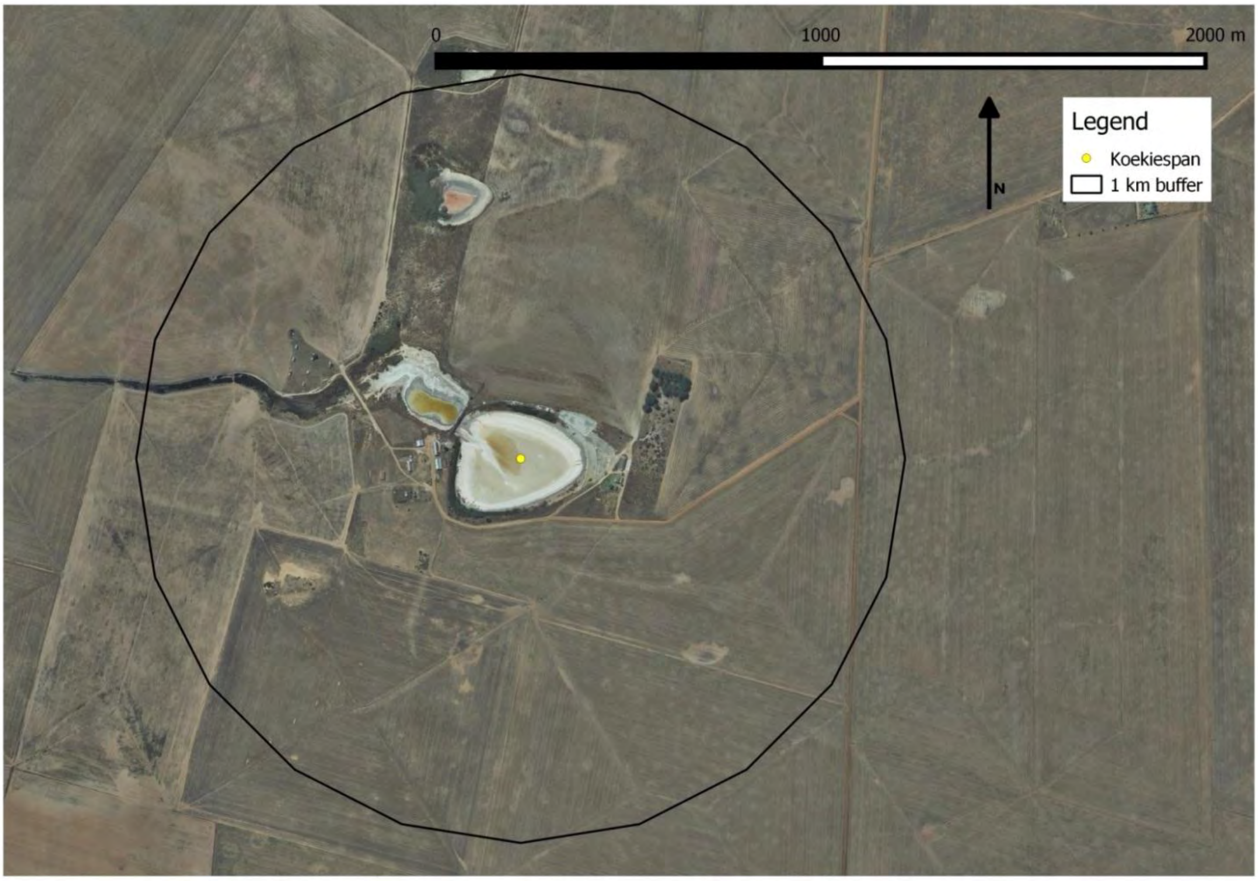
Keikoesvlei



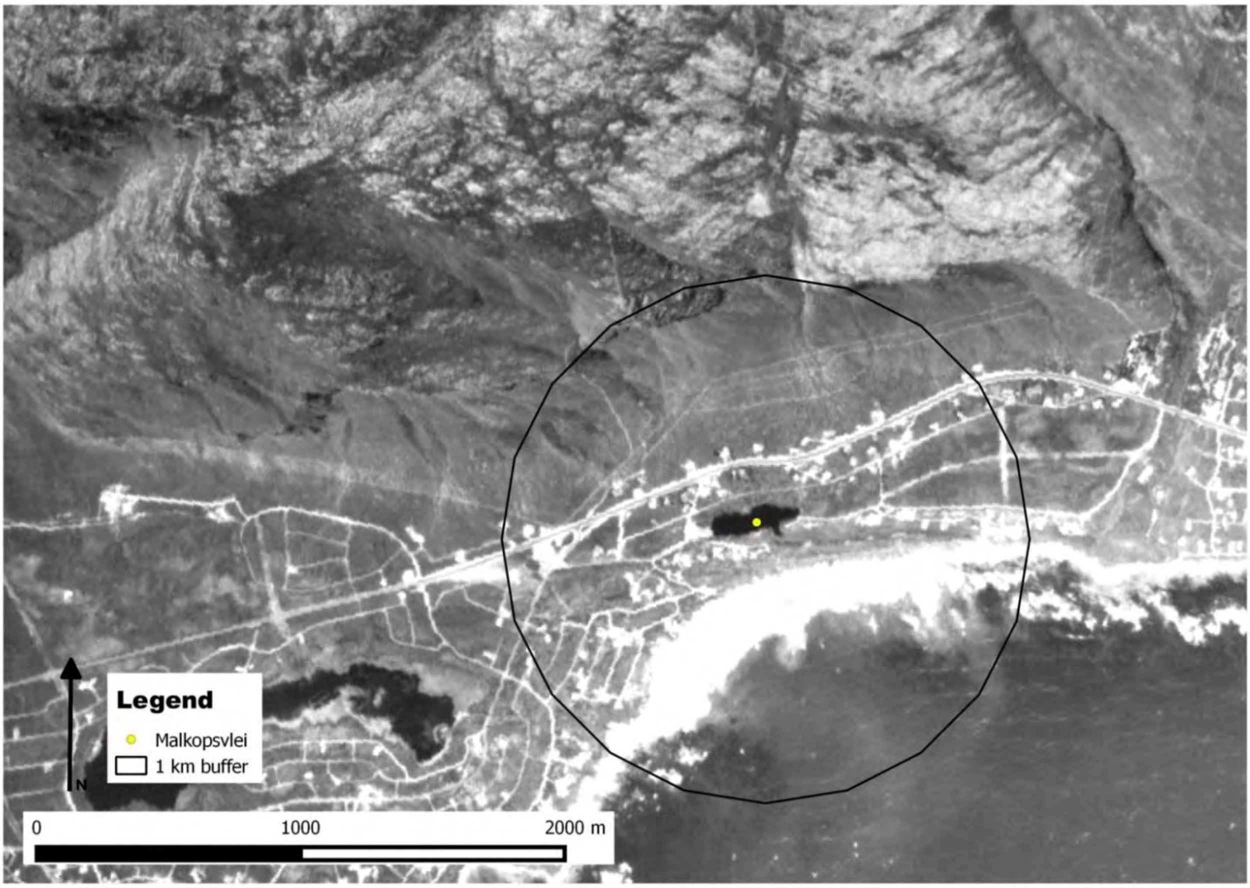


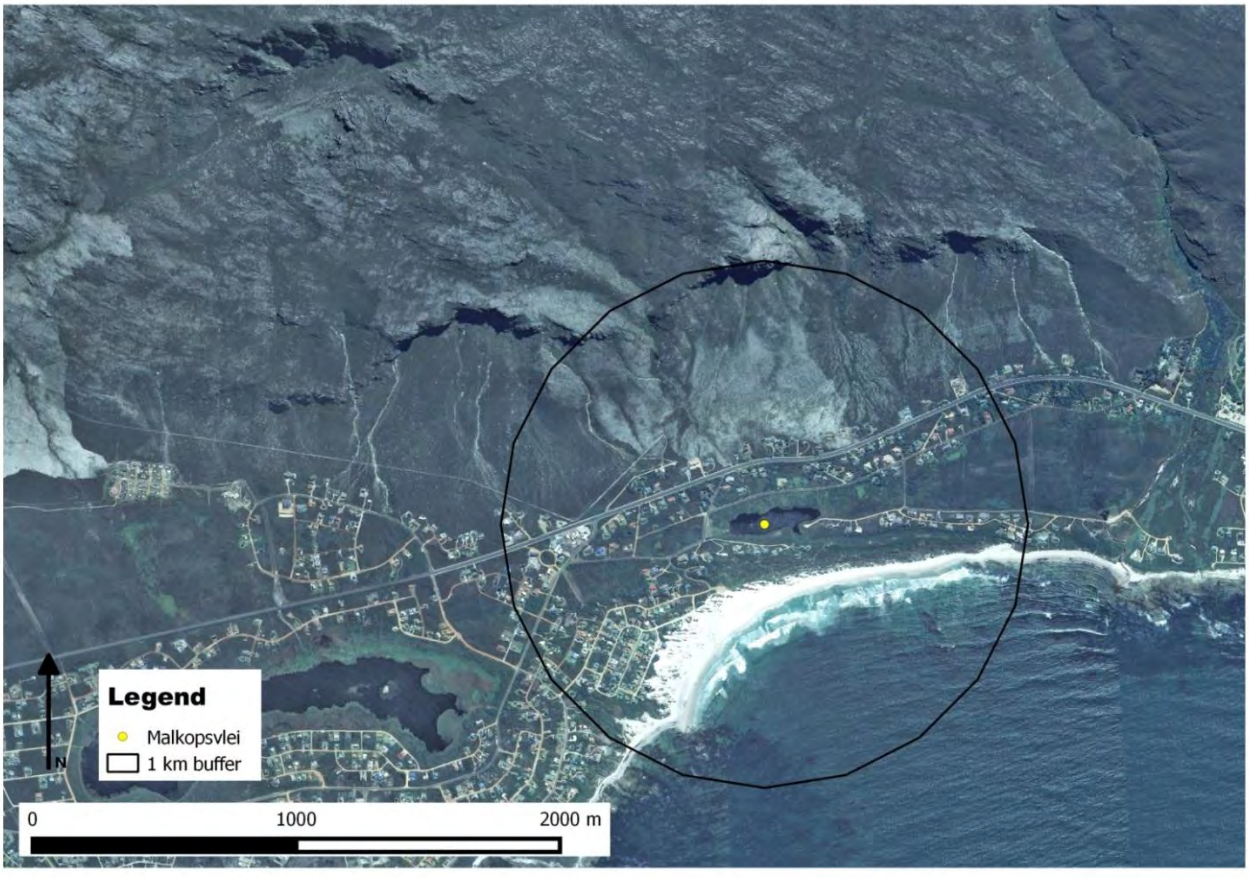
Koekiespan


0
1000
2000 m
N
Legend
Koekiespan
1 km buffer

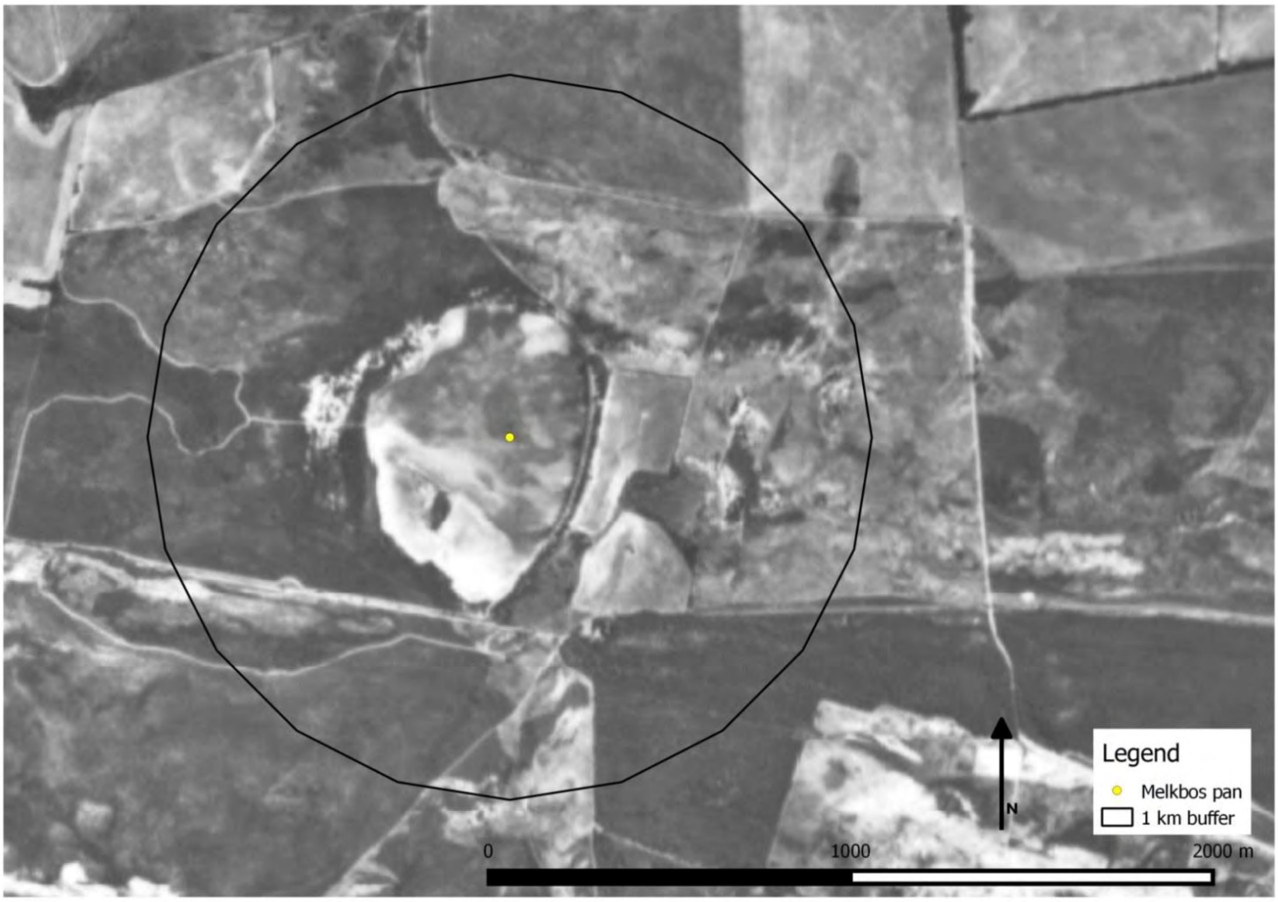

0
1000
2000 m
N
Legend
Koekiespan
1 km buffer

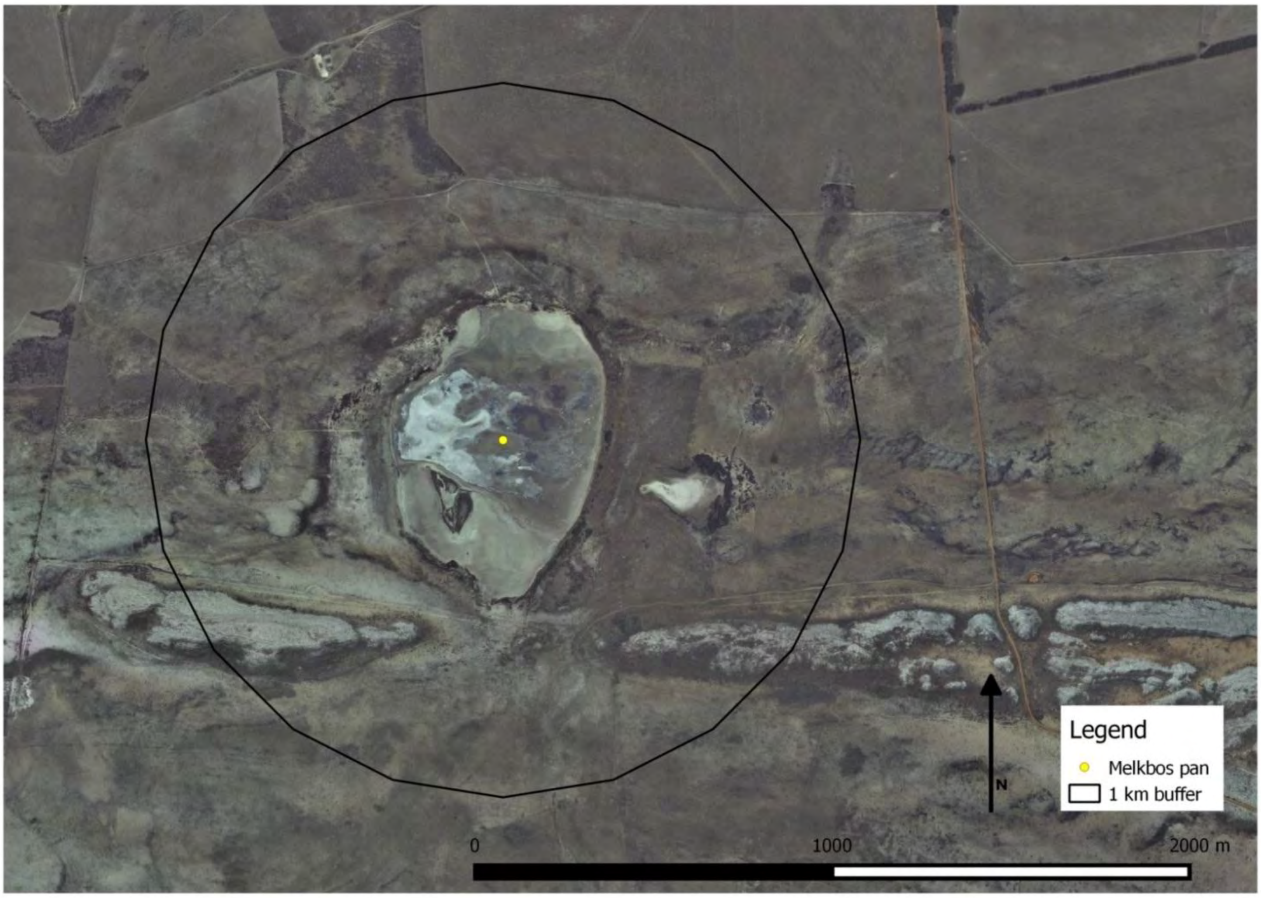
Malkopsvlei



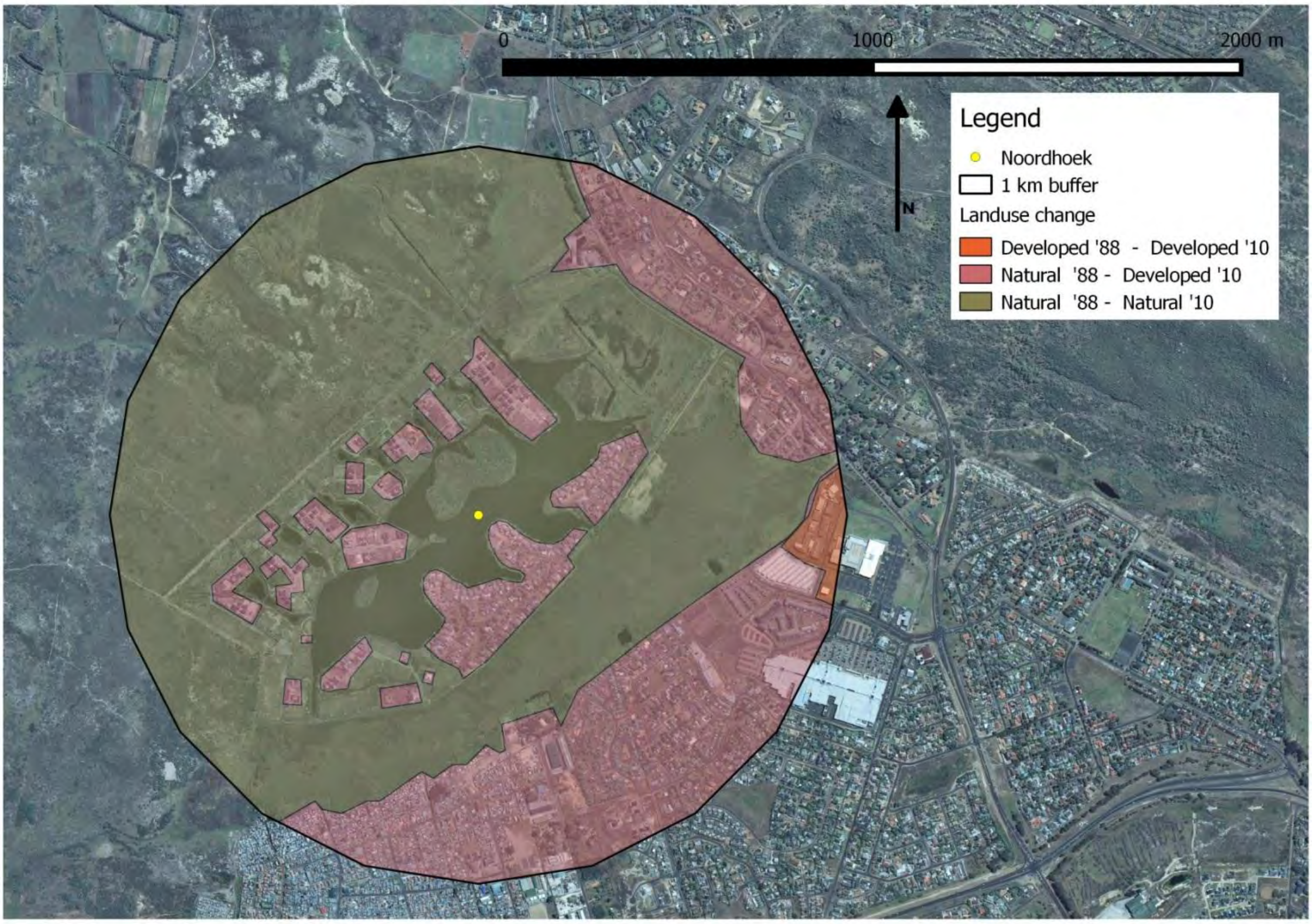


Melkbos pan


Legend
Melkbos pan
1 km buffer
N
0
1000
2000 m

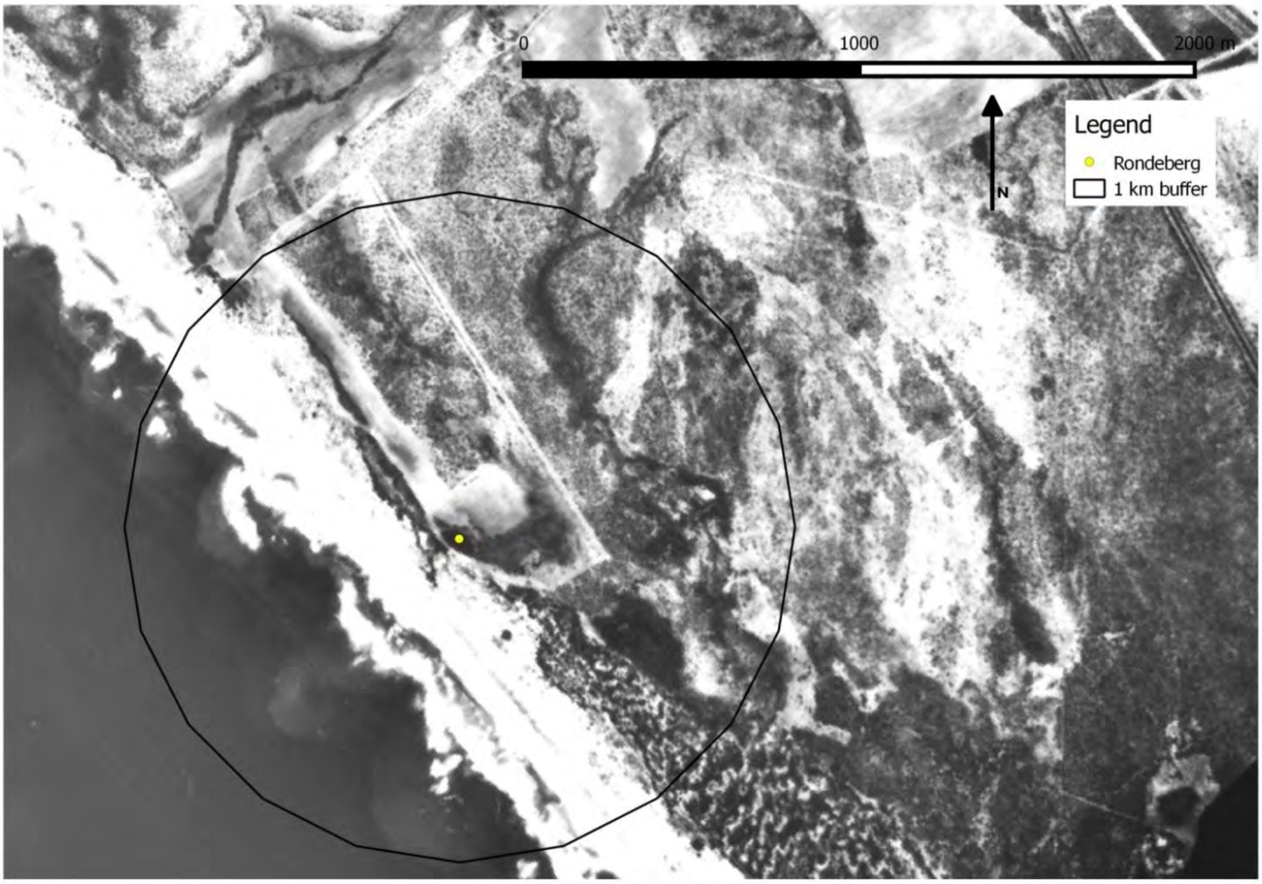

Legend
Melkbos pan
1 km buffer
N
0
1000
2000 m

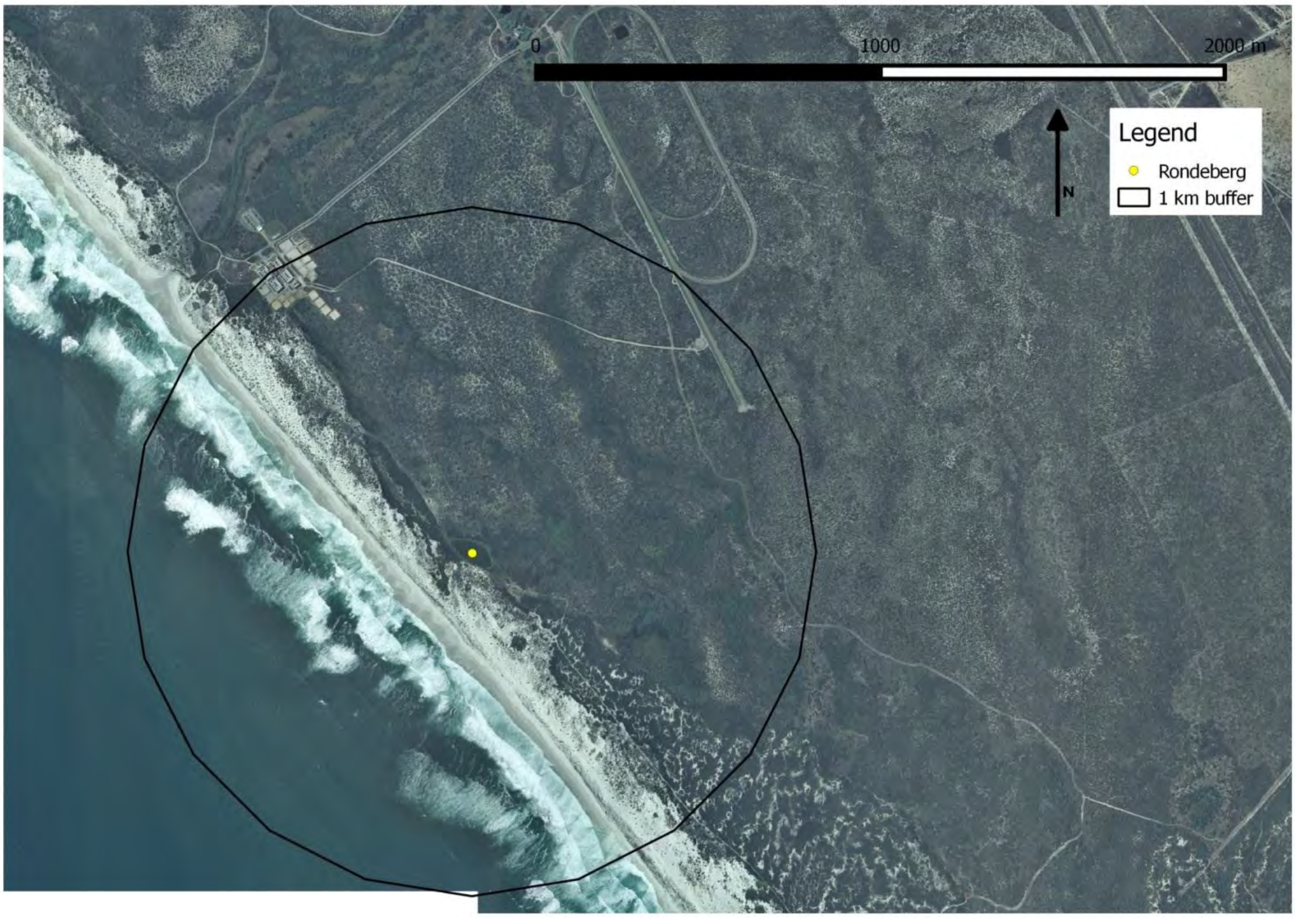
Noordhoek soutpan


0
1000
2000 m
Legend
Noordhoek
1 km buffer
Landuse change
Developed '88 - Developed '10
Natural '88 - Developed '10
Natural '88 - Natural '10
N

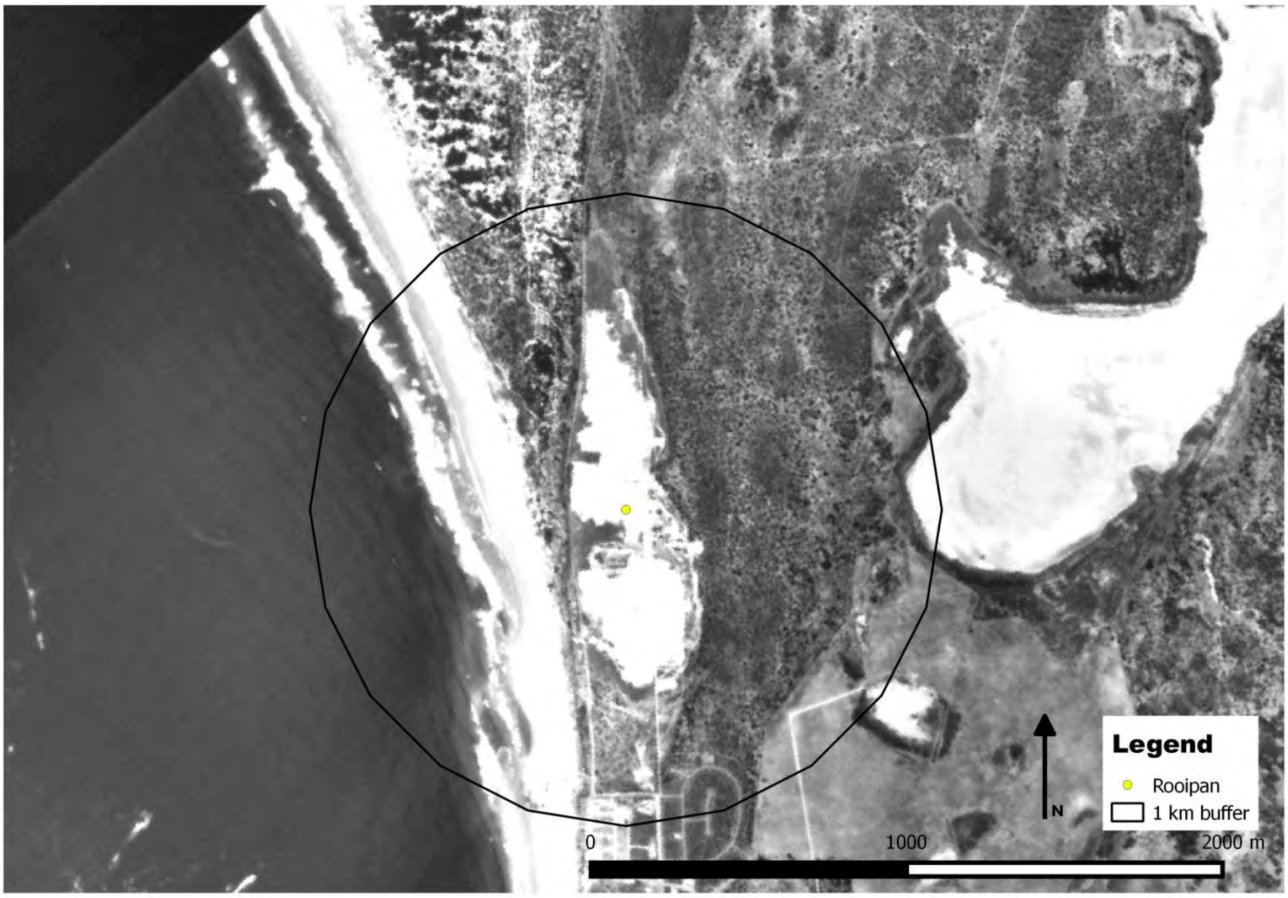
.

Rondeberg

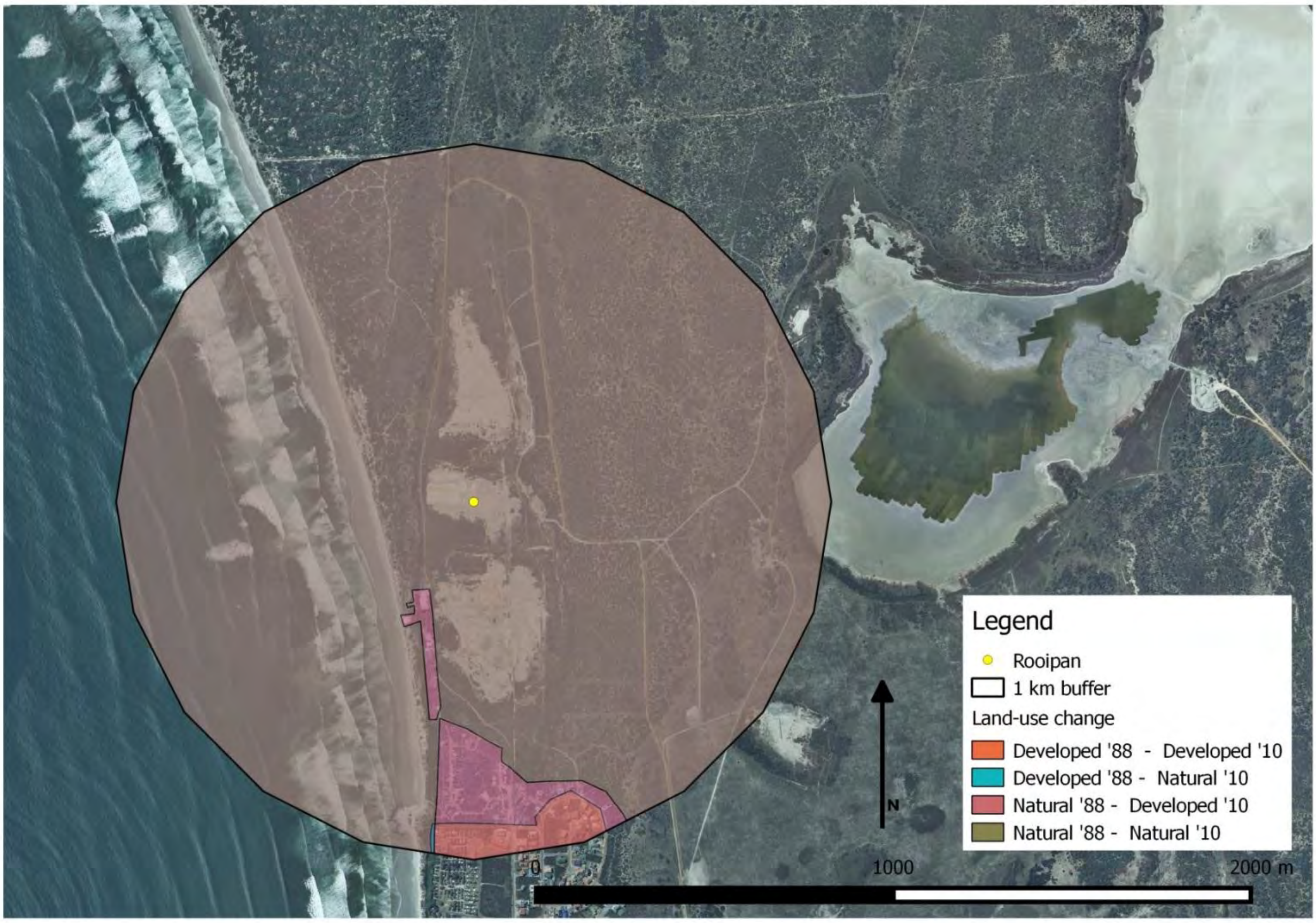

0
1000
2000 m
N
Legend
Rondeberg
1 km buffer


0
1000
2000 m
N
Legend
Rondeberg
1 km buffer

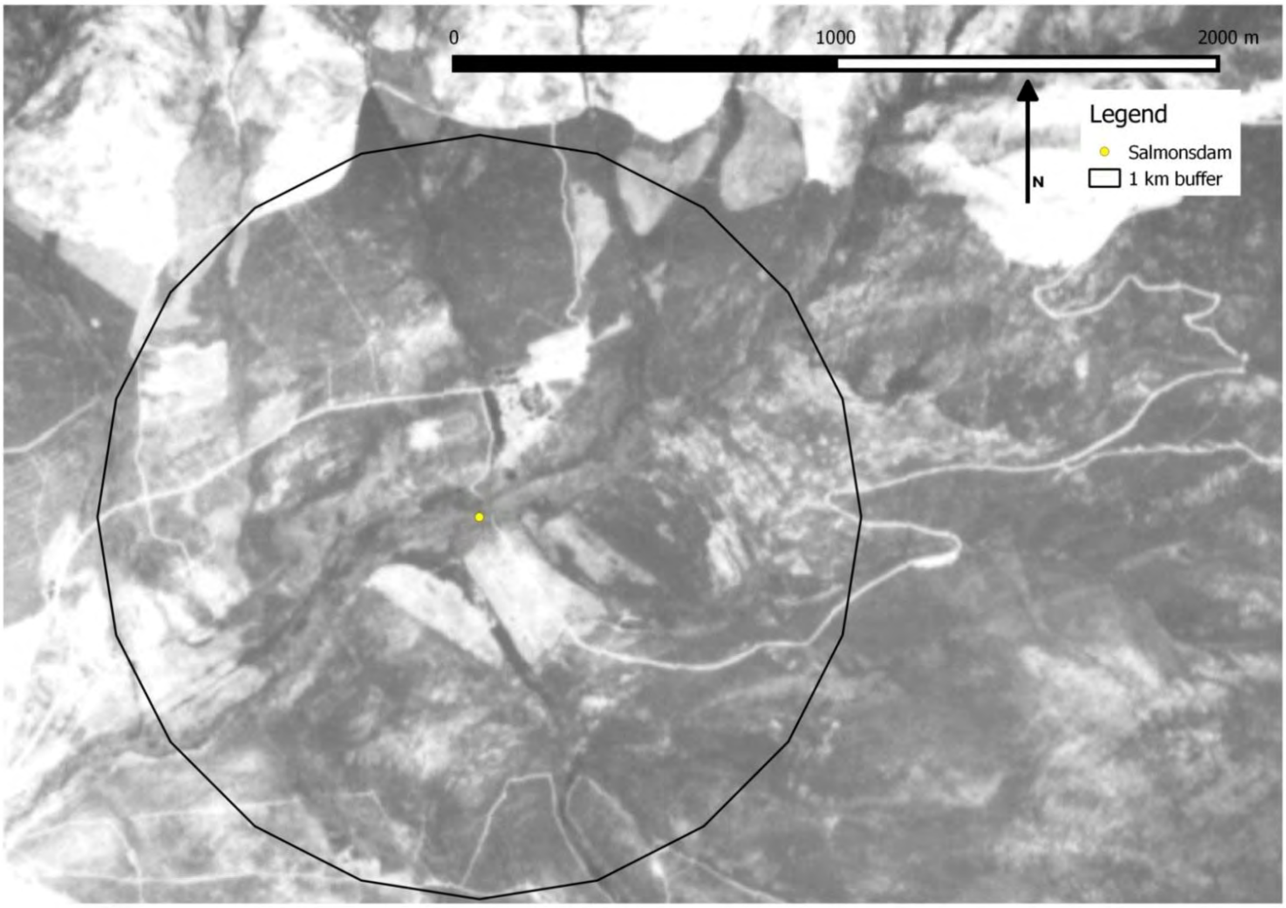
Rooipan

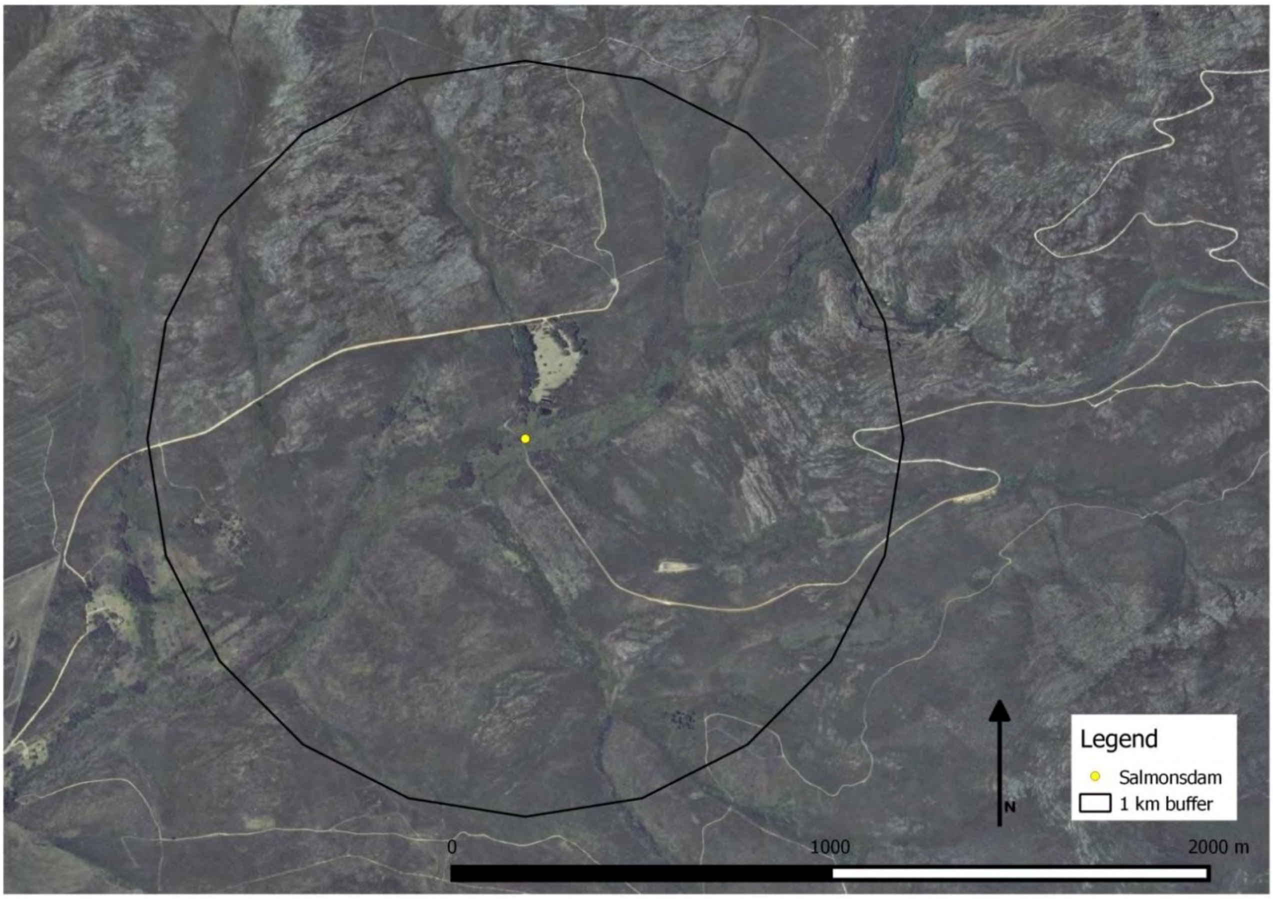

Legend
Rooipan
1 km buffer
N
0
1000
2000 m


Legend
Rooipan
1 km buffer
N
0
1000
2000 m

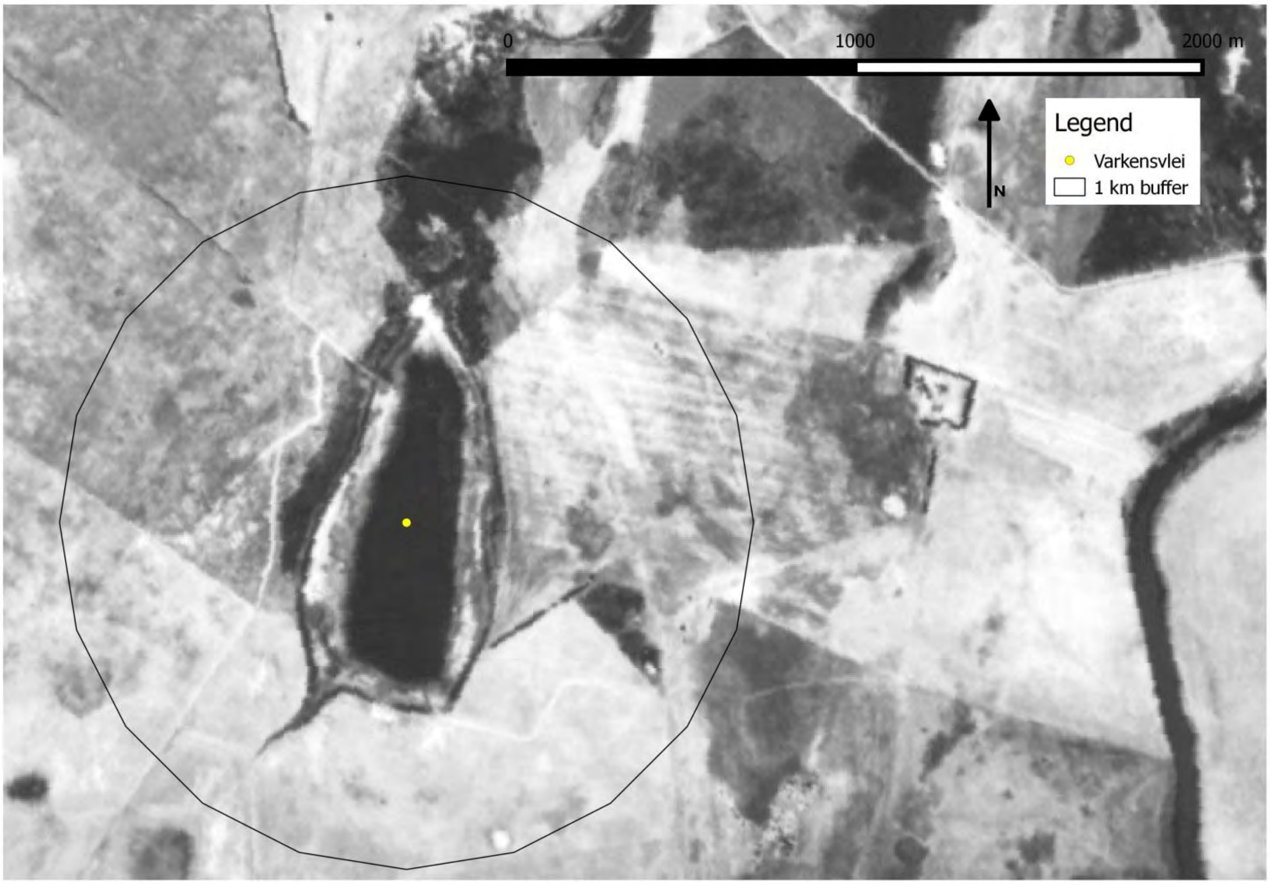

Legend
Rooipan
1 km buffer
Land-use change
Developed '88 - Developed '10
Developed '88 - Natural '10
Natural '88 - Developed '10
Natural '88 - Natural '10
N
0
1000
2000 m

Salmonsdam

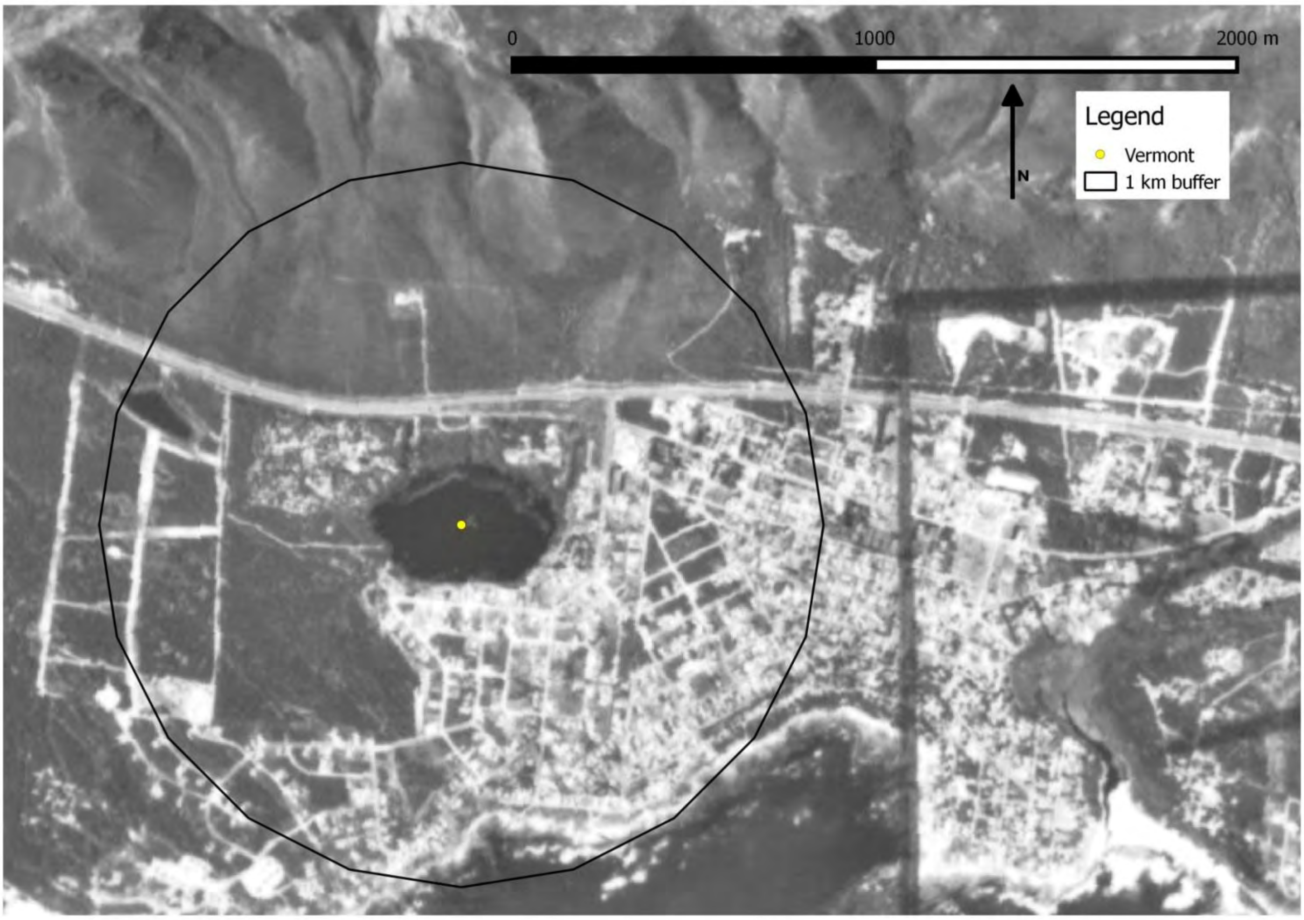

0
1000
2000 m
Legend
Salmonsdam
1 km buffer
N


Legend
Salmonsdam
1 km buffer
N
0
1000
2000 m

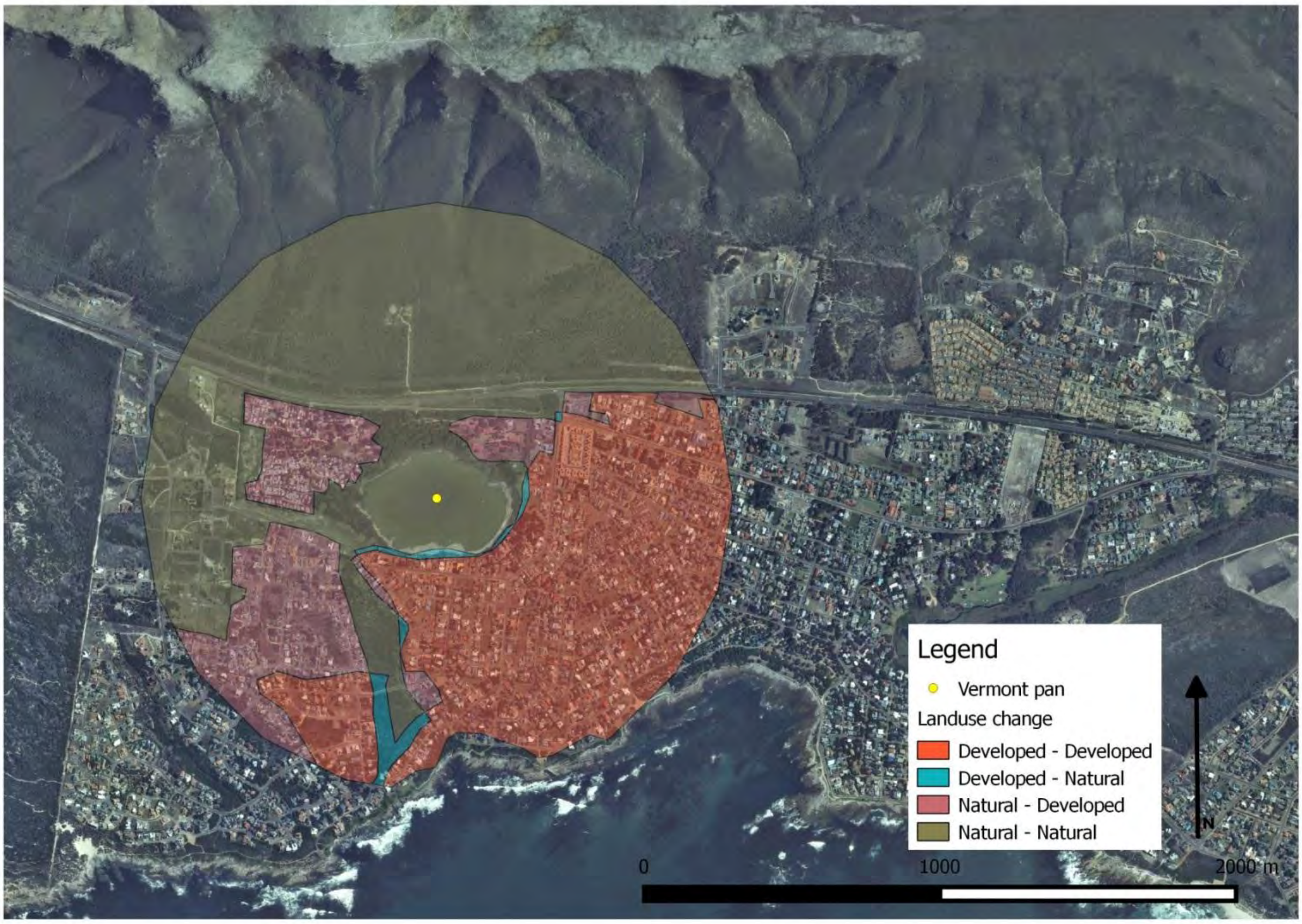
Varkensvlei



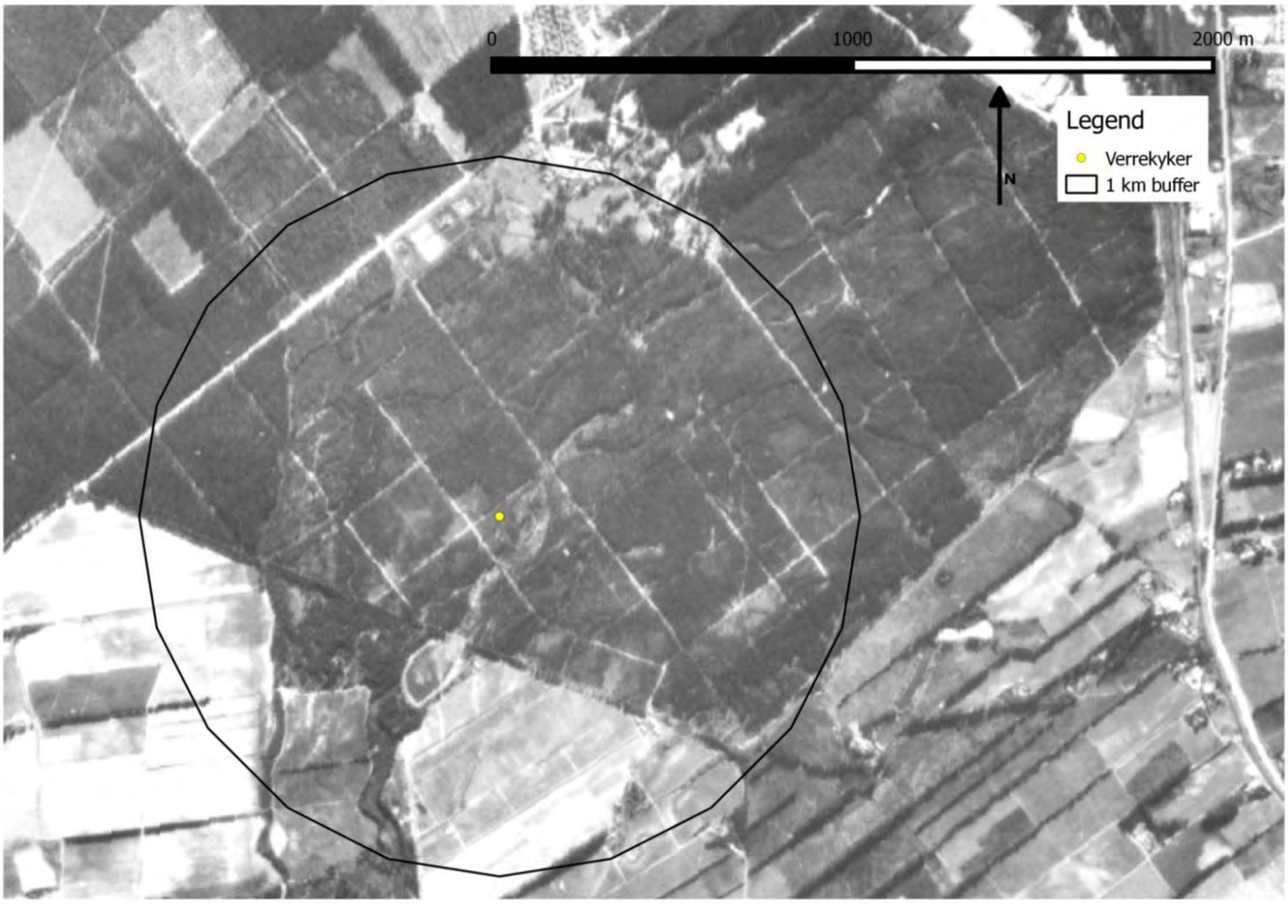
Vermont pan


0
1000
2000 m
N
Legend
Vermont
1 km buffer


0
1000
2000 m
N
Legend
Vermont
1 km buffer


Legend
Vermont pan
Landuse change
Developed - Developed
Developed - Natural
Natural - Developed
Natural - Natural
N
0
1000
2000 m

Verrekyker


0
1000
2000 m
N
Legend
Verrekyker
1 km buffer


0
1000
2000 m
N
Legend
Verrekyker
1 km buffer