A systematic plan for a protected area system in the Knersvlakte region of Namaqualand

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Executive summary

The objectives of this study were to locate a system of areas to conserve the unique plant patterns and processes in the Knersvlakte region of the Succulent Karoo; and to identify immediate priorities, in terms of land parcels, for acquisition by the Leslie Hill Succulent Karoo Trust.

These objectives were achieved by using a systematic conservation planning approach and GIS-based methodology that provides a flexible solution for an effective (in terms of achieving conservation goals) and efficient (in terms of area requirements) system of conservation areas.

Six conservation scenarios, each with a set of explicit targets for the conservation of biological pattern and process, were developed. The only scenario that achieved all targets (and, therefore, a conservation system that would preserve indefinitely biological patterns and the processes that sustain and generate these), included a core reserve of 57 724 ha, and a buffer zone of about 105 246 ha.

The priorirty ranking for acquisition by the Trust for the core reserve, as based on vulnerability to cropping agriculture and mining threats, are Rooiberg 255 (4 230 ha) (state land), Wolvenest 212 (5 064 ha), Luiperskop 211 (7 022 ha), Grasduin 315 (3 414 ha) (state land), Moedverloren 208 (7 357 ha), Bergplaat 316 (3 677 ha) (state land), Groot Graaf Water 210 (10 581 ha) and Mostert Kop (6 411ha).

The implementing agency for the protected area system should use the GIS-based planning tool developed in this project to implement and fine tune the system. In doing so, consideration should be given to:

- initiating negotiations and consultations with relevant stakeholders.
- taking seriously in terms of priority setting, the imminence of mining and agricultural threats;
- negotiating for the immediate transfer of state land to the agency

1 Introduction

1.1 Background

1.1.1 The Succulent Karoo

The Knersvlakte – the area considered in this study – comprises one of 12 bioregions (Hilton Taylor 1994a) identified for southern Africa's Succulent Karoo biome. This biome is a predominantly winter-rainfall desert region that occupies 112 000 km^2 on the arid fringes of the Cape Floristic Region. On account of its spectacular biodiversity, this region is the only arid land to qualify as a biological hot-spot (Cowling and Pierce 1999). It includes 4 849 species of vascular plants (40% endemic) and is home to the richest succulent flora in the world. It is also a centre of diversity for reptiles and many different groups of invertebrates. The recent and explosive diversification in the Mesembryanthemaceae, the largest succulent plant family in the region, has been described as an event unrivaled among flowering plants (Desmet et al. 1998).

As a consequence of an unusual composition and high endemism, the flora of the Succulent Karoo is unique (Cowling and Hilton-Taylor 1999). The region includes 1 940 endemic plant species and 67 endemic genera. Local and regional plant richness is very high. Thus, on average 70 species are recorded in a tenth-hectare plot (in one plot, the tally was 113!) (Cowling et al. 1998). Larger areas support about four times the number of species than comparable winter-rainfall deserts elsewhere in the world. This high regional richness is the result of high compositional change of species-rich communities along environmental and geographical gradients, i.e. high beta and gamma diversity, respectively (Cowling and Hilton-Taylor 1999). Many species are extreme habitat (mainly edaphic) specialists of limited range size. Point endemism is most pronounced among succulents (especially Mesembryanthemaceae) and bulbous lineages, and is concentrated on hard substrata, especially quartzites, shale ridges and quartz lag-gravel plains (Schmiedel and Jürgens 1999). The area is home to 851 Red Data Book species, 38% (A. Lombard pers. comm.) of which have ranges that occupy less than one quarter degree square (or 68 000 ha) (Lombard et al. 1999).

Given its global significance as a biodiversity hot-spot (Cowling and Pierce 1999), and its long-standing recognition as a regional conservation priority (Hilton-Taylor 1994a, Rebelo 1994), the current protected area system in the Succulent Karoo is woefully inadequate. Only 2.1% or 2 352 km^2 of the Succulent Karoo is conserved in six statutory reserves (Hilton-Taylor 1994a). Larger reserves (>10 000 ha) occur in only four of the Succulent Karoo's 12 bioregions and conserve only 80 (9%) of its 851 Red Data Book plant species (Lombard et al. 1999).

More than 90% of the Succulent Karoo is used as natural grazing (Hilton-Taylor 1994a), a form of land use that is, at least in theory, not incompatible with the maintenance of biodiversity and ecosystem processes. About 100 000 km^2 remains in a natural or semi-natural state. However, much of this remaining natural habitat is vulnerable to a wide range of immediate threats (Cowling et al. 1999). These, in order of their overall importance, are:

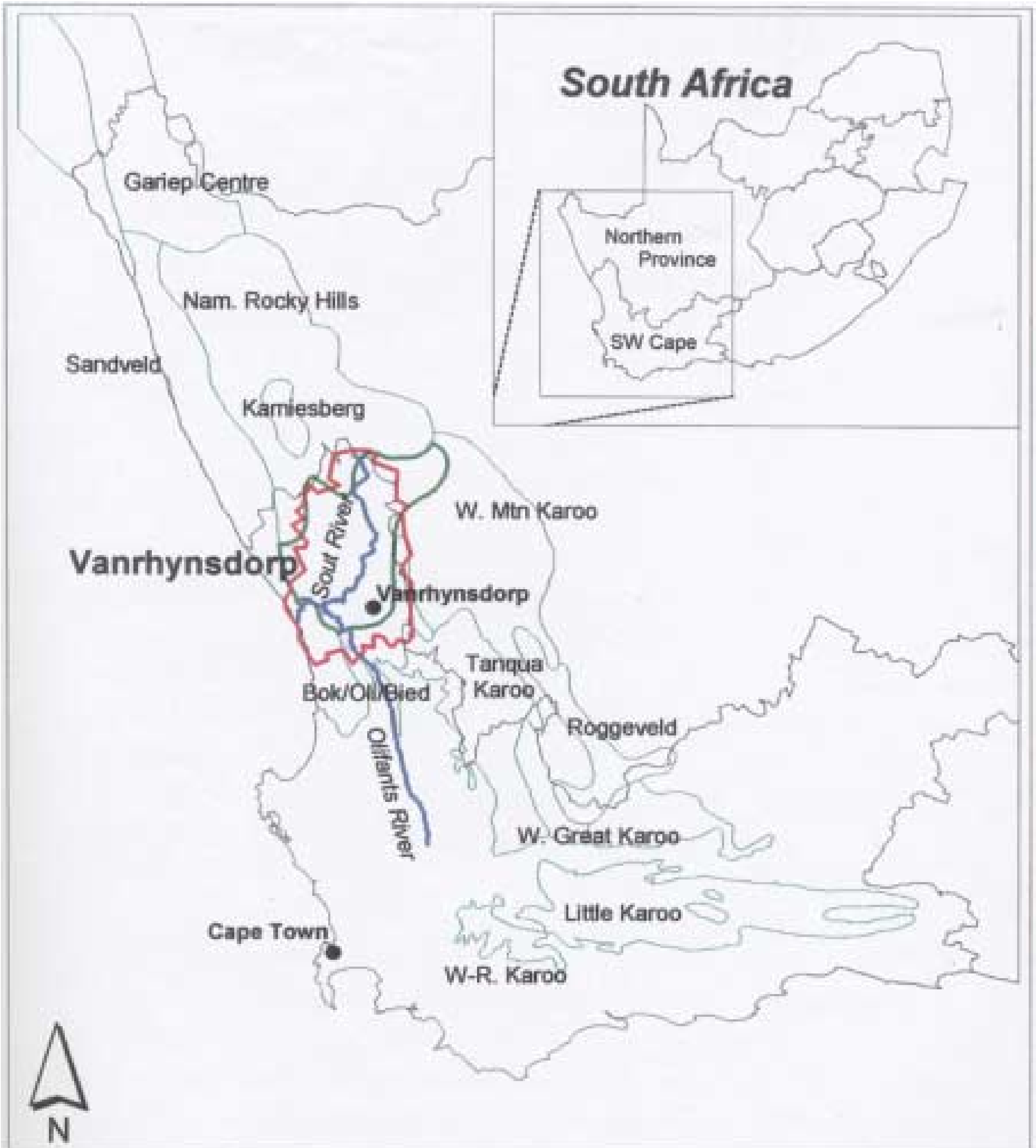
- the expansion of communally-owned land and the associated overgrazing and desertification;
- overgrazing of commercial (privately-owned) rangelands;
- agriculture, especially in the valleys of perennial rivers;
- mining for diamonds, heavy minerals, gypsum, limestone, marble, monazite, kaolin, ilmenite and titanium in the Sandveld, Southern Namib Desert, Vanrhynsdorp (Knersvlakte) Centre and Richtersveld bioregions;
- illegal collection of succulents and bulbs.

Bearing in mind the overall conservation value of the Succulent Karoo, the looming threats to its biodiversity, and the potential availability of large tracts of land for reservation, a systematic approach to the conservation of the region is long overdue

1.1.2 The Knersvlakte

The Knersvlakte, or Vanrhynsdorp Centre, is a bioregion within the Succulent Karoo (Hilton Taylor 1994a) (Figure 1). The area, comprising approximately 10 000 km^2, is home to some 133 Red Data Book plant species. It is renowned for its rich flora of minute succulents associated with quartz fields (Schmiedel and Jürgens 1999). Other hard rock substrata such as shale, quartzite and (especially) limestone also support a biologically interesting and distinct flora (PG Desmet et al. unpubl. data). The intervening matrix of heuweltjie veld on reddish, colluvial sands is biologically uniform and lacks range-restricted endemics. Details on the biophysical and biological environment of the Knersvlakte are provided by Jürgens (1986), Hilton Taylor (1994a) and Schmiedel and Jürgens (1999).

The Knersvlakte has long been recognized as a priority region for plant conservation (Hilton Taylor and Le Roux 1989, Hilton Taylor 1994a, Cowling et al. 1998, Lombard et al. 1999). Both the provincial conservation authority (Western Cape Nature Conservation – WCNC) and South African National Parks (SANP) have expressed interest in establishing a system of conservation areas in the region (see, for example, Le Roux and Simpson 1994, Hilton-Taylor 1994b).



Key to map

- Provincial boundaries
- Rivers
- Planning domain
- Biogeographical regions

Scale 1:4 000 000

Knersvlakte Reserve Design Project

Figure 1

Regional context of planning domain.

1.2 Conceptual basis for conservation planning

This section outlines the conceptual basis of the conservation planning approach used for the Knersvlakte study. The concepts and analytical tools used in this study reflect the most recent advances in systematic conservation planning. The detailed approach, together with applications in the Succulent Karoo, is presented in a report recently submitted to the Leslie Hill Succulent Karoo Trust (Cowling and Lombard 1998). This source should be consulted for more information.

The past 20 years have witnessed a shift in conservation planning from *ad hoc* reserve establishment to systematic protocols that identify whole sets of complementary areas which collectively achieve some overall conservation goal - the “minimum set” approach (Pressey et al. 1993). In this strategy, the conservation goal consists of quantitative targets for each species (e.g. at least one occurrence) or each habitat (e.g. at least 10% of its total area). The aim is to represent the required amount of each species or habitat in as small an area as possible. Usually, rapid implementation of the reserve system is assumed implicitly, so there is no basis for deciding how to schedule conservation action in relation to prevailing threats.

A more realistic scenario, however, is for implementation of the reserve system to take years or decades, during which time the agents of biodiversity loss continue to operate. In such situations, strategies for maximizing representation on paper must be complemented or replaced by those that maximize “retention” in the face of ongoing loss or degradation of habitat. A crucial consideration in maximizing retention is the assignment of priorities based on the irreplaceability or conservation value of a site, and its vulnerability to biodiversity loss as a result of current or impending threatening processes (Pressey et al. 1996, Pressey 1997). Areas of high irreplaceability and high vulnerability are the highest priorities for conservation action. This approach should minimize the extent to which representation targets are compromised by ongoing loss of habitat and species.

A further step is needed, however, for conservation planning to truly address the long-term persistence of biodiversity. The implementation of reserve systems that are designed to achieve only the representation of biodiversity pattern will not ensure long-term conservation. This is because these systems do not explicitly consider the ecological and evolutionary processes that maintain and generate biodiversity (Cowling et al. 1999). The ultimate goal of conservation planning should be the design of systems that enable biodiversity to persist in the face of natural and human-induced change. Design is defined here as the size, shape, connectivity, orientation and juxtaposition of conservation areas intended to address issues such as viable populations, minimization of edge effects, maintenance of disturbance regimes and movement patterns, continuation of evolutionary processes, and resilience to climate change.

Given that the implementation of reserves systems is almost always gradual, and accompanied by ongoing loss of habitat, the conservation of both pattern and process will require consideration of:

- representation and design in the identification of potential conservation areas; and
- sound decisions about the progressive implementation of conservation action so that land use and other threats have minimal impact on the desired outcome.

Conservation planning is therefore about promoting both retention and persistence. Importantly, the only path from retention to retention + persistence is by adding design to representation before identifying priorities for implementation. In the implementation phase of a reserve system designed for retention + persistence, the importance of threatening processes in compromising the achievement of both representation and design goals will need to be considered and balanced (Cowling et al. 1999). This strategy should achieve greater long-term benefits for biodiversity than alternative strategies based only on the representation of pattern.

1.3 Protocol for reserve design

In this section, we describe an explicit and logical protocol (Cowling et al. 1999) for reserve design on the Knersvlakte. The protocol, which is guided by the conceptual approach described above, comprises a series of steps (Table 1) that are required to identify and implement a reserve system designed for the persistence of biodiversity (Cowling et al. 1999). The crucial issue here is the retention of both pattern and process. The processes required for maintaining and generating plant biodiversity on the Knersvlakte, together with the spatial components that sustain them and the temporal scales over which they operate, are shown in Appendix 1.

The first step is to identify types, patterns and rates of threatening processes. On the Knersvlakte, this amounts to assessing the vulnerability of cadastral units (i.e. farms) to threats such as grazing, agriculture and mining (Cowling et al. 1999). Furthermore, the time frame over which these threats will operate must be estimated.

The second step involves identification of the spatial components that need to be protected in the expanded conservation system. Some of these will be elements of biodiversity pattern. Others will serve as surrogates for the ecological and evolutionary processes that should be protected in a reserve system intended for retention + persistence (Appendix 1).

Table 1. Steps in the protocol for achieving retention and persistence (from Cowling et al. 1999)

Steps	Action
Step 1	Identify types, patterns and rates of threatening processes
Step 2	Identify natural features to be protected (these will be elements of biodiversity pattern, e.g. species, habitats, as well as spatial components of the region that act as surrogates for ecological and evolutionary processes; see Appendix 1 for examples relevant to the Knersvlakte)
Step 3	Set targets for representation and design
Step 4	Lay out options for achieving representation + design targets
Step 5	Locate and design potential conservation areas to achieve representation + design targets
Step 6	Implement conservation actions in priority order • Set priorities on the basis of irreplaceability and vulnerability • Allocate forms of conservation management • Fine-tune

In the third step, quantitative targets must be set for the representation of these spatial components, taking into account the need of each component for protection from threatening processes. This presents a serious challenge to conservation planners. For example, how many and which quartz-field drainage basins are required to maintain diversification of Mesembryanthemaceae lineages? Which climatic gradients and associated juxtaposed landscapes are most likely to facilitate migration of poorly dispersed organisms in response to climate change?

The fourth step requires that the options for achieving representation + design targets - the ultimate but elusive goal for conservation planning - are laid out. A way of mapping the spatial options for achieving a set of conservation targets is to calculate and map the irreplaceability of each part of the landscape (Pressey et al.

1995). A map of irreplaceability, with values allocated to all parts of the landscape, is therefore a map of the options for achieving a set of targets. Areas that are totally irreplaceable are non-negotiable parts of an expanded conservation system, regardless of what form of conservation management is applied (see Step 6). Other areas are replaceable and negotiable to varying extents.

Step 5 is to locate and design potential conservation areas for representation + design. The overall aim of this step is to identify conservation areas that will collectively achieve all the targets for pattern and process. The system of proposed conservation areas might be much larger than the area considered feasible, but sound decisions about the relative importance and urgency of protection for specific parts of the landscape (Step 6) can only be made when the full requirements of all targets have been laid out. Candidate areas will be chosen that contribute to as many targets as possible.

Step 6 is the actual implementation of conservation action - a very complex part of the planning process. It involves three interdependent lines of work, which are likely to proceed in parallel, not sequentially. These are:

- scheduling conservation action (reservation or other) for specific parts of the region;
- deciding on the balance between strict reservation and off-reserve management;
- fine-tuning of conservation recommendations by selective inspection of areas on the ground and reassessment of data.

Scheduling requires that the recommended timing of conservation action should minimise the extent to which conservation targets are compromised before conservation management is applied (Pressey 1997, Lombard et al. 1999). This requires information on both threat (the likelihood or imminence of adverse impacts – from Step 1) and irreplaceability (the consequences of loss or degradation of habitat – from Steps 4 and 5). When conservation goals deal with both pattern and process, as is the case here, there are no established ways of comparing the risks of alternative approaches to implementation. For example, how should the outright loss of five RDB species or a 20% loss of the target for a land type be compared to the effect of a new mine covering 100 ha of a sand corridor, or the narrowing of a migratory pathway for ungulates?

The issue of which form of protective management should be applied to particular parts of the landscape is complex. Decisions about the form of management to be applied to specific areas will depend on:

- the need to use off-reserve management as a fall-back when resources for strict reservation are limited or when reservation priorities are unavailable for acquisition;
- the distribution of threatening processes that do not warrant protection by reservation;
- which parts of the unreserved matrix most require management to maintain the integrity and connectivity of reserves.

All these decisions will be taken in the context of the variety of off-reserve management tools (e.g. Biosphere Reserve buffer zones, private nature reserves, conservancies) currently or potentially available.

1.4 Objectives of this study

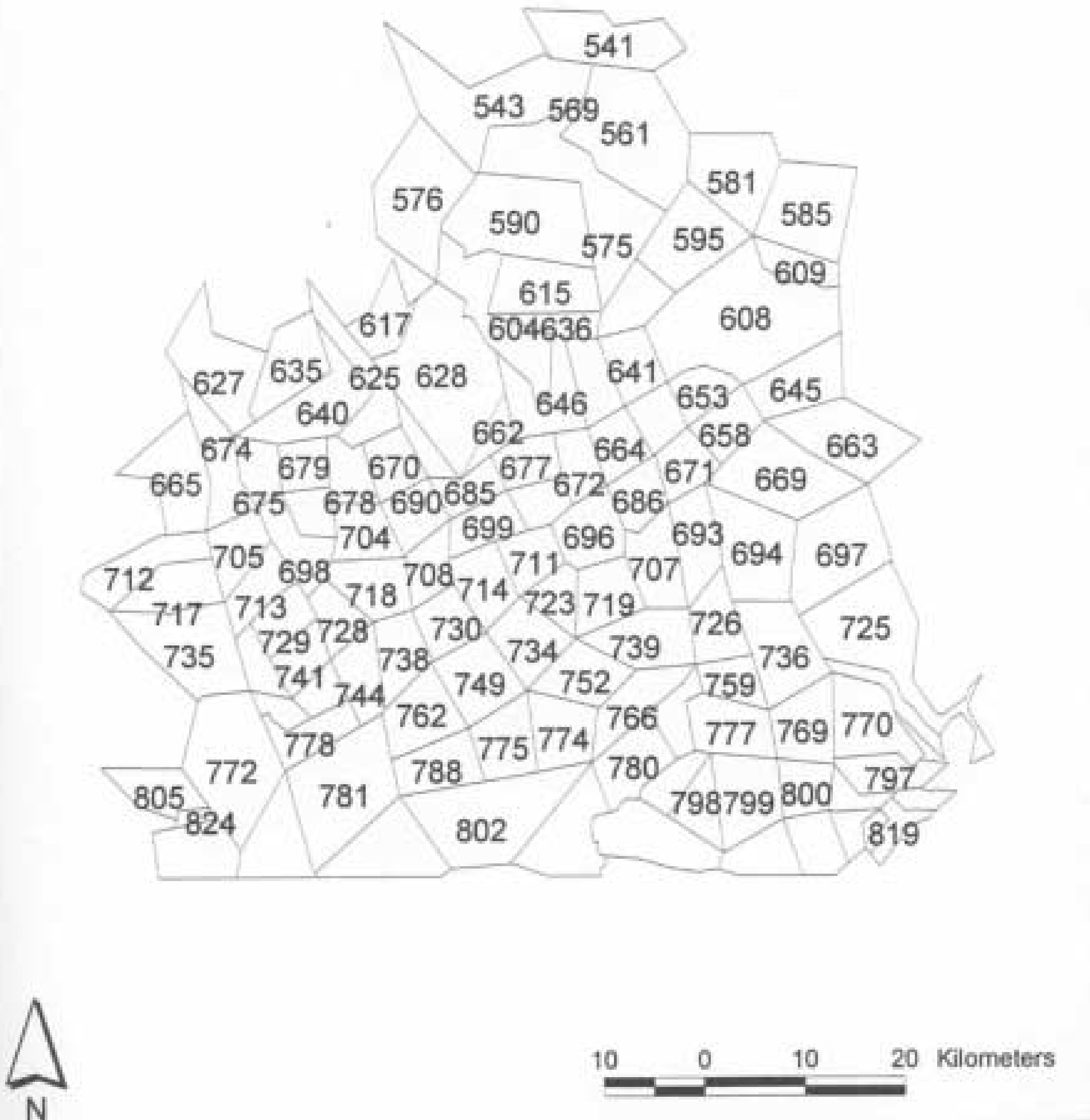
The major objective of this study is the identification of priority areas for a protected area system in the Knersvlakte. A strong emphasis has been placed on the conservation of the patterns of biodiversity and ecological and evolutionary processes associated with the region’s quartz field habitats. These habitats support the overwhelming number of the Knersvlakte’s endemic plant species, most of which are dwarf succulents.

Emphasis has also been placed on identifying a system of areas that can be readily developed as a core conservation zone (i.e. a national park or provincial nature reserve). Thus, we have incorporated practical constraints into the planning approach, specifically size constraints (as determined by funds for land purchase over the short to medium term); and the configuration of the reserve system in relation to major transport infrastructure. However, the planning approach and tools used for this study embody great flexibility and enable the identification of areas outside of the core zone that will also contribute to the realization of conservation goals, especially process-related targets that operate over very large spatial scales.

A further objective of the study was to develop a plan sufficiently flexible to enable interactive engagement among stakeholders regarding the development of the conservation system. This plan should enable the implementing agency to assess priorities in terms of practical constraints (cost and availability of land, park development potential) in addition to conservation value (irreplaceability) and vulnerability to threatening processes.

2 Application of the conservation planning protocol

This section describes the application of the protocol outlined in Table 1 for conservation planning on the Knersvlakte. The end product is a number of scenarios for potential reserve systems. Some comments on implementation (step 6) are also provided although it was not our brief to recommend explicitly the forms of conservation management for the Knersvlakte reserve.



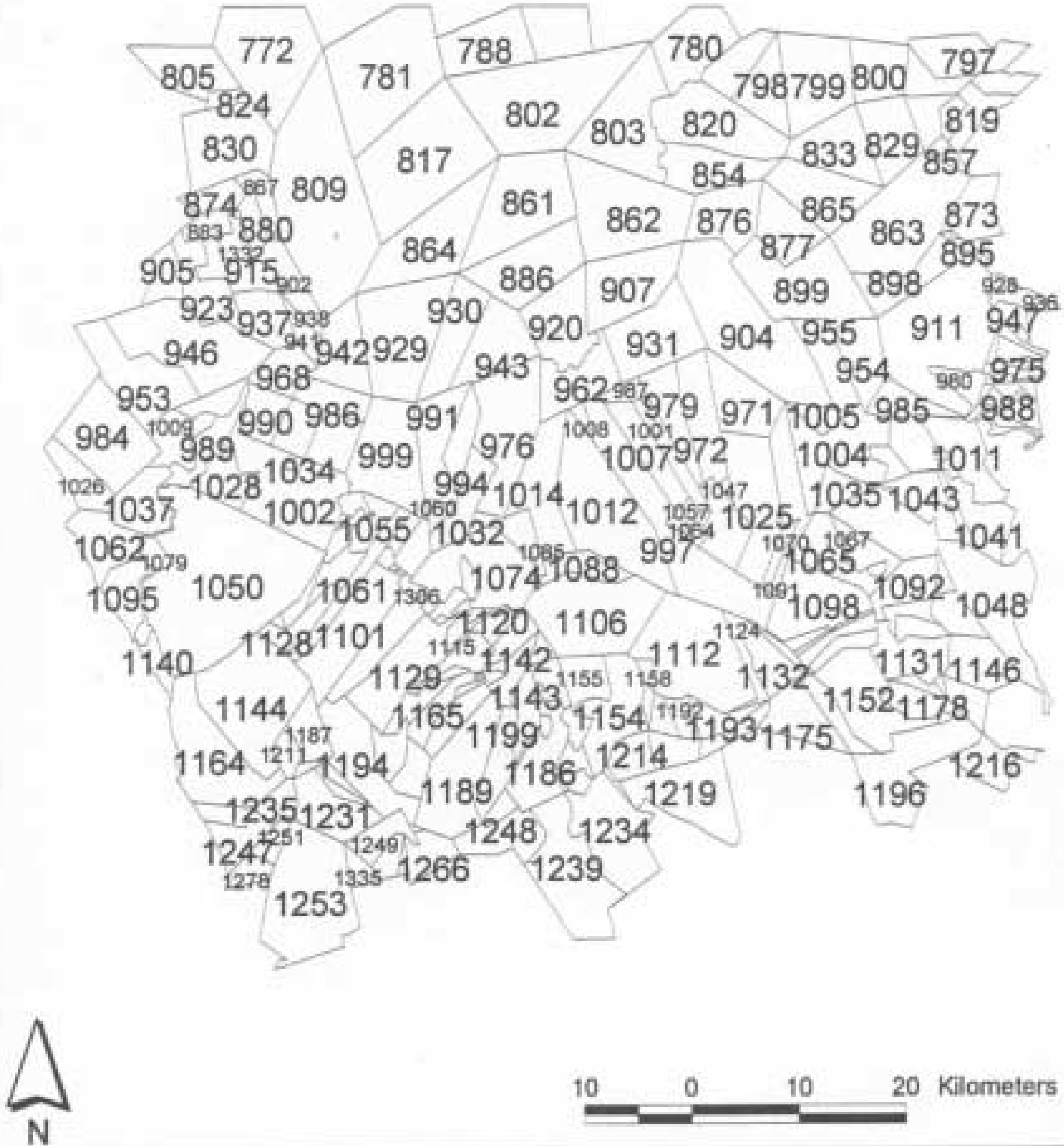
Key to map

Farm boundaries

Knersvlakte Reserve Design Project

Figure 2a

Key to farm names in the northern half of the planning domain.
Farm numbers correspond to key field numbers in Appendix 3



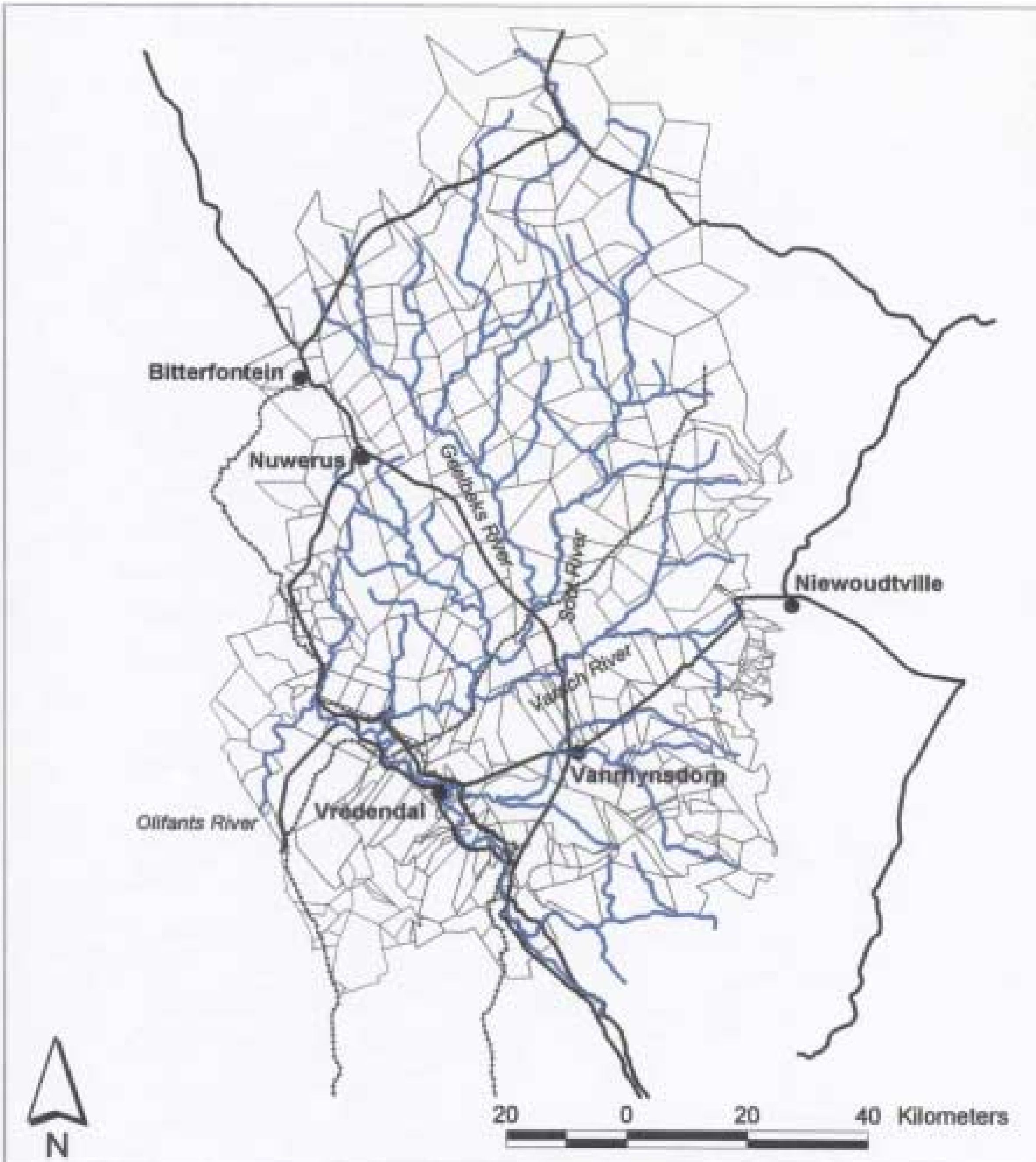
Key to map

Farm boundaries

Knersvlakte Reserve Design Project

Figure 2b

Key to farm names in the southern half of the planning domain. Farm numbers correspond to key field numbers in Appendix 3. Farm numbers along the Olifants River are omitted .



Key to map

- Farm boundaries
- Rivers
- Roads
- Railways

Knersvlakte Reserve Design Project

Figure 3

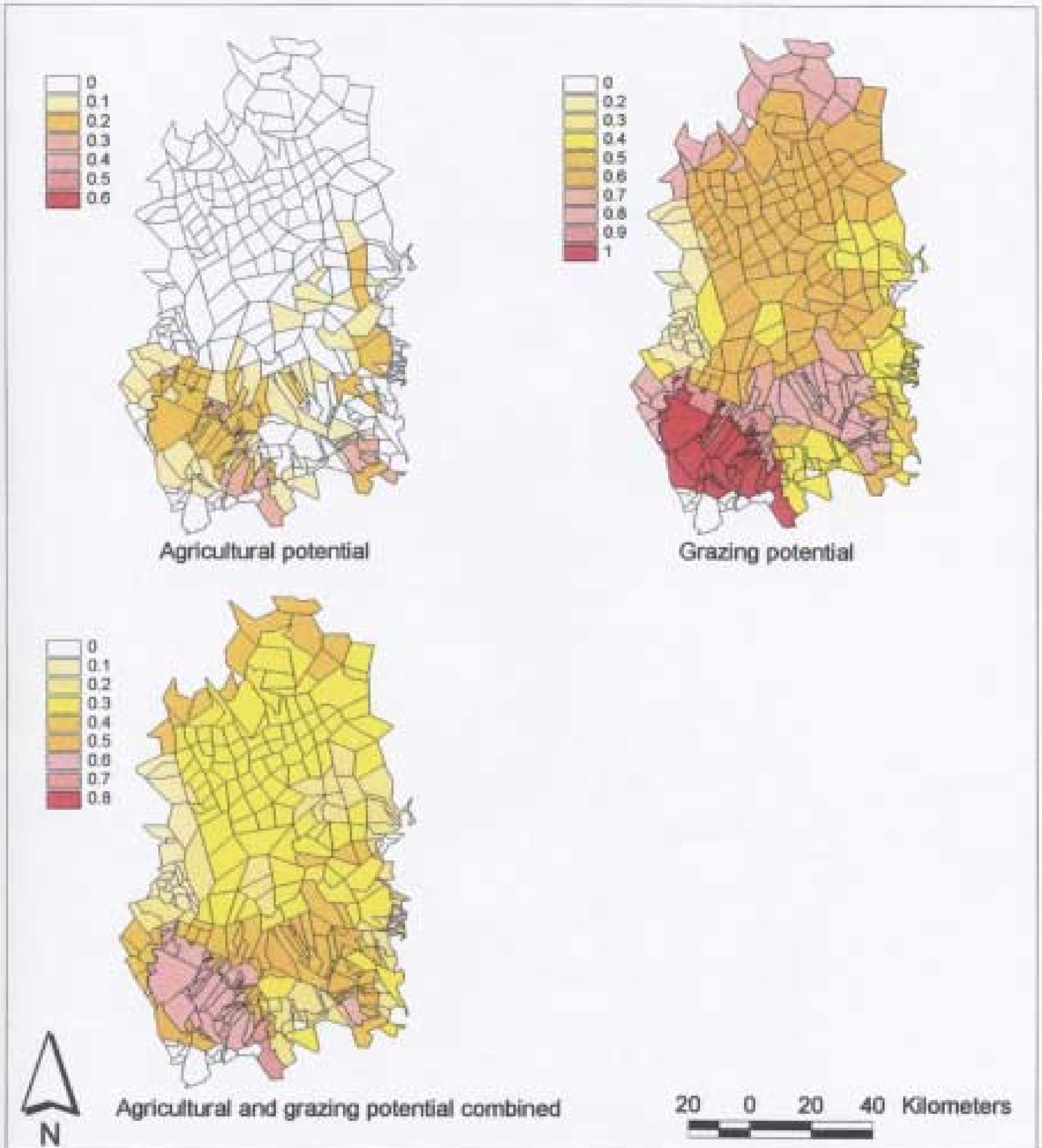
Location of towns, major transport routes and rivers within the planning domain.

The **planning domain** for the study is shown in Figure 1 (regional context) and Figure 2 (detail showing cadastral units). These cadastral units, mostly privately owned farms but also including parcels of state-land, are listed in Appendix 2. Individual farms are used as the units of selection for the conservation planning process, as these are the units of most land tenure transactions. The planning domain is not entirely coincident with the Knersvlakte or Vanrhynsdorp Centre bioregion, as delineated by Hilton Taylor (1994a). Our domain corresponds to the distribution of quartz-rich rocks (and associated quartz fields) within this bioregion. The reason for this is that the major goal for the reserve system is the conservation of the extraordinary plant patterns and processes associated with the quartz-field habitats. Figure 3 shows the location of major transport routes in the planning domain. This infrastructure is a major constraint for the identification of the core conservation system.

2.1 Step 1. Identify types, patterns and rates of threatening processes.

Threats to biodiversity on the Knersvlakte were estimated by assessing the actual and potential patterns of land use in the planning domain that will compromise or destroy biodiversity patterns and processes. The primary threats to conservation are any form of land use that irreversibly transforms natural landscapes, thereby disrupting natural processes. Three major forms of land use were identified:

- cropping agricultural potential (Figure 4)
- grazing potential (Figure 4)
- mining potential (Figures 5 and 6)



Key to map

Farm boundaries

Knersvlakte Reserve Design Project

Figure 4

Indices of agricultural threat

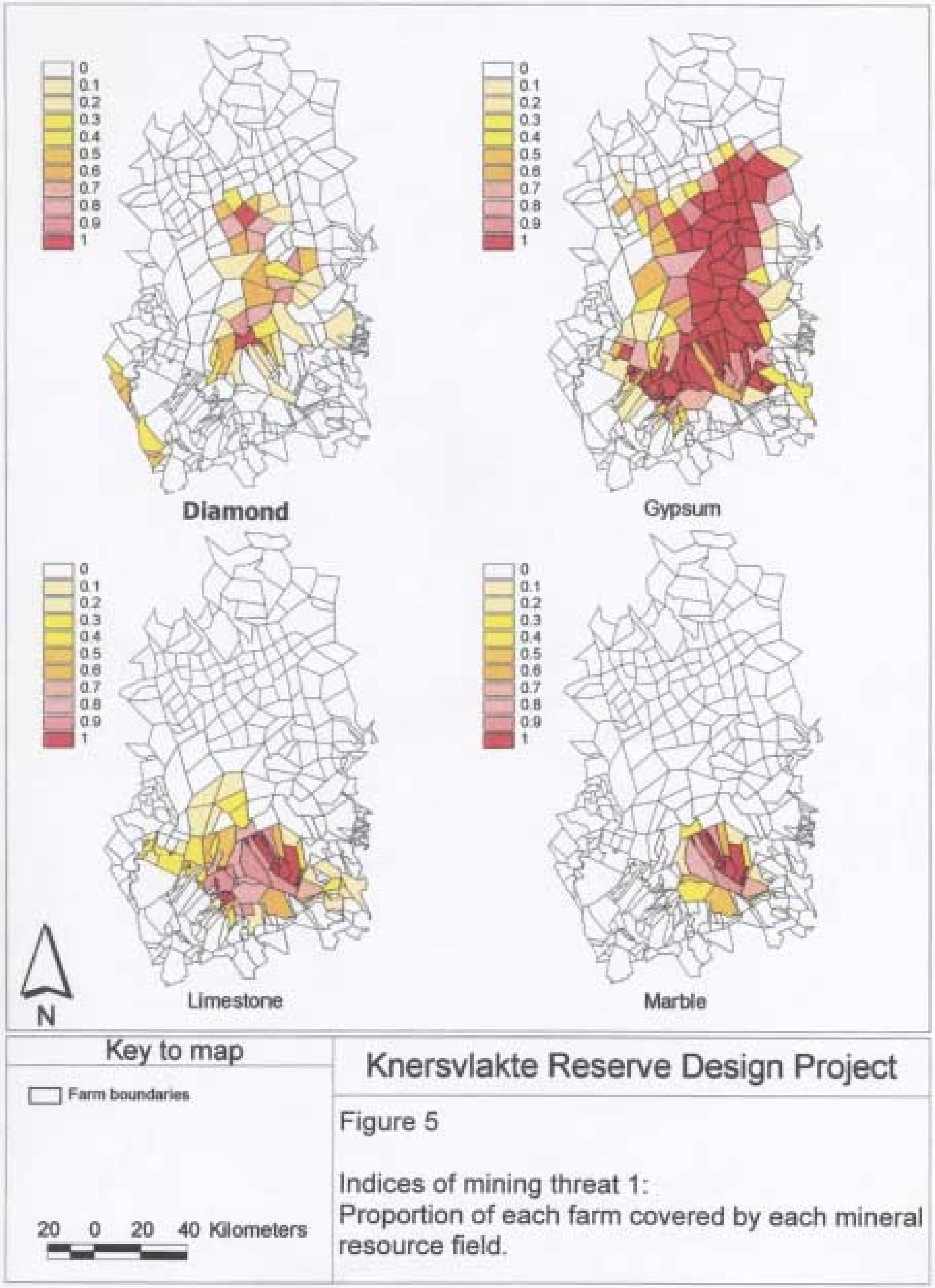
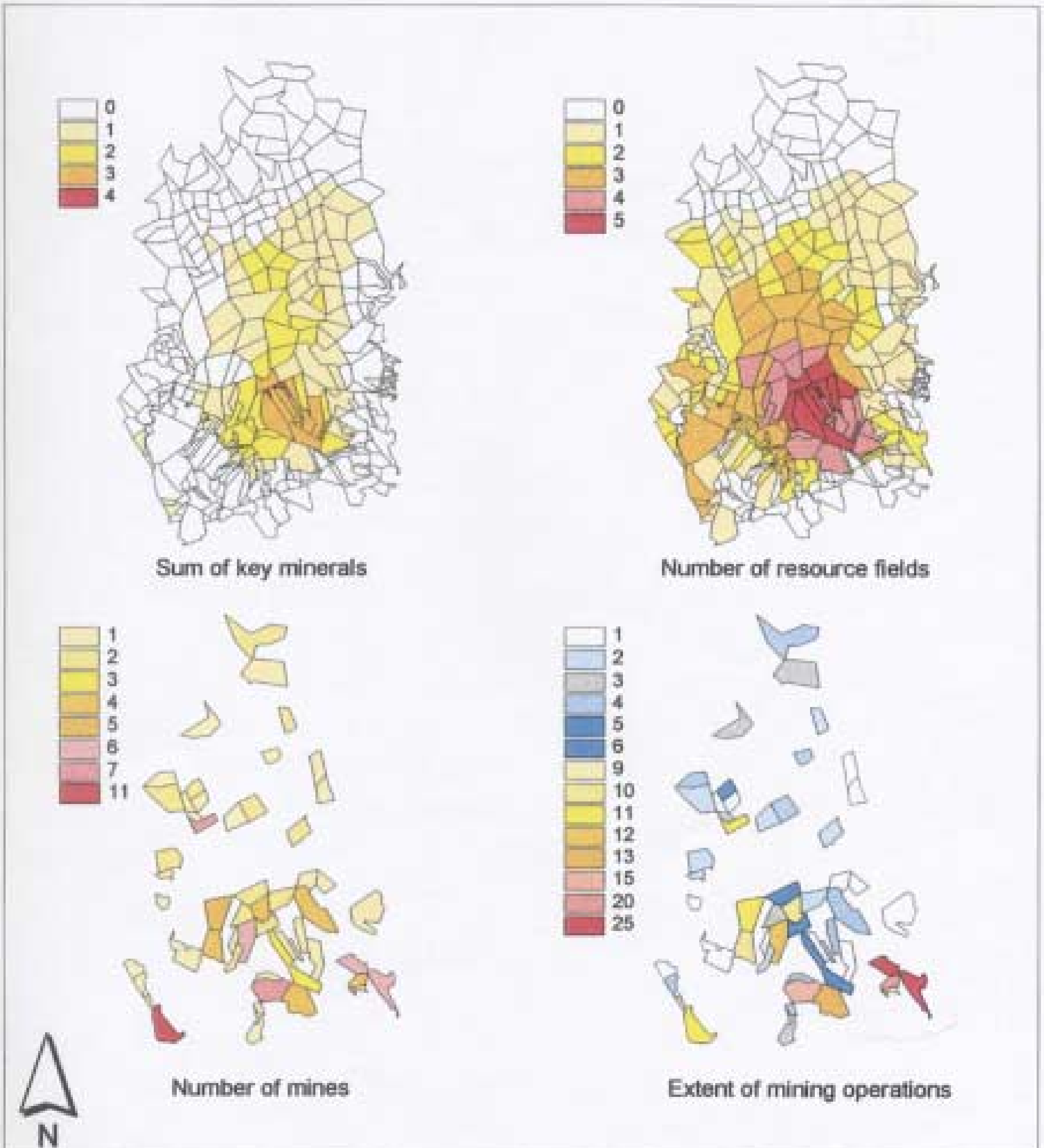


Figure 5

Indices of mining threat 1:
Proportion of each farm covered by each mineral resource field.



Key to map

Farm boundaries

10 0 10 20 Kilometers

Knersvlakte Reserve Design Project

Figure 6
Indices of mining threat 2:
Summed proportion of farm area covered by 4 key mineral resource fields; number of resource fields per farm; and, number of mine sites and extent of mining per farm.

These three forms of land use are recognized as the major threats to biodiversity in the Namaqualand region of the Succulent Karoo (Hilton Taylor and Le Roux 1989, Hilton Taylor 1994a, Lombard et al. 1999). Of these, cropping agriculture and mining are of greatest concern. These are generally associated with irreversible landscape transformation. Grazing, which is presently practiced throughout the region is potentially very destructive. However, although grazing operates over a much larger spatial scale than agriculture and mining, the temporal scale of degradation is slower and potentially controllable through conservation orientated land management practices. In section 2.6.1 (Step 6 - setting priorities for conservation) we do not use grazing threat to prioritize conservation action.

Cropping agriculture threats (Figure 4) are concentrated on the alluvial soils along the Olifants River and other rivers such as the Varsch and Sout that have access to water for irrigation. Also, the sandy soils in the south of the planning domain are threatened by dry-land cropping and, should water resources become available, by irrigation farming as well. Similarly, this area is also the centre of mining potential (Figures 5 and 6). Overall, threats are largely concentrated in the south, whereas the areas to the north of the N7 are mostly free from cropping agricultural and mining threats

The identification of rates of threatening processes is problematic, especially since market forces, whose magnitude and direction are difficult to predict, often drive changes in land use. At present, mining potential in the planning domain is regarded as very low, owing to the limited economic benefits of extraction under the current climate and the fact that most economically viable deposits have been mined already (Council for Geosciences pers comm.). However, the quarrying of limestone – a substratum that supports an interesting endemic flora – is a rapidly escalating threat, owing to demands from the Saldanha industrial node to the south. Extraction of the Knersvlakte diamonds is not an economically viable practice at present. Although small-scale prospecting operations are in evidence, there are no successful diamond mines on the Knersvlakte. However, this does not stop individuals from prospecting further, thus additional prospecting must still be considered a major threat.

We have attempted to assign a rank-order threat index to each of the cadastral units (farms) in the planning domain. The three identified groups of threats were assessed individually. This is because the different threats operate over different spatial and temporal scales and target different natural resources. For example, a site that is low for one threat may be very high on another; an index incorporating the two may not reflect this.

For cropping agriculture (Figure 4), indices of threat for each selection unit (farm) were developed by determining the proportions of that site covered by a particular combination of cropping agricultural potentials. There were a total of 15 combinations of seven cropping potentials each with a possibility of three potentials for cropping classes per crop. For each site, the proportion of each threat coverage was summed and standardized to produce a threat index ranging from 0 to 1 where 0 is no threat and 1 a very high threat for all of the site.

A similar method was employed for all other indices - i.e. one based on the proportion of that site covered by a particular resource potential field. For grazing potential (Figure 4), high values mean all of a site has a high grazing potential (LSU = 30 ha per large stock unit) and low values mean all of a site has a low grazing potential (LSU = 75). In Figure 5, indices are presented for the four most economically import minerals - diamonds, gypsum, limestone and marble. The indices represent the proportion of a site covered by each particular resource field. These proportions are summed in Figure 6 (sum of key minerals). The number of resource fields (Figure 6) - i.e. the number of mineral resource fields recorded out of a total of 10 mineral fields for each site; provide a crude index of mining threat. The number of mines (existing and abandoned mines per site) and extent of mining operations (sum of Geoscience Council ranking of each mine)(Figure 6) provides an indication of the present extent of destruction due to mining, as well as the potential for future impacts.

All the threat indices presented are simple linear combinations of proportional coverage of sites by the various resource fields. There is no weighting of individual indices. For example, the sum of key minerals (Figure 6) is a sum of the proportion of a site covered by each of the four key mineral resources in the planning domain. This must be regarded as a crude index and will require refinement during the implementation phase of the project.

These data are used in Step 6 of the protocol to identify priorities for implementation on the basis of our assessment of vulnerability of a selection unit to threatening processes.

2.2 Step 2 Identify natural features to be protected

Biologically, the major aim of this conservation planning exercise was to identify a system of reserves that would conserve existing patterns of endemic plant diversity on the Knersvlakte, as well as the processes that maintain and generate these patterns. The Knersvlakte is renowned for its fine-scale patterns of plant endemism and contemporary evolutionary diversification, especially among lineages of Mesembryanthemaceae (Ihlenfeldt 1994, Schmiedel and Jürgens 1999, Desmet et al. 1998). Of prime interest here are pattern and process associated with the quartz-field flora.

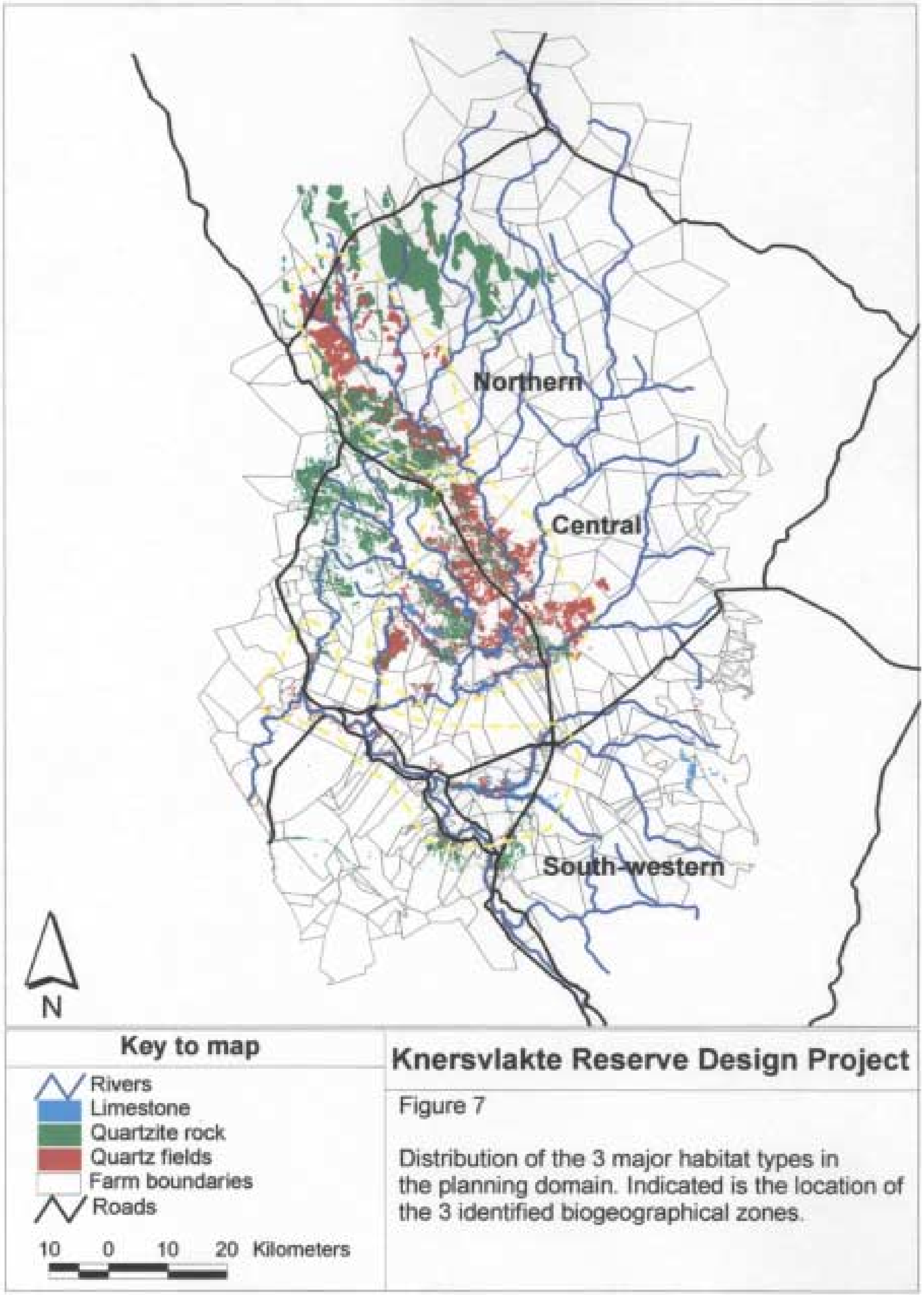
The identification of the features (patterns and process) requiring protection in order to fulfill this mandate was the most difficult and time-consuming part of the study. Unfortunately, there were virtually no data on biological patterns and processes for the Knersvlakte. Therefore, we had to gain an understanding of biodiversity patterns in terms of species and habitats, as well as develop insights regarding important ecological and evolutionary processes. Finally, in order to incorporate pattern and process features into the reserve design process, these had to be represented as spatially explicit surrogates.

This aspect of the study involved sampling of species-level pattern in relation to habitat gradients and a rapid assessment of the spatial requirements for accommodating key processes (see Appendix 1). The activities associated with this part of the study are not reported on in detail here as they will be published in the primary literature in due course. However, we do present below a summary of the biological patterns and processes that played a key role in the reserve selection process.

- Quartz fields are the most important habitat for plant diversity, with quartzite rock and shale rock the next most important. Quartz fields support the most derived (most highly evolved) species in the regional flora and, due to the extreme nature of the habitat, also support the most range-restricted or habitat-specific taxa (Ihlenfeldt 1994, Desmet et al. 1998, Schmiedel and Jürgens 1999).
- Quartz-field specialists are thought to have evolved from quartzite rock-dwelling ancestors along the ecocline: quartzite to acid quartz fields to saline quartz fields (Ihlenfeldt 1994, Desmet et al. 1998). Many acid quartz field specialists also occur on quartzite rock. Thus, quartzite rock is an important habitat as it is a potential refuge, a source of new species, and also provides a habitat avenue for plant migration.
- Limestone supports a subset of habitat-specialist species endemic to the Knersvlakte. This group of species comprises lineages broadly unrelated to the quartz field endemics.
- Patterns of quartz field species diversity are consistent with those encountered on certain archipelagos i.e. there is a marked "island effect". A "mainland" centre of diversity is associated with the area of greatest quartz field density in the central-

east sector of the domain (Moedverlooren to Quaggaskop centred on the Sout River). Separate branches of diversity are associated with the chains of quartz fields that branch off to the north and the west/southwest from this region (Figure 7).

- Compositional turnover of quartz-field Mesembryanthemaceae is greatest across the "mainland" centre of the quartz-field archipelago and declines markedly away from this centre (Figure 7 and Figure 8a). Overall diversity, number of species restricted to limestone habitats and turnover of the limestone flora is much lower than for the quartz-field flora (Figure 8b).
- Quartz-field flora distribution patterns are nested within the minor drainage basins of the Knersvlakte (Figure 9); other environmental predictors such as latitude, longitude, altitude, homogeneous climate zones or landtypes are relatively poor predictors of pattern. Most ecological processes associated with the flora are also nested within a drainage basin; thus, drainage basins comprise the minimum ecological unit required to adequately conserve ecological processes (Appendix 1). However, in order to conserve evolutionary processes, at least two or more contiguous (i.e. linked via river corridors) drainage basins will be required. Such a configuration will maintain several active evolutionary fronts and provide the opportunity for dispersal between drainage basins, via patches of suitable habitat, along river corridors. Therefore, the potential for ongoing diversification is likely to be considerably enhanced by including more than one entire drainage basin in the conservation system.



Knersvlakte Reserve Design Project

Figure 7

Distribution of the 3 major habitat types in the planning domain. Indicated is the location of the 3 identified biogeographical zones.

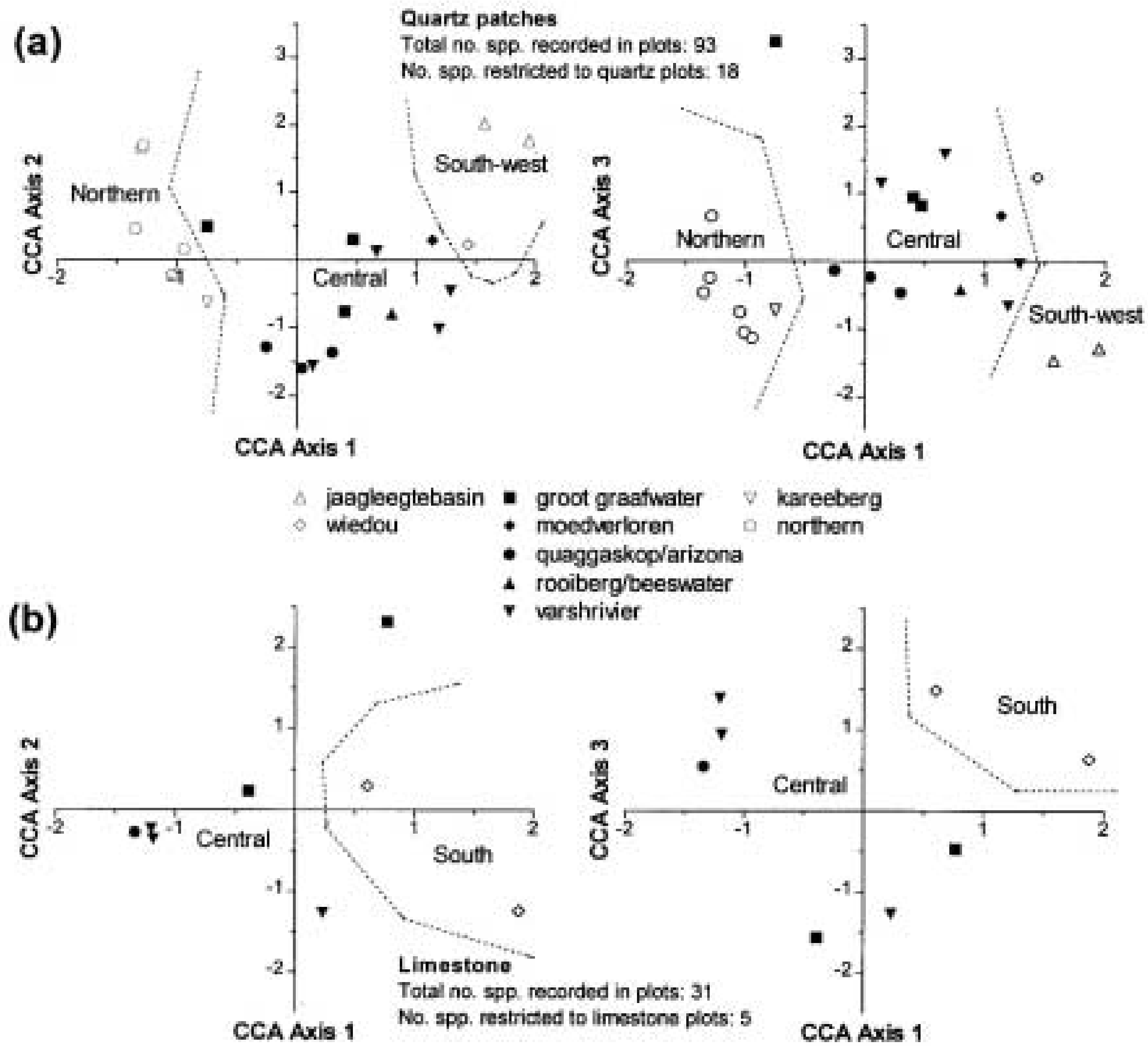


Figure 8 Direct gradient analysis of species presence data for plots in (a) quartz fields and (b) limestone outcrops. Axes represent amount or turnover of species between plots. Thus, plots close together on the ordination space are more similar in species composition that plots further apart. For quartz fields, by far the most spread in points is recorded in the central region. All three regions are comparable in their area. Thus the central region is considered the centre of diversity with the outlier drainage basins being less diverse with greater similarity between plots.

Key to map

Rivers
Roads
Drainage basins
Farm boundaries

10 0 10 20 Kilometers

Knersvlakte Reserve Design Project

Figure 9

Drainage basins in the planning domain

2.3 Step 3 Setting targets for representation and design

Setting representation targets is a crucial stage in the reserve design process since these targets affect profoundly the ultimate configuration of the conservation system. Targets for biological components need to be objectively defined such that they reflect regional needs for conservation. In this study, targets were set for two groups of priorities. The first group we call pattern targets. These are targets that set specific goals for the amount of area of a specific plant habitat that we wish to conserve. The second group we call process targets. These are targets that set explicit goals for the spatial surrogates (e.g. drainage basins) for the processes that will sustain the long-term persistence of the biodiversity included in the reserve system.

2.3.1 Representation of pattern

The major objective for the reserve is to conserve the endemic flora, especially that associated with quartz fields, of the Knersvlakte. Therefore, we only set explicit targets for habitats that are important in achieving this objective (Table 2). Targets for specific habitats were set according the local importance of each habitat and also relative to its regional extent. Widespread habitats create more opportunities for conservation elsewhere, whereas for localized habitats, i.e. those restricted to the Knersvlakte, our planning domain represents the major opportunity for achieving goals. However, it must be borne in mind that there is very high compositional turnover between floras growing in similar habitats in different parts of Namaqualand (Cowling and Hilton Taylor 1999). Therefore, relatively high targets are required in order to capture features not represented outside of the local planning domain.

Our regional planning domain for this study comprised south and central Namaqualand, an area of some 36 000 km^2. The extents of the relevant habitats were mapped within this area using ArcView GIS by mapping combinations of altitude and geology as surrogates for vegetation.

Table 2. Targets and extent of habitat required for a representative reserve system on the Knersvlakte.

Habitat	**Local extent**		**Targets**		
	Area (ha)	**% of regional**	**% of local extent**	**% of regional extent**	**Area (ha)**
Quartz field	27 370	91.9	50	46	13 687
Quartzite	35 693	35.1	25	10	8 923
Shale	17 176	4.2*	25	≈10	4 292
Limestone	4 914	100	50	50	2 457

* Shale as mapped in the Knersvlakte comprises shale with quartz veins (quartz rich metamorphic rock). At the 1:250 000 scale, the geological map of South Africa does not differentiate between quartz-rich and quartz-free shale in their metamorphic rock category. The actual regional extent of this rock type should be closer to that of quartzite as these two rock types are generally closely associated with one another throughout Namaqualand.

The largest concentration of quartz fields in Namaqualand occurs on the Knersvlakte (Table 2). Therefore, a relatively high target (50%) was set for this habitat. The target set by IUCN for biodiversity patterns is 10% (McNeely et al. 1990) although higher levels are recommended in some circumstances. The higher target is justified by the fact that (a) plant patterns and processes on the Knersvlakte are globally unique; (b) there are no other opportunities elsewhere within the Succulent karoo to conserve such a large connected area of this habitat (Schmiedel and Jürgens 1999) within a single reserve.

A target of 25% was set for the quartzite and shale habitats. These habitats form and integral part of the geomorphological development of quartz fields (i.e. they are the parent rock from which the quartz pebbles are derived); and, as well as the evolutionary models put forward explaining the diversity patterns that require conservation. Consequently many species are shared between quartz fields, quartzite and shale rock habitats. The three habitats form an integrated biological unit. Therefore it is important when conserving the target habitat (quartz fields) to conserve sufficient area of this complimentary habitat. In addition, quartzite floras throughout Namaqualand are rich in locally endemic species (Desmet and Cowling 1999). This is true for the Knersvlakte where quartzite habitats have the highest total species diversity relative to quartz fields, but lower numbers of range-restricted habitat-specialists.

Limestone, which is entirely restricted to the Knersvlakte, supports a small endemic flora that shows lower total diversity, numbers of endemics and compositional turnover across the planning domain (Figure 8b). There are no opportunities to conserve limestone habitats elsewhere in Namaqualand; therefore, a target of 50% is set for this habitat.

An additional target was to include in the reserve system the centre of quartz-field species diversity (i.e. the region of high compositional turnover in the "central" region of the quartz fields) (Figures 7 and 8). This region covers approximately 96 000 ha and include 16 farms.

No targets were set for the other habitat types, namely heuweltjie veld, various forms of strandveld, sandveld, and sandplain fynbos that occur in the planning domain. This was done for the following reasons:

1. These were not regarded as key habitats necessary to conserve the unique plant diversity of the region.
2. Since targeted habitats were distributed in a matrix of these non-targeted habitats, realization of reservation goals would ensure adequate representation (ca. 10%) of these habitats in the final conservation system.

3. Non-targeted habitats are widespread elsewhere in Namaqualand and will probably be over-represented in the nascent Namaqua and Groen-Spoeg national parks (see Cowling et al. 1999).

2.3.2 Representation of processes

The challenge here was to set explicit targets for spatial surrogates for ecological and evolutionary processes. As can be seen in Appendix 1, there are numerous processes that encompass a wide range of spatial scales. Although it is very difficult to estimate the spatial and temporal requirements for the conservation of these processes, we have had to do so since there is inadequate time for additional research to provide better guidelines. As can be seen in Appendix 1, most processes essential for the maintenance and generation of the plant biodiversity require spatial surrogates in the order of 10 – 10 000 ha. Long-term processes such as evolutionary processes or responses to climate change require larger areas (up to 100 000 ha) that include adjacent drainage basins or migration corridors. However, certain processes, especially those involving migratory patterns of larger mammals, require even larger areas (Cowling et al. 1999). Ultimately, only off-reserve or substitution management actions can accommodate these processes.

In addition to the biological targets, of central concern on the Knersvlakte is the conservation of the geomorphological processes that have formed, and continue to shape, the distribution of quartz fields in the region. These processes can only be effectively captured within a single complete drainage basin. Evolutionary processes on the quartz fields (and other hard substrata), however, require that at least two or more complete basins be conserved together with the river corridors that connect these basins. This will ensure that at least two interacting evolutionary fronts within a monophyletic lineage (e.g. *Argyroderma*) are maintained. Taking these factors into consideration, we established the following process-related targets:

- The reserve system should include at least two adjacent drainage basins that preferably together contribute substantially to the habitat targets (i.e. include substantive areas of quartz field and quartzite, shale and limestone habitats). The best options are the Grootgraafwater and the Quaggaskop/Arizona basin, a total area of 85 424 ha. To avoid selecting farms that only contribute a very small proportion to the overall basin target (i.e. <1%), the basin target was set to include at least 90% of each basin.
- In order to accommodate for more smaller-scale ecological processes, the combined area of the drainage basins in the reserve system should exceed 10 000 ha.
- The reserve system should include an area of at least 100 000 ha within a broader conservation area (including mandatory or core reserve, buffer reserves, contractual reserves, and, conservation farming buffer zones) to conserve processes that require large spatial scales.

2.3.3 Practical constraints

Two practical issues constrained the reserve design. These were:

- Owing to financial constraints, the initial core area should not exceed 50 000 ha. However, the design should be such that the reserve could be expanded, either in the form of additional core area or as areas subject to different forms of conservation management (e.g. Biosphere Reserve buffer zones, nature conservancies, etc.)
- No part of the core area should be traversed by the transport infrastructure shown in Figure 3.

2.4 Step 4. Lay out options for achieving representation and design targets

To assess options for reserve design, we used an ArcView GIS-linked software product called *Cplan* (Anon 1998). This conservation-planning tool was developed by the New South Wales National Parks and Wildlife Service to assist conservation planners to identify and evaluate spatial options for the development of conservation systems.

The programme prioritizes parcels of land (e.g. farms) based on a computed measure of conservation value, namely irreplaceability. The irreplaceability index is a measure assigned to a land parcel that reflects the importance of that area, in the context of the planning domain, for the achievement of the regional conservation target for selected biological features. Features can be vegetation types, habitats, species or spatial surrogates for processes.

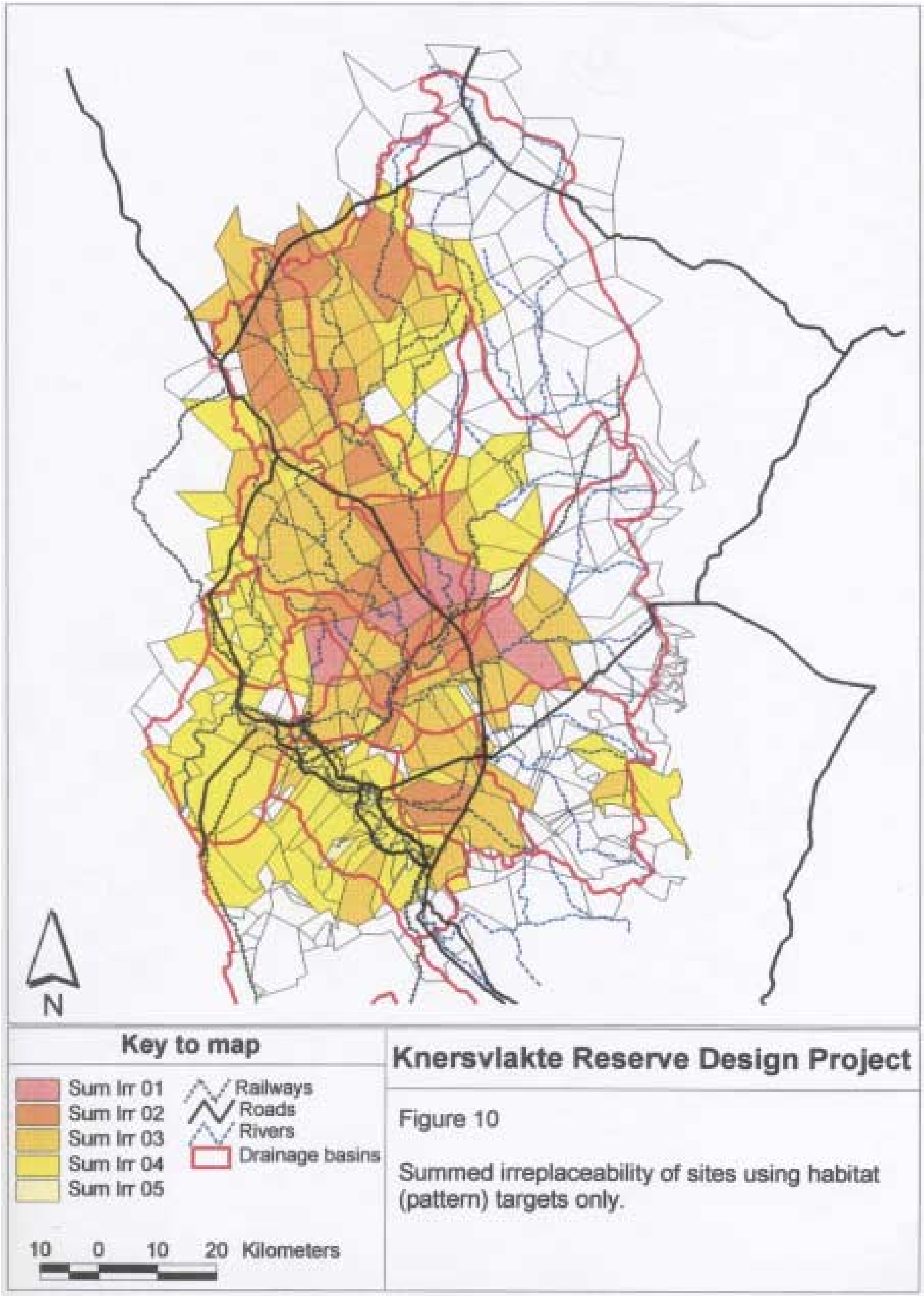
Site irreplaceability is a function of how much of each target is achieved. Thus irreplaceability can be viewed in two ways:

- The potential contribution of any site to a conservation goal or the likelihood of that site being required to achieve the goal.
- The extent to which the options for achieving a system of conservation areas that is representative (achieves all the targets) are reduced if that site is lost or made unavailable.

As land is "reserved", *Cplan* updates the irreplaceability index for each unreserved site to reflect how much that site contributes towards achieving the remaining conservation target. Sites with a high irreplaceability value are essential components of the reserve system if targets are to be met (i.e. if that site is not included in the reserve system then it is unlikely that targets will be achieved). Low site irreplaceability means that there is flexibility in terms of which sites can be chosen to achieve the target.

Cplan does not provide explicit solutions for conservation systems. It does, however, enable the evaluation of informed conservation decisions in terms of irreplaceability: after each decision, the irreplaceability of each site in the planning domain is recalculated and displayed on screen. Therefore, it is possible to objectively compare the tradeoffs between different reserve designs by comparing how each configuration contributes towards achieving a set of targets.

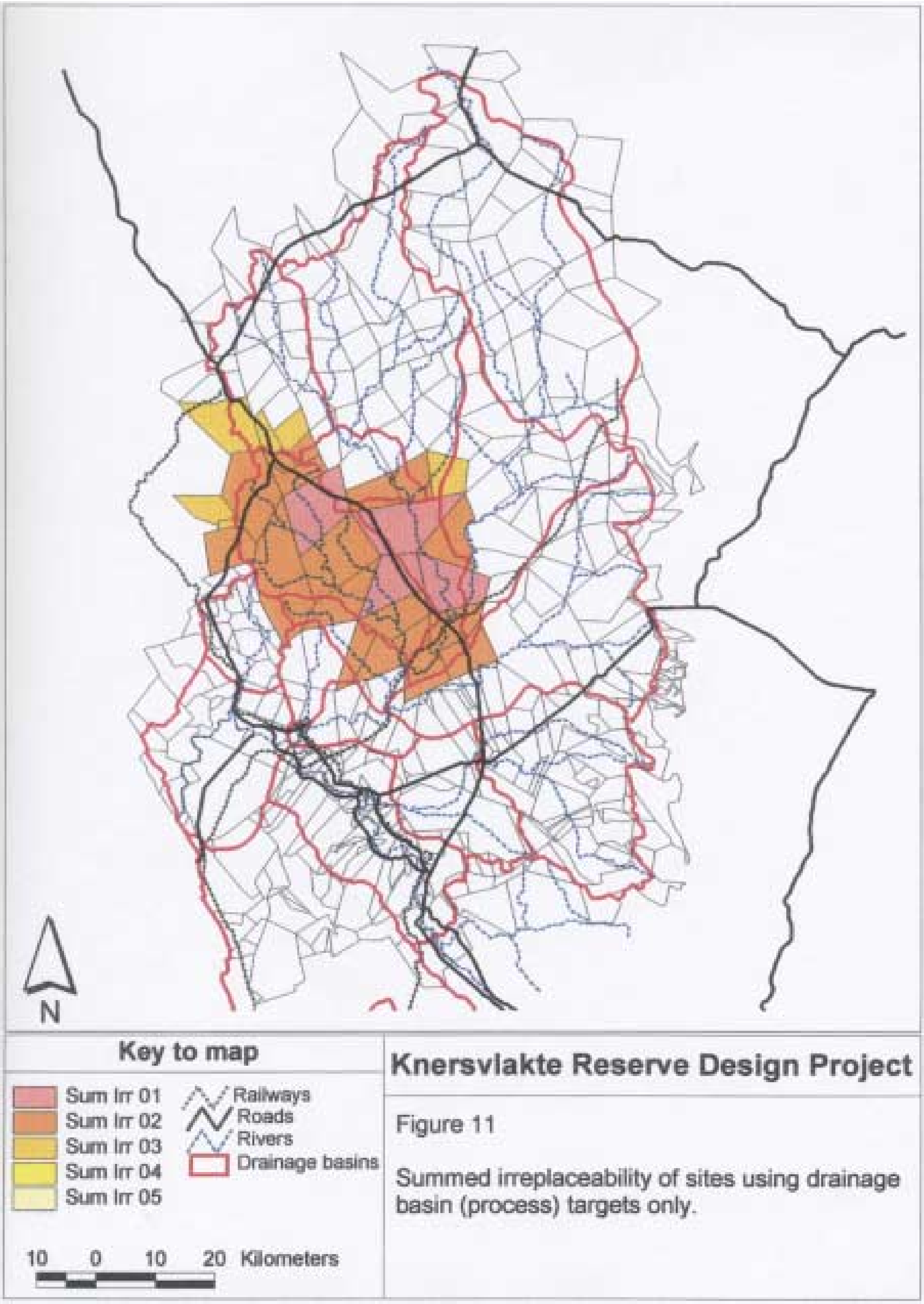
We have used *Cplan* in this study to assess the options for achieving pattern and process targets. This was done by producing maps of the summed irreplaceability (calculated by adding the irreplaceability of all features in that site (Anon 1998)) with respect to targets for pattern, process and both of these (Figures 10, 11 and 12). The application of a standard reserve selection algorithm (select the site with highest irreplaceability at each iteration) provides the minimum set of sites required to achieve all targets for pattern (Figure 13) and process (Figure 14). These spatial depictions provide the backdrop for further design that is mindful of practical and biological constraints (e.g. adjacency of sites, avoidance of transport infrastructure, buffering of core reserve) that could not be built into the targets. Thus, the final configuration does not necessarily reflect the best configuration for achieving targets, but is a compromise between achieving biological targets and real world constraints on reserve design.



Knersvlakte Reserve Design Project

Figure 10

Summed irreplaceability of sites using habitat (pattern) targets only.



Knersvlakte Reserve Design Project

Figure 11

Summed irreplaceability of sites using drainage basin (process) targets only.

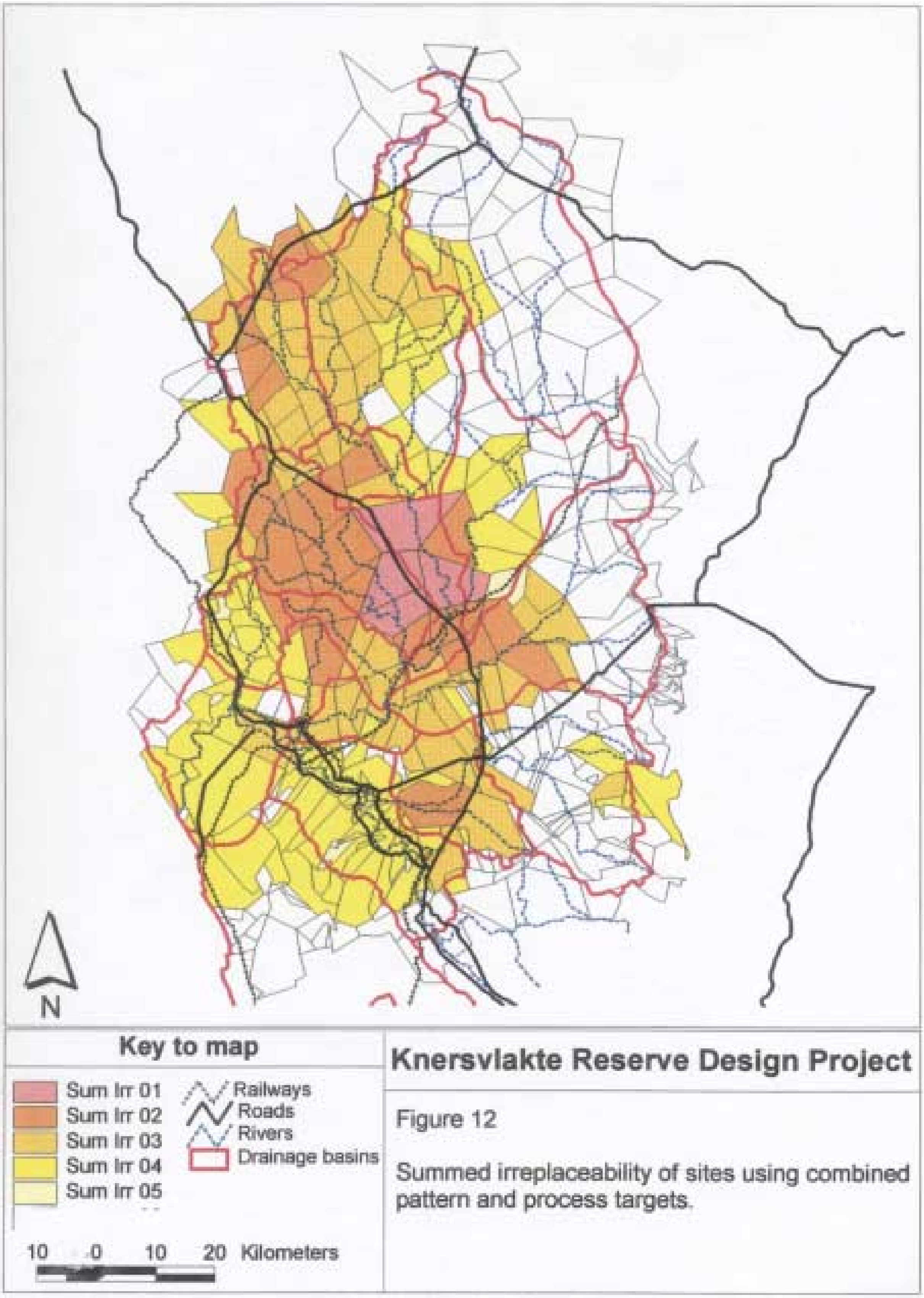


Figure 12

Summed irreplaceability of sites using combined pattern and process targets.

2.5 Step 5. Locate and design candidate conservation areas for representation and design

In this section we use *Cplan* to assess potential conservation areas to achieve the representation targets (pattern and process) in a tractable manner. In a sense, this is "real world" planning. We do this by developing a series of planning scenarios, each with its own combination of the goals and constraints discussed in section 2.3. For each scenario, we select a system of conservation areas. This system is depicted visually, showing the summed irreplaceability of land parcels excluded from the system (Figures 10-18). The extent to which the configuration achieves the pattern and process targets is also computed (Table 3).

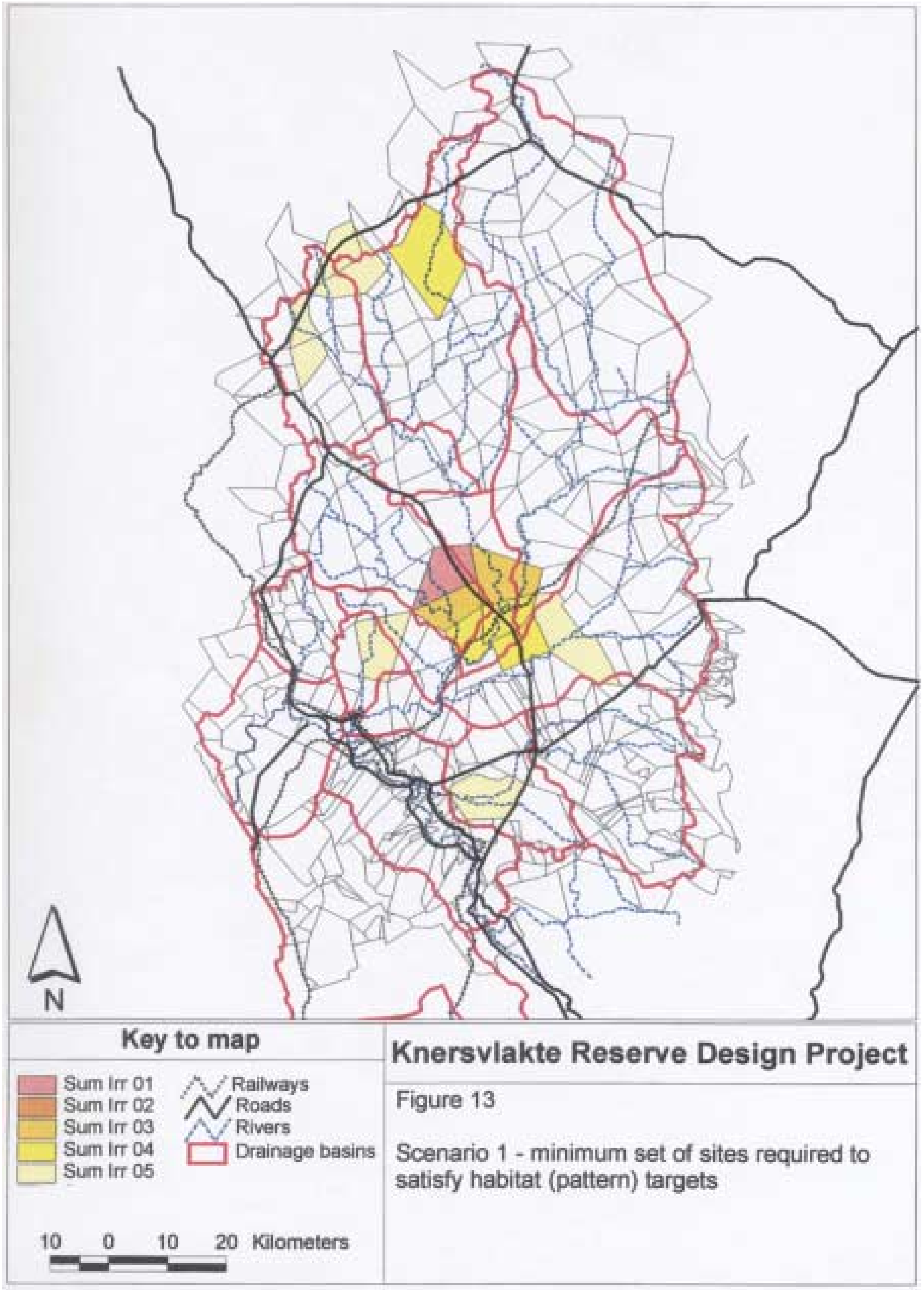
2.5.1 Scenario 1: Minimum set of sites to satisfy pattern targets (habitats).

This scenario involves the selection of the minimum set of sites required to achieve all habitat targets (Figure 13). An algorithm was used to automatically select from the list of available sites those that best satisfy all habitat targets. With each iteration of the algorithm, *Cplan* selects the site with the highest irreplaceability until the targets are met. The habitat whose target is most difficult to achieve essentially drives the selection of sites, such that in the final configuration many features are over-represented (Table 3).

Although the reserve configuration achieved all the habitat targets, shale and limestone are over represented. However, only 44% of the quartz filed centre of diversity was included in the system. Moreover, this scenario fails to achieve any process-related targets. The reserve comprises three sub-systems in the central, southern and northern centres of quartz field diversity (see Figures 7 and 8). This maximizes the number of species conserved by spreading the reserve between each of the important local centres of diversity. However, the N7 National Road and the Sishen-Saldanha railway bisect the central node. In terms of adjacency the reserve is fragmented and is not practical from a management perspective. Also, the area selected exceeds that specified by financial constraints.

Table 3 Summary of the effectiveness of the different scenarios in terms of fulfilling pattern and process targets for a Knersvlakte conservation system.

	Scenario					
	1	**2**	**3**	**4**	**5**	**6**
Pattern features						
Habitats (% of target included in reserve)						
Quartz fields	102	69	67	50	40	109
Quartzite rock	106	93	27	45	52	132
Shale rock	168	244	167	172	157	343
Limestone	100	57	75	70	50	96
Centre of diversity						
% included	43	66	52	50	38	100
No. of farms	7	9	9	8	5	16
Process features						
Drainage basins (% of target included in reserve)						
Grootgraafwater basin	26	100	33	66	80	106
Quaggaskop/Arizona basin	55	103	50	13	6	114
No. of partial basins included	9	4	4	3	3	6
No. of complete adjacent basins	0	2	0	0	0	5
Total No. of farms	14	13	9	9	7	29
Total area conserved (ha)	89 790	101 834	49 978	57 724	61 035	162 970


N
Key to map
Sum Irr 01
Sum Irr 02
Sum Irr 03
Sum Irr 04
Sum Irr 05
Railways
Roads
Rivers
Drainage basins
10 0 10 20 Kilometers
Knersvlakte Reserve Design Project
Figure 13
Scenario 1 - minimum set of sites required to satisfy habitat (pattern) targets

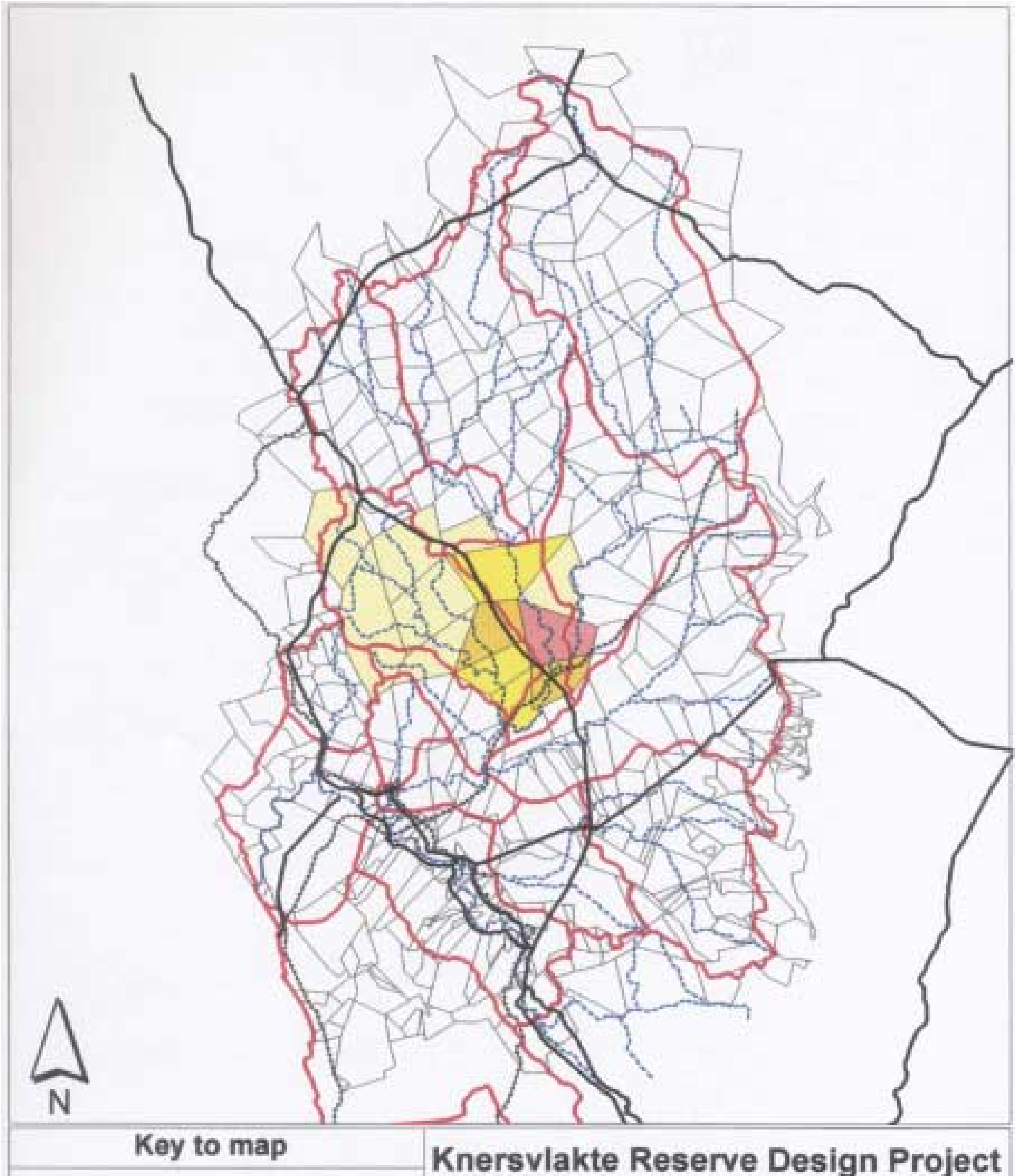


Figure 14

Scenario 2 - minimum set of sites required to satisfy drainage basin (process) targets

2.5.2 Scenario 2: Minimum set of sites to satisfy process targets (drainage basins).

This scenario uses the same selection algorithm as in scenario 1 to select the minimum set of sites required to achieve all process targets (Figure 14). Understandably this reserve looks very different to scenario 1. In addition to achieving the process targets, the reserve system identified in this scenario was relatively effective in achieving pattern targets (Table 3). However, the problem of the reserve being bisected by major transport routes persists, and the size of the selected area is larger than allowed by financial constraints.

2.5.3 Scenario 3: Pattern targets and adjacency

In this scenario we designed a single system of conservation areas (i.e. with adjacency) that would achieve pattern targets and not exceed 50 000 ha (Figure 15). This scenario does well in approaching the habitat targets and is within the aerial target set by the reserve size rule (Table 3). However, the problem of bisection of the reserve area by major transport routes persists. This scenario does not adequately satisfy process targets.

2.5.4 Scenario 4: Pattern targets and adjacency west of the N7

In this scenario we selected sites as above, but attempt to avoid the transport infrastructure problem by selecting sites mainly to the west of the N7 (Figure 16). The configuration comes close to achieving the aerial extent rule, but at the expense of the quartz field target, which falls by 17% to 50% of target achieved (Table 3). This achieved target can be considered as the absolute minimum that should be included in the core reserve. Given the route of the N7 relative to the spatial configuration of the quartz field centre of diversity, any core reserve will be forced to compromise between achieving biological targets and incorporating real world constraints.

2.5.5 Scenario 5: Scenario 4 excluding state land

Since the three state farms (Grasduin 315, Bergplaat 316 and Rooiberg 225) are subject to land claims and may not be available for conservation, we ran scenario 4 excluding these properties (Figure 17). Generally, the effectiveness and efficiency of the system in achieving pattern and process targets was considerably reduced relative to the other to the other scenarios (Table 3). Therefore, the three state farms may be considered an essential component of any core reserve system for the Knersvlakte.

2.5.6 Scenario 6: Buffer model

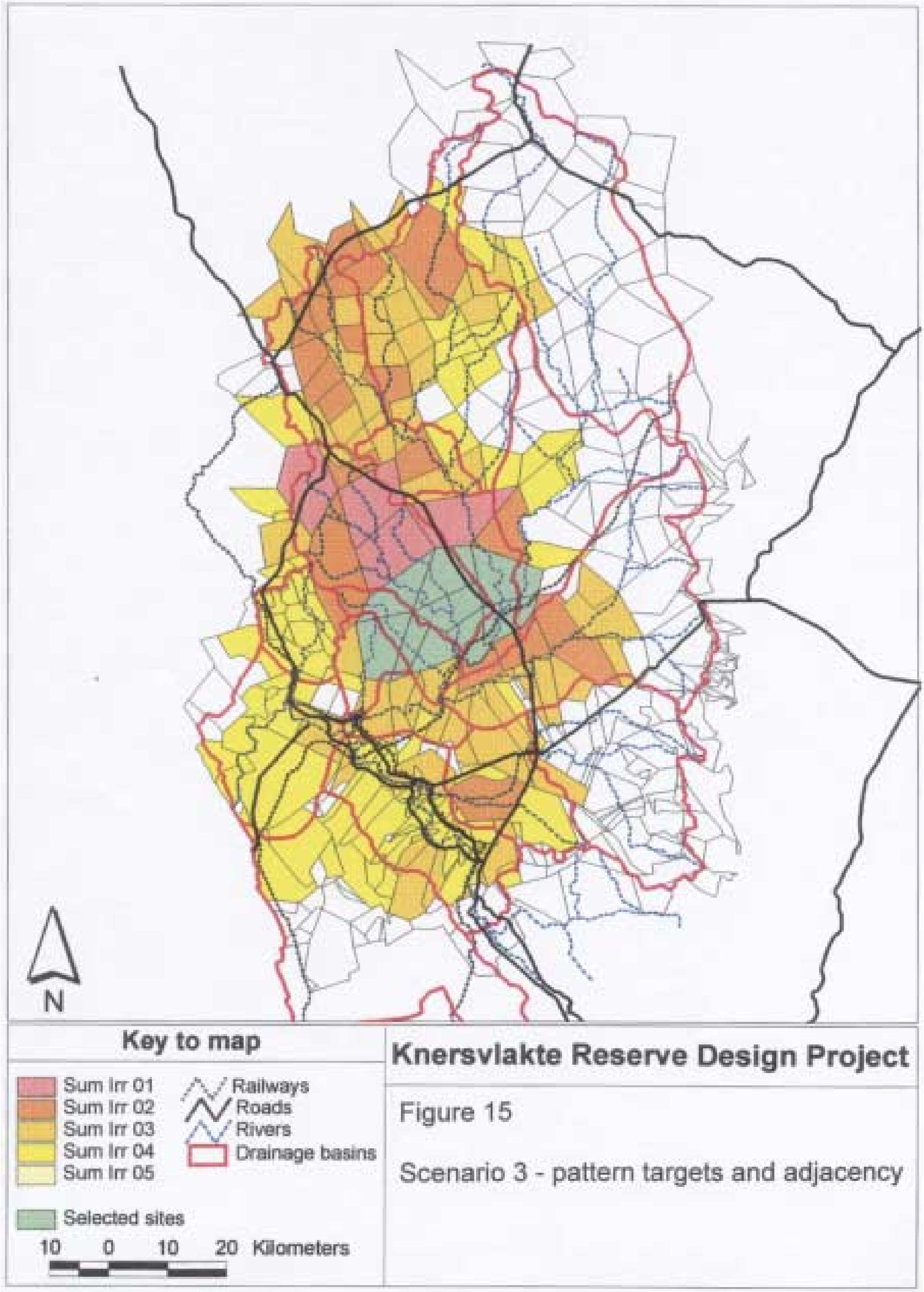
None of the pattern-based scenarios achieved the process-based targets of conserving at least two complete and adjacent drainage basins. Clearly, it will not be possible to accommodate these processes in a core reserve system of ca. 50 000 ha. Therefore, we designed a system that comprised a core reserve that most effectively and efficiently achieved pattern targets and comprised adjacent land parcels to the west of the N7 (scenario 4), as well as a buffer zone of land parcels that enable the realization of process targets (Figure 18, Table 3). Thus the buffer zone would cushion the impact of edge effects on the core. A variety of conservation-orientated land management options (conservation farming, nature conservancy, private nature reserve, Biosphere Reserve, contractual national park) would need to be enacted in order to prevent forms of land use (e.g. mining or cropping) that would negatively impact on biological patterns and processes.

2.6 Step 6. Implementation of conservation action

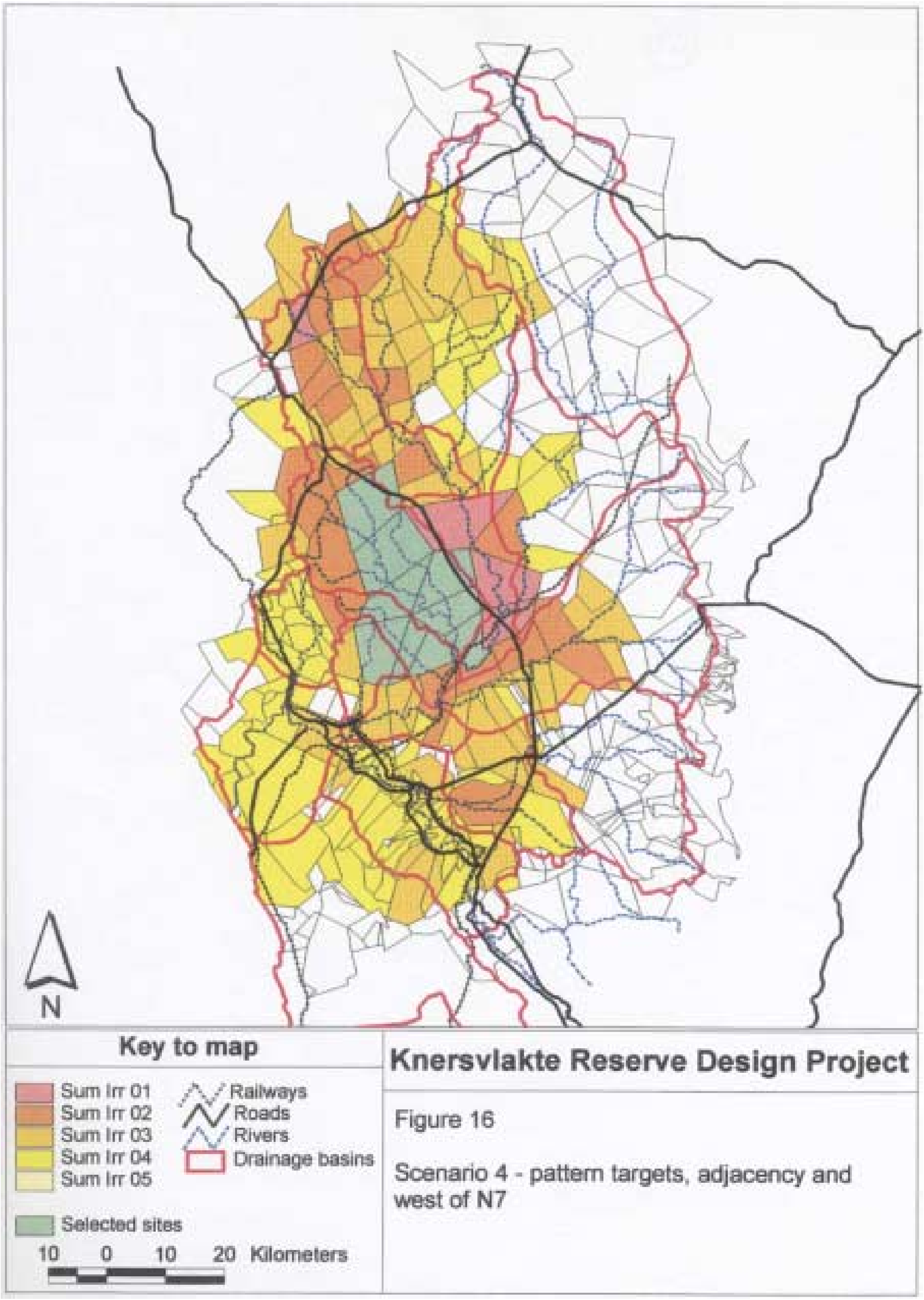
2.6.1 Step 6.1 Setting priorities on the basis of irreplaceability and vulnerability

Our brief for this study stipulated the identification of priorities (land parcels) for inclusion in the core conservation system. Priorities are usually recognized on the basis of irreplaceability and vulnerability (Pressey et al. 1995); in other words, selection units (farms) that have high conservation value for the system, but are also highly vulnerable to processes that threaten their biodiversity, are immediate priorities for intervention. Conversely, sites that have relatively low irreplaceability and vulnerability are not priorities for conservation action.

In the context of this study, the identification of priorities is a dynamic process. Irrespective of the scenario for reserve development, the establishment of the Knersvlakte conservation system is likely to be a gradual process. As different land parcels are added to the system, so does the summed irreplaceability of the remaining parcels change. Similarly, vulnerability will also change in relation to market forces and other dynamic factors that influence threatening processes. Therefore, priorities need to be re-identified after each land acquisition. Fortunately, the recalculation of irreplaceability of residual land parcels as a conservation system is being developed, is a standard routine in *Cplan.*



N
Key to map
Sum Irr 01
Sum Irr 02
Sum Irr 03
Sum Irr 04
Sum Irr 05
Railways
Roads
Rivers
Drainage basins
Selected sites
10 0 10 20 Kilometers
Knersvlakte Reserve Design Project
Figure 15
Scenario 3 - pattern targets and adjacency



Knersvlakte Reserve Design Project

Figure 16

Scenario 4 - pattern targets, adjacency and west of N7

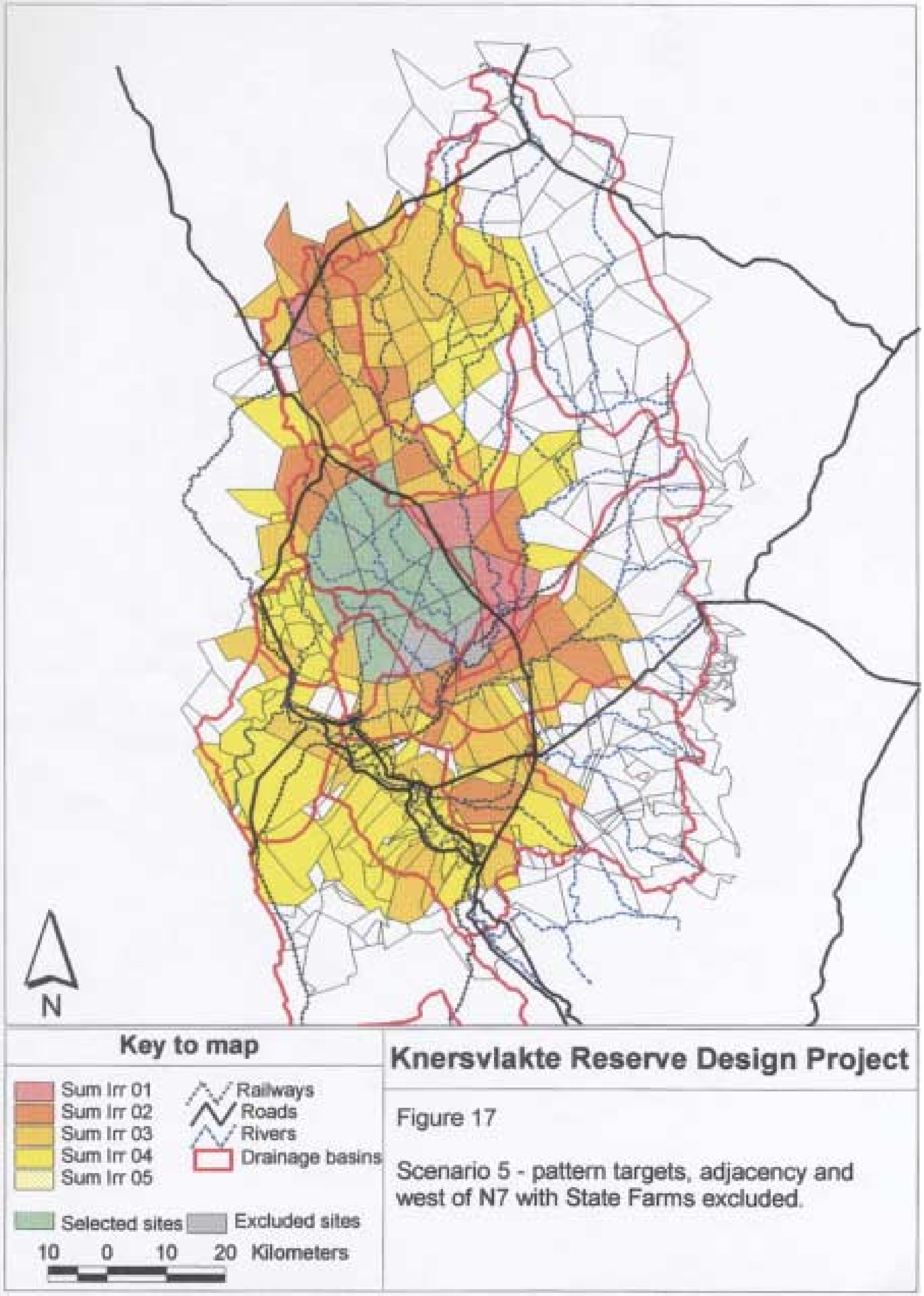


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Figure 17

Scenario 5 - pattern targets, adjacency and west of N7 with State Farms excluded.

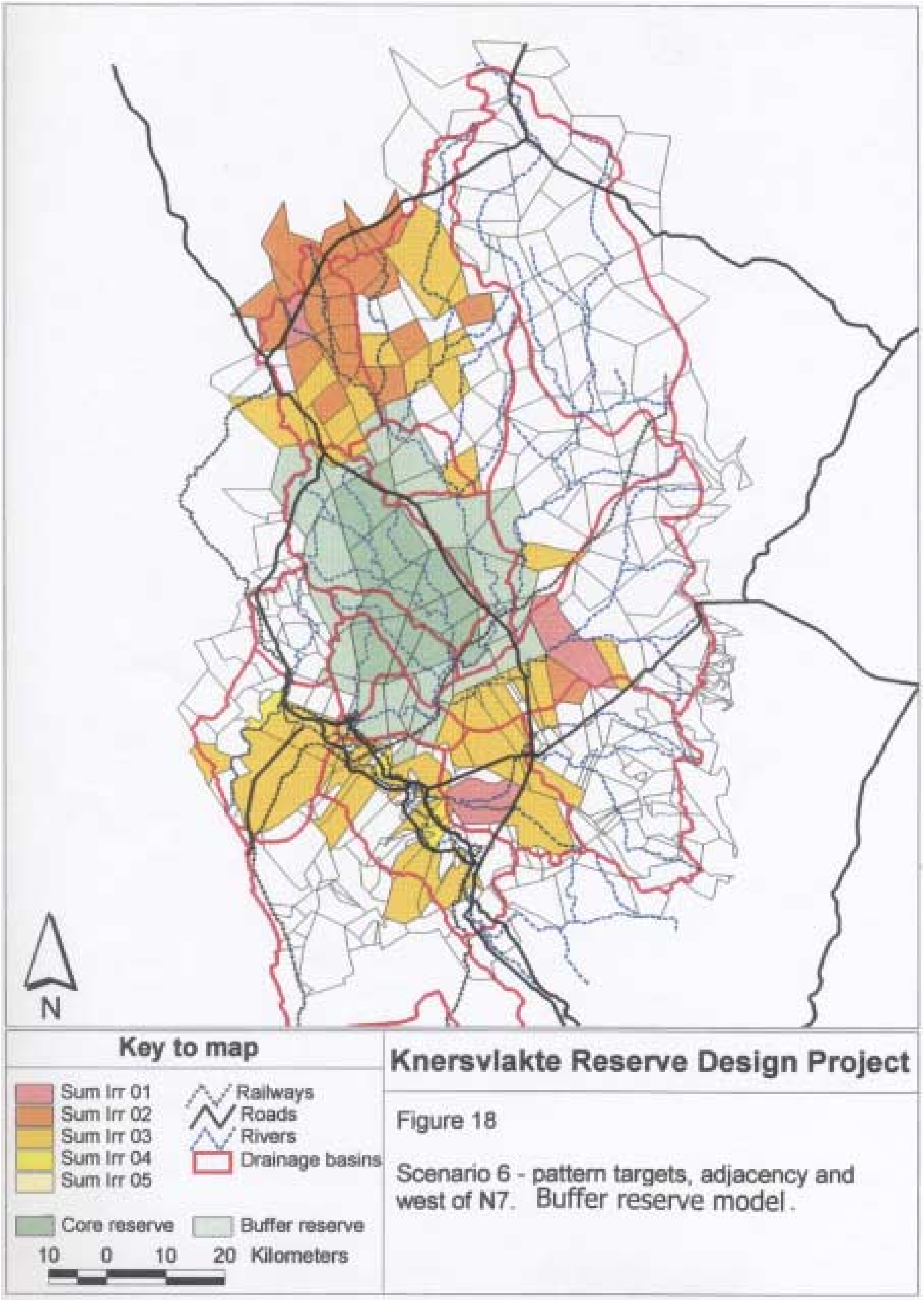

Figure 18

Scenario 6 - pattern targets, adjacency and west of N7. Buffer reserve model.

Therefore, at this stage we can only give an indication of immediate priorities for land acquisition. As all farms selected in scenario 6 are considered essential for the reserve system, immediate priorities are based on the estimate of vulnerability for each farm. Table 4 lists only the 29 farms selected for the reserve prioritized according to cropping agriculture and mining threat. Acquisition and negotiation for land should be prioritized according to the listing this table. As can be noticed, farms are prioritized from the south northwards as threats are concentrated in the southern are of the reserve (see Figures 4-6, 19 and 20).

2.6.2 Step 6.2. Allocating forms of conservation management

It was not our brief to provide recommendations on appropriate implementing agencies for the Knersvlakte conservation system, nor to provide guidelines for different forms of conservation management. However, it is clear that with regard to Scenario 6, it will not be feasible for all land to be incorporated into the formal reserve system. Consideration will have to be given to some form of off-reserve conservation (e.g. Biosphere Reserve buffer zone, nature conservancy, contractual national park, conservation farming) in order to maintain land use regimes compatible with the conservation of biodiversity pattern and process.

2.6.3 Step 6.3 Fine-tuning

This ongoing activity – principally involving re-identification of priorities as the reserve system is being developed – should be undertaken by the implementing agency using *Cplan.* Special attention must be given to the ever-changing nature of processes that threaten biodiversity pattern and process

Table 4 Priority of farms for acquisition in the core and buffer zones of the Knersvlakte protected area system based on vulnerability to cropping agriculture and mining threat. Note that summed irreplaceability is the initial value for each farm. The irreplaceability of farms is recalculated to reflect outstanding targets as farms are added to the conservation system. For each index, farms are ranked relative to others farms in the planning domain (370 parcels, regional rank 1-30; - denotes not ranked) and relative to other farms in the conservation system (rank 1-29). For regional summed minerals, farms are ranked 1-100. Cropping agricultural threat and summed mineral threat are illustrated in Figures 19 and 20.

CORE RESERVE		**Irreplaceability**				**Agriculture**					**Mining**																
Farm key field	Farm name and number	Irreplaceability of farm	**Summed irreplaceability of farm**	Weight irreplaceability of farm	Percent contribution of features on farm to achieving targets	Regional **cropping agriculture** rank	Reserve **cropping agriculture** rank	Regional **grazing** rank	Reserve **grazing** rank	Overall agricultural rank	No. of **mines**	**Extent** of mining operations	No. of **resource fields**	Regional **resource** fields rank	Reserve **resource** fields rank	Regional **diamond** rank	Reserve **diamond** rank	Regional **gypsum** rank	Reserve **gypsum** rank	Regional **limestone** rank	Reserve **limestone** rank	Regional **marble** rank	Reserve **marble** rank	Regional **summed minerals** rank	Reserve **summed mineral** rank	Overall minerals rank	**Overall rank**
920	ROOIBERG 255	0.997	**1.977**	0.173	35.73	-	9	-	25	2	4	10	4	18	3	4	2	-	7	-	7	-	4	20	2	1	**1.5**
886	WOLVENEST 212	0.999	**2.610**	0.311	36.53	-	13	-	26	4	2	6	4	19	7	-	11	-	15	-	6	-	11	71	10	2	**3**
861	LUIPERS KOP 211	1.000	**2.834**	0.314	46.22	-	17	-	27	6	-	-	3	-	14	-	14	-	9	-	11	-	12	77	11	3	**4.5**
930	GRASDUIN 315	0.396	**0.440**	0.027	24.59	-	7	-	19	1	-	-	3	-	19	-	24	-	25	-	10	-	24	-	24	8	**4.5**
929	MOEDVERLOREN 208	0.994	**1.702**	0.239	23.66	-	10	-	15	3	5	11	4	17	10	-	23	-	24	-	12	-	3	-	23	7	**5**
943	OLIFANTS R. SETTLEMENT 316 BERGPLAAT	0.482	**0.503**	0.065	55.23	-	14	-	20	5	2	3	4	22	9	-	12	-	20	-	15	-	22	-	21	6	**5.5**
817	GROOT GRAAF WATER 210	1.000	**1.347**	0.015	14.60	-	28	-	16	8	-	-	3	-	17	-	18	-	14	-	13	-	18	-	17	4	**6**
864	MOSTERT KOP 209	0.947	**1.176**	0.047	8.69	-	29	-	22	9	-	-	3	-	18	-	20	-	22	-	9	-	20	-	19	5	**7**
781	OOR-KRAAL 114	1.000	**1.449**	0.048	28.55	-	27	-	17	7	-	-	3	-	20	-	26	-	26	-	26	-	26	-	26	9	**8**

Table 4 cont.

BUFFER RESERVE		**Irreplaceability**				**Agriculture**					**Mining**																
1032	VOGELSSTRUISVLAKTE 188	0.001	**0.001**	0.000	0.03	-	1	-	1	1	2	2	4	23	4	29	7	14	2	-	2	-	5	21	3	2	**1.5**
976	ZOUTFONTEIN 178	0.559	**0.579**	0.029	3.74	-	6	-	2	6	6	12	4	16	6	19	6	-	13	-	4	-	7	44	5	4	**5**
907	QUAGGA 'S KOP 215	0.999	**2.429**	0.278	1.77	-	12	-	24	9	2	2	4	24	5	12	3	-	3	-	16	-	6	42	4	3	**6**
999	HOLRIVIER 317	0.150	**0.182**	0.005	4.07	-	4	-	6	4	4	10	3	-	13	-	13	-	10	-	5	-	10	64	9	8	**6**
862	QUAGGA 'S KOP 213	1.000	**3.087**	0.298	19.61	-	8	-	21	7	-	-	3	-	12	17	5	-	5	-	18	-	9	52	7	6	**6.5**
962	VARSCHE RIVIER EXTENTION B 226	0.668	**0.661**	0.026	5.73	-	18	-	7	12	2	5	5	1	1	3	1	6	1	-	1	22	1	6	1	1	**6.5**
991	ZOUTFONTEIN 178	0.041	**0.063**	0.001	3.74	-	3	-	4	3	-	-	3	-	15	-	15	-	19	-	3	-	14	79	13	10	**6.5**
994	HOLRIVIER 179	0.067	**0.093**	0.005	9.38	-	5	-	3	5	1	1	4	26	8	-	9	-	18	-	8	-	13	78	12	9	**7**
803	ZANDKRAAL 98	0.912	**1.099**	0.019	5.75	-	15	-	14	10	-	-	3	-	11	15	4	-	4	-	17	-	8	50	6	5	**7.5**
986	631	0.005	**0.009**	0.000	0.27	-	2	-	8	2	-	-	2	-	21	-	17	-	12	-	21	-	17	-	16	13	**7.5**
931	VALSCHE RIVIER EXTENSION A227	0.931	**1.064**	0.103	19.45	-	16	-	5	11	-	-	5	12	2	-	8	-	6	-	14	-	2	61	8	7	**9**
738	BIESJES VLEY 116	0.126	**0.158**	0.014	10.12	-	19	-	10	13	-	-	1	-	26	-	16	-	8	-	20	-	16	-	15	12	**13**
942	KLIPDRIFT EXTENSION 207	0.031	**0.046**	0.001	0.00	-	11	-	9	8	-	-	2	-	24	-	25	-	23	-	25	-	25	-	25	17	**13**
762	KAREE BERG 113	0.779	**0.763**	0.117	38.36	-	21	-	12	15	1	2	2	-	22	-	19	-	16	-	22	-	19	-	18	14	**15**
744	SPITS BERG 115	0.391	**0.380**	0.049	34.22	-	20	-	11	14	-	-	1	-	27	-	22	-	21	-	24	-	23	-	22	16	**15**
802	FLAMINT VLAKTE 111	1.000	**2.542**	0.156	12.99	-	25	-	23	19	-	-	3	-	16	-	10	-	11	-	19	-	15	-	14	11	**15**
788	BUSHMANS GRAVE 112	0.313	**0.424**	0.011	9.88	-	24	-	13	18	-	-	2	-	23	-	21	-	17	-	23	-	21	-	20	15	**17**
772	QUAGGA S KOP 125	1.000	**1.312**	0.065	24.20	-	22	-	29	16	-	-	1	-	29	-	29	-	29	-	29	-	29	-	29	20	**18**
778	DE TOEKOMST 126	0.289	**0.438**	0.004	12.35	-	23	-	18	17	7	11	1	-	28	-	28	-	28	-	28	-	28	-	28	19	**18**
809	POTKLEY 127	1.000	**1.310**	0.026	0.00	-	26	-	28	20	-	-	2	-	25	-	27	-	27	-	27	-	27	-	27	18	**19**

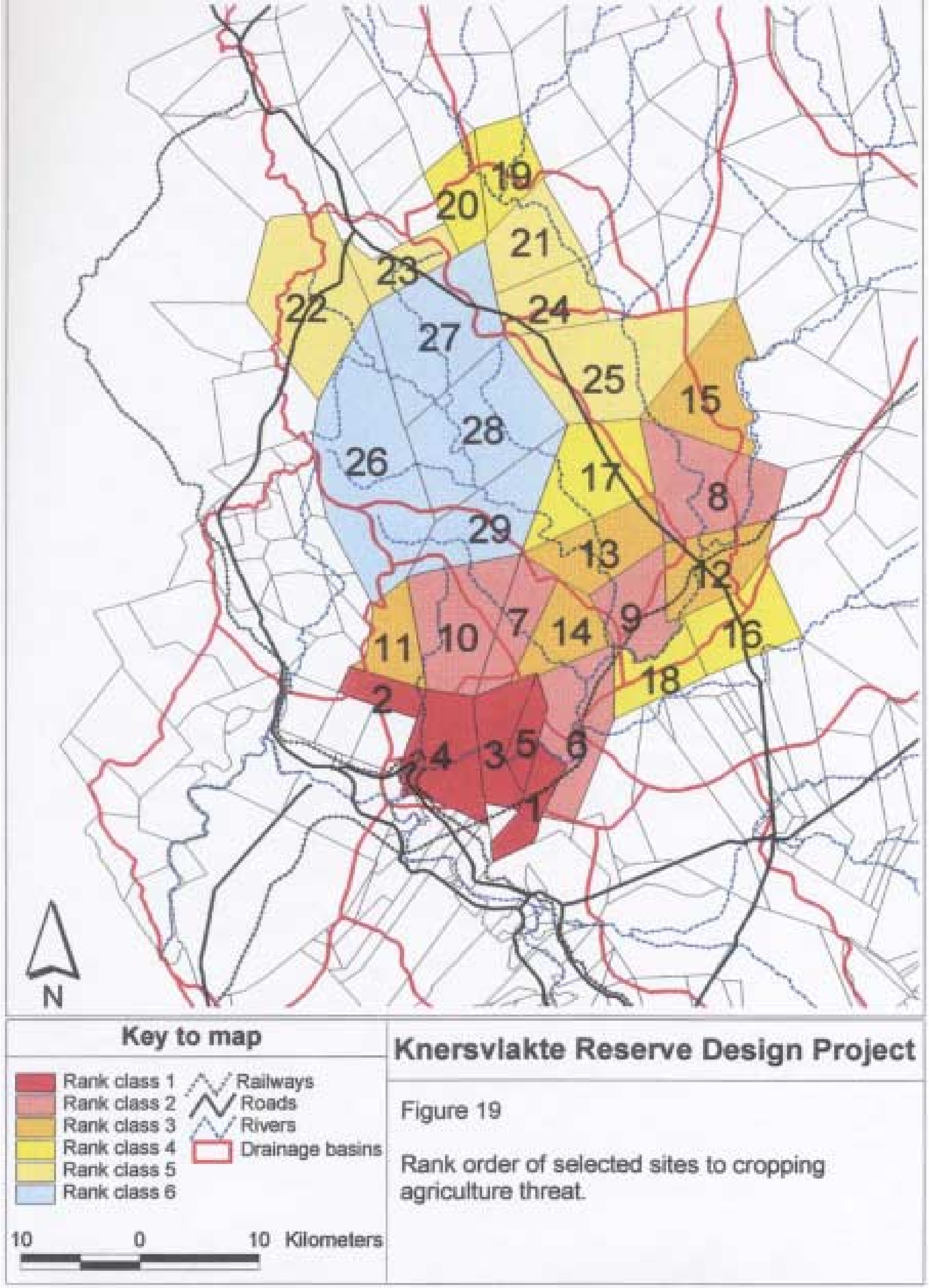

Figure 19

Rank order of selected sites to cropping agriculture threat.

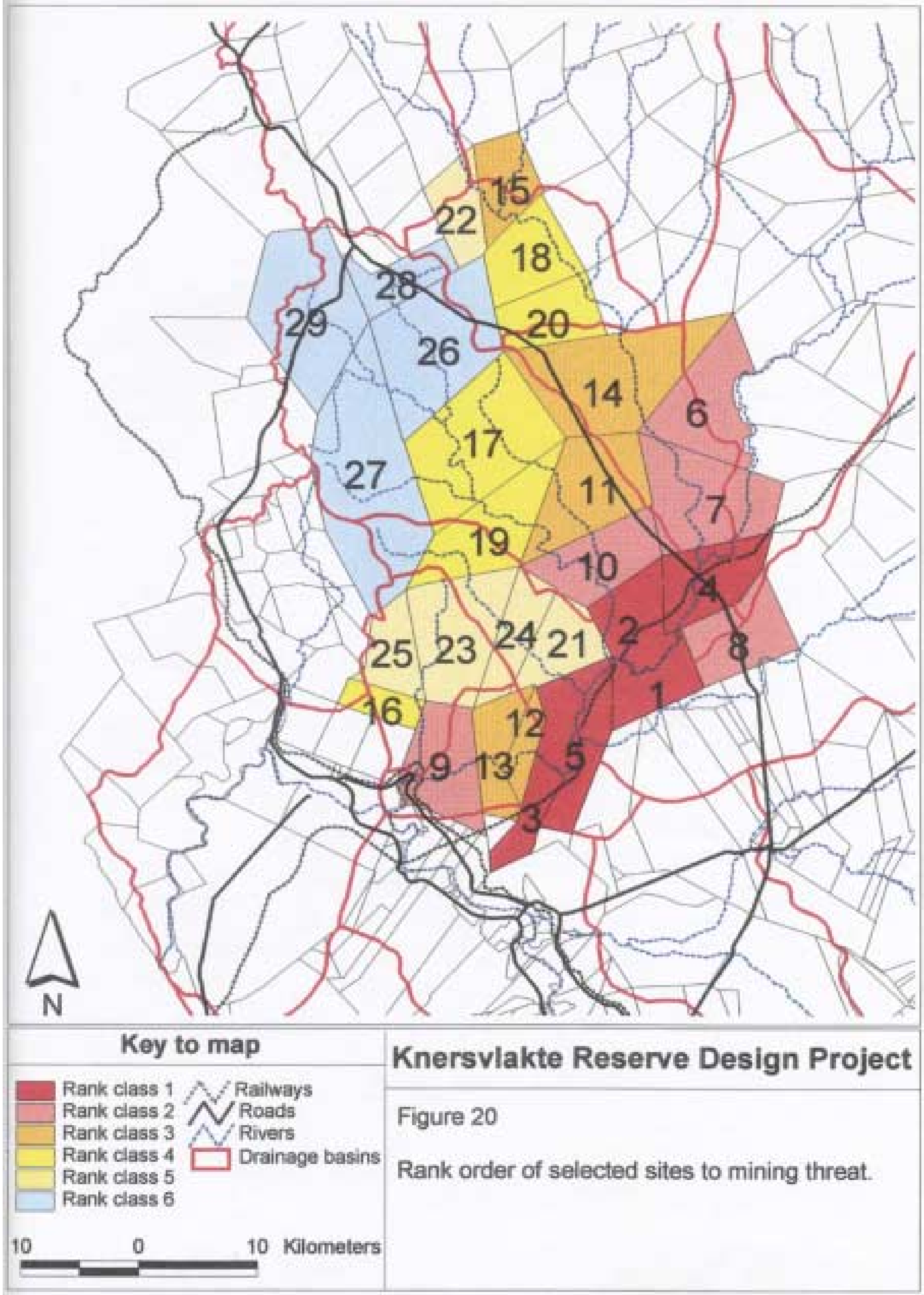

Figure 20

Rank order of selected sites to mining threat.

3 Recommendations

1. Immediate priorities for acquisition for the core reserve system for the Knersvlakte are Rooiberg 255, Wolvenest 212, Luiperskop 211, Grasduin 315 and Moedverloren 315. Priorities for inclusion in the buffer zone are Vogelsstruisvlakte 188, Zoutfontein, 178, Quagga's Kop 215, Holrivier 317 and Varsche Rivier Extension B 226.
2. Threatening processes, especially mining of limestone and gypsum and prospecting for diamonds, must be taken very seriously in terms of priority setting.
3. The implementing agency (IA) needs to re-examine the threat analysis by introducing economic forces into the weighting of individual threats. This will also help refine the list of implementation priorities.
4. The IA must become acquainted with *Cplan* software and use this in setting priorities for land acquisition.
5. The IA needs to initiate negotiations and consultations with stakeholders as soon as possible, preferably via stakeholder meetings.
6. The IA needs to consult the relevant state and provincial departments dealing with mineral and agricultural affairs in order to avoid practices that will threaten the integrity of the proposed park.
7. The IA will also need to consult the Department of Land Affairs regarding the inclusion of the irreplaceable state farms in the reserve system.
8. Consideration must be given by the IA regards conservation action for the sites of interest discussed in Appendix 2.

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Appendices

Appendix 1 Spatial components for key ecological processes considered in the reserve design process

	Processes	Scales		Human
		Spatial	Temporal	perspective
1 Abiotic				
1.1 Climate				
1.1.1 Rainfall	• Spatial variation in rainfall	>10 000 ha	seasonal	static?
	• Climate change	>10 000 ha	geological	static?
	• Dispersal (see below)			static
	• Drought (see below)			
1.1.2 Fog	• Temperature moderation and alternative source of moisture for plant growth.	individual plant	daily, seasonal	static
	• Greater diversity of habitats in areas with both high and low lying areas that get fog.	>10 000 ha	evolutionary	static
1.1.3 Wind	• Long distance dispersal.	all levels	daily, seasonal	active
	• Wind erosion of exposed surfaces, e.g. sand fields.	1 ha upwards	seasonal to geological	active
	• Redistribution of plant organic matter influences nutrient cycling, plant recruitment and patchiness.	<0.1 ha	seasonal	active
1.1.4 Temperature	• temperature gradient perpendicular to coast	>10 000 ha	evolutionary/geo logical	static
1.2 Geological				
1.2.1 Erosion	• Fluvial	<10 000 ha	seasonal to geological	active
	• Aeolean	>10 000 ha	seasonal to geological	active
1.2.2 Tectonics	• Continental uplift	>100 000 ha	geological	static
	• Local tectonics	>10 000 ha	geological	static
1.2.3 Lithology	• Quartz veins a source material for quartz fields.	>1000 ha	geological	fixed
	• Mosaics of different substrata maintain ecological (edaphic)	1 ha upwards	geological	fixed

	diversification of poorly-dispersed lineages.			
	• Distance between rock refugia for bulbs from predation (see below).	max distance related to pollinator type and distance pollen moved	geological	fixed
	• Grassland vegetation on SAND (Sandveld) is a keystone plant habitat as it is an important summer grazing resource and breeding ground for intra-karoo migratory birds.	10 000 - 100 000 ha	seasonal to geological	active
1.2.4 Pedological	• Soil formation and its contributes to habitat mosaic.	<0.1 ha	geological (but see below)	static?
	• Soil ecological processes as influenced by other processes such as wind erosion, trampling.	<0.1 ha upwards	seasonal to decades	active
1.2.5 Hydrological (geohydrological)	• Saline vs. fresh water rivers as two very distinct riparian habitats for plants.	>100 000 ha	(seasonal) climatic to geological	static (active)
	• Fresh water riverine wash plant communities are important refuge habitat many invertebrates and vertebrates.	<0.1 – 100 ha	geological	static
	• Run-off		seasonal	active
	• Saline seepage areas as important breeding habitat for insects.	<0.1 - 1 ha	seasonal? climatic	active
2 Biotic				
2.1 Dispersal	• Mammal – baboons also important agents of disturbance.	< 10 000 ha	daily to seasonal	active
	• Reptiles (tortoises – although not shown yet is suspected) What is a tortoises home range?		daily to seasonal	active
	• Birds – mostly frugivores and granivores which are probably very nomadic.	>100 000 ha	daily to seasonal	active
	• Water (passive dispersal) movement of seed to inter-plant fields and within community to down-slope within drainage basins.	<0.1 – 10 ha	seasonal to decades	active
	• Wind (passive dispersal) of seed within communities and between rock outcrops and drainage basins.	<0.1 - >1000 ha	seasonal	active
	• Ants	<10 ha	seasonal	active
	• Long-distance by migratory birds and raptors.	>1 000000 ha	seasonal to decades	active
	• Rock outcrops in the sides of incised river valleys provide	>10 000 ha	decade to >100	active

	stepping stones for lithophilus plants.		years	
	• Quartz fields associated with erosional surfaces on the banks of rivers are important stepping stones for plants restricted to quartz patch habitats.	1000 ->10 000 ha	decade to >100 years	active
	• River corridors act as important seed vectors.	>10 000 ha		
2.2 Seed-bank dynamics	• Dispersal (see above)	<100 ha	seasonal	active
	• Longevity	<0.1 ha	seasonal	active
2.3 Pollination This is a very important component of ecological-evolutionary reserve design for plants	• Pollinator biology - where do they eat, what are their food requirements (pollen, nectar, blood), where do they breed? Scale of process dependent on type of pollinator and how feeding habits relate to breeding requirements.	Small distance pollinator (e.g. solitary bees) - <0.1 to 10 ha Long distance (e.g. honey bees) – 10 to >1000 ha	daily to seasonal	active
	• How far does pollen move? (pollinator behavior, very dependent on type of pollinator)	<0.1->1000 ha	daily	active
2.4 Population biology	• Competition	indiv. plant	daily to seasonal	active
	• Facilitation	indiv. plant	daily to seasonal	active
	• Succession	indiv. plant	seasonal to decade	active
	• Recruitment	indiv plant	seasonal to decade	active
	• Death	indiv. plant	seasonal to decade	active
	• Nurse plants	indiv. plant	seasonal to decade	active
	• Patch creation (see below).	indiv. plant to <0.1 ha	seasonal to decade	active
	• Phenology (see pollination).	indiv. plant	seasonal	active
	• Minimum viable population (small, short-lived, high density succulent or geophyte, e.g. *Oophytum oviforme*).	1 ha	seasonal to decade	active
	• Minimum viable population (large, long-lived, low density succulent, e.g. *Euphorbia schoenlandii*).	100 ha	decade	active
2.5 Primary production	• Photosynthesis by higher plant.	indiv. plant	daily to	active

	• Photosynthesis by biogenic crusts (algal mats).	<0.1 ha	seasonal daily to seasonal	active
2.6 Herbivory and the role consumers play in nutrient-cycling especially decomposition	• Episodic herbivore outbreaks (e.g. locusts swarms, springbok migrations)	100 - >100 000 ha	seasonal to decade	active
	• Resident invertebrate grazing (from caterpillars to monkey beetle herbivory of flowers).	<0.1 – 10 ha	daily to seasonal	active
	• Rodents (seed collection & herbivory, fossorial rodents) RESIDENT HERBIVORES	<0.1 – 10 ha	daily	active
	• Mammals (e.g. small antelope, sheep, goats and cattle in the absence of large indigenous ungulates). MIGRATORY HERBIVORES	0.1 – 1000 ha	daily to seasonal	active
	• Harvester termites could be the largest consumers of plant biomass in the system - keystone consumers? RESIDENT HERBIVORES	<0.1 – 10 ha	daily	active
2.7 Patch creation (disturbance regimes)	• Living plants	individual plant	decade	active
	• Dead plants	individual plant	decade	active
	• Ants	<0.1 ha	decade	active
	• Harvester termites and the creation of heuweltjie and inter-heuweltjie habitat matrix.	<100 ha	decade to >1000 years	active
	• Burrowing by other arachnids.	<0.1 ha	daily to seasonal	active
	• Rodent foraging creating disturbances and eating bulbs (e.g. porcupines – their digging is probably a keystone process in the life-history or many geophytes).	<0.1 – >1000 ha	daily to seasonal	active
	• Fossorial rodents and other animals turning over soil and creating fields (e.g. golen moles, elephant shrews, whistling rats, ground squirrels).	<0.1 – >1000 ha	decade	active
	• Large burrowing mammals create large disturbances replicated over a much larger areas and require larger areas to maintain minimum viable populations (e.g. aardvarks, bat-eared fox, suricates).	<0.1–>10 000 ha	daily to seasonal	active
	• Large mammal migration and maintenance of viable populations of large ungulates and predators (e.g. rhino and	>100 000 ha.	decade	static

	leopard).			
2.8 Nutrient cycling	• See decomposition by animals, inverts and soil fauna. • Redistribution of nutrients by water and wind – this is a keystone process in arid lands (see Tongway and Reynolds) see above under abiotic section for spatial context.	<0.1 to 100 ha	daily to seasonal	active
2.9 Soil biological processes	• Biogenic crusts	<0.1 ha	daily to seasonal	active
	• Decomposition	<0.1 ha	daily to seasonal	active
	• Symbiotic relationships (mycorrhizal relationships).	<0.1 ha	daily to seasonal	active
2.10 Evolution	• Allopatric speciation where "species" are separated by geographical distance such as different drainage basins or mountain ranges.	>10 000 ha	seasonal to >1000 years	active
	• Sympatric speciation where "species" occupy separate niches across adjacent habitat (e.g. geological or catenal sequences).	<0.1 ha upwards	seasonal to >1000 years	active
	• Whole minor drainage basins associated with quartz fields maintain presumed evolutionary fronts, distinct between basins, consisting of different nested clades of derived taxa •	10 –10 000 ha	seasonal to >1000 years	active

Appendix 2 Special features.

Several landscape features in the Knersvlakte planing domain area are discussed here. These features were not explicitly included in the reserve design process via explicit targets or rules. These features are, however, considered to warrant conservation effort due to their unique physiographical nature, biological properties or aesthetic. Thus, assessments are based on biological or aesthetic value judgements rather than on a set of objectively derived, regionally explicit targets for a particular feature. Where these features fall within the proposed reserve they serve to strengthen the argument for these areas being included. Where these features fall outside the proposed reserve, special conservation action over and above efforts directed towards establishing the reserve is proposed. This action could be at the level of provincial or private nature reserves, or conservation orientated farming practices.

Jaagtleegte Basin

The most westerly of the Knersvlakte drainage basins that contains significant quartz fields (Figure 21 site1). This basin is a fairly small, discrete area of quartz fields surrounded by Sandveld and gneiss mountains. It is located on **Farm 630** adjacent to the Namaqua Sands Koekenaap processing plant and is bounded in the west by the Koekenaap – Brandsebaai road. This basin is a discrete entity, isolated from other similar habitat to the east. Maintianing the integrity of this basin would allow evolutionary processes to continue within the basin. This basin could be linked via intervening Sandveld habitat to the adjoining Moedverlooren basin, however, as the Jaagleegte River drains into the lower Olifants River there is no possibility of connecting basins via a river corridor.

Wiedou Basin

The most southerly of the major Knersvlakte quartz rich basins, this basin contains a significant area of very good quartz field development around the confluence of the Wiedou and Troe-Troe rivers on the farm **Vaderlandsche Rietkuil 308** (Figure 21 site 2). Other interesting features associated with this basin is the spectacular gorge that the Wiedou carves through limestone cliffs after the confluence of the two rivers; and, the high density of iron pebbles that are mixed with the quartz. On a satellite image this basin appears black whereas all other basins in the Knersvlakte appear white. The main area of quartz field development located between Aties and the gorge. Mining of this iron has resulted in extensive damage to the basin in places. Present mining operations for limestone in the gorge is having a significant impact on the vegetation of the area. The remote nature of this basin make it impossible to include within the proposed reserve, however, the uniqueness and extent of the quartz fields on the farm Vaderlandsche Rietkuil warrant some form of conservation action.

In addition to the quart fields in this basin, there are extensive limestone outcrops. In order to achieve the target set for limestone it will be necessary to conserve some of the remaining limestone habitat in this basin.

Rooiberg Hills and Beeswater

This area is one of the most physiographically heterogeneous in the Knersvlakte region (Figure 21 site 3). In addition to the quartzite and shale Rooiberg hills, there are significant limestone outcrops in the area; large river valleys of the Sout (brak water) and Grootgraafwater (fresh water) Rivers; and, many well developed quartz fields. Between Beeswater and the Hol River there is a high cliff on northern bank of the Sout River, which cuts into the proto-Orange sediments that fill parts of the

Knersvlakte. These cliffs are capped by bands of river gravels, 100m above the present river channel! On top of these cliffs lies a large area of aeolean sands. From the natural landscape perspective, this area is certainly the most diverse in the Knersvlakte and should be included in the reserve.

Sout River Canyon

Between the N7 and Beeswater, the Sout River cuts an impressive canyon through the landscape (Figure 21 site 4). This essentially forms the southern boundary of the farm Rooiberg. This is an exceedingly interesting and unexplored terrain, a unique feature in the regional landscape that would add to the attractiveness of any reserve.

Spiny-grassland Sandveld

Free draining, neutral sand habitats adjacent to the Olifants River have the potential for irrigated crop farming and thus are under considerable threat of transformation (Figure 21 sites 5a & 5b). Strandveld vegetation types are widespread throughout the coastal plain of Namaqualand, however, the most eastern extremes of the Sandveld in the Knersvlakte are occupied by a unique Spiny-grassland vegetation type. As this vegetation is unrelated to the quartz flora it was not directly targeted by this project. The Spiny-grassland vegetation in the Knersvlakte is the best example of this vegetation type in Namaqualand. The dominance of perennial grass species (*Cladoraphis spinosa* and *Stipagrostis zeyheri*) contrasts greatly to the shrub dominated Succulent Karoo vegetation types that surround this vegetation. The proposed reserve conserves a significant proportion (10% of Knersvlakte extent) of this vegetation in the southern buffer zone between Moedverlooren, Beeswater and the Sout River **(Moedverloren 208, Olifants Rivier Settlement 316 Bergplaat,**

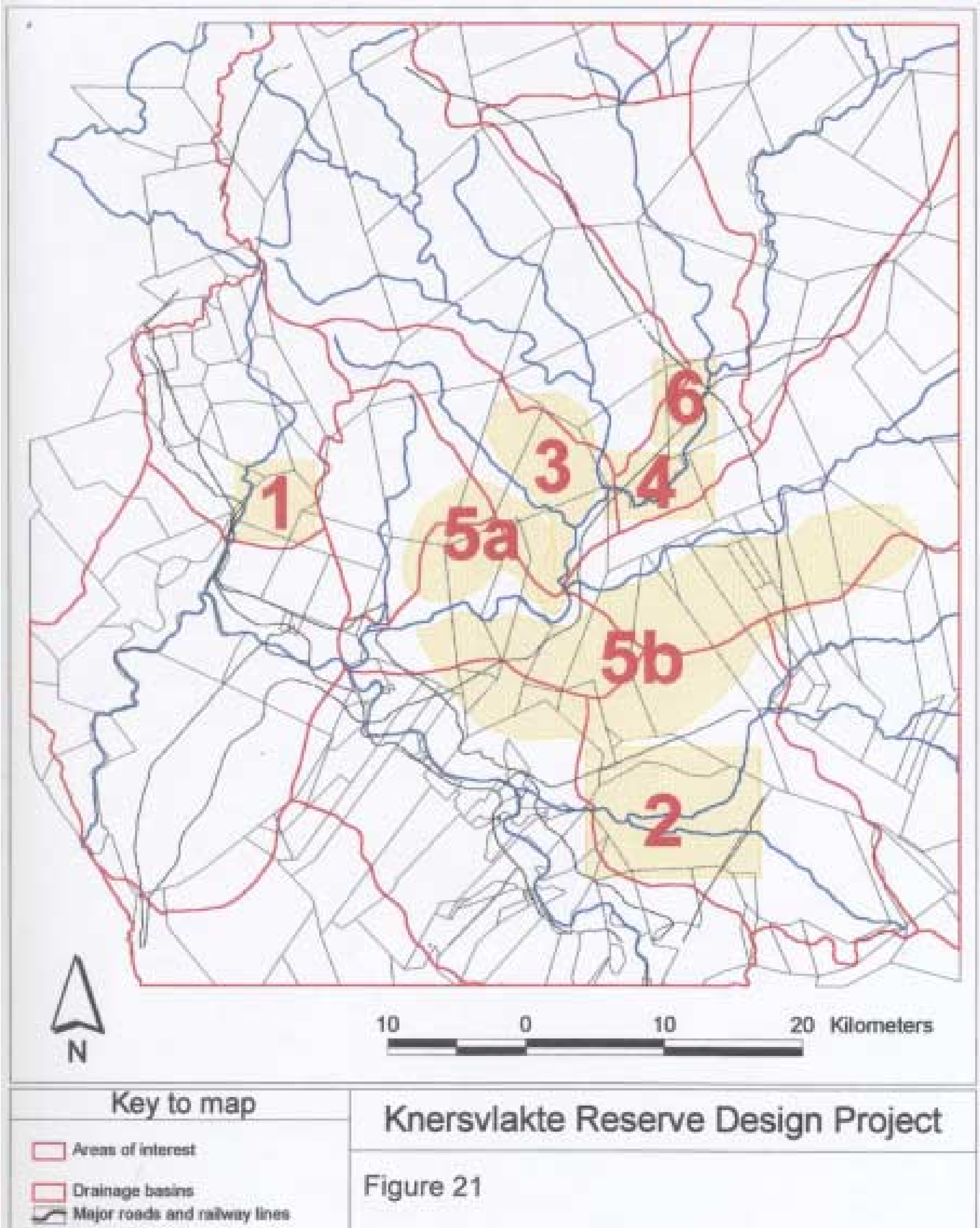
Holrivier 317, Grasdiun315, Holrivier 179, Zoutfontein 178 (1) and Zoutfontein 178 (2)).

Quaggaskop private nature reserve

The private nature reserve on the farm **Quagga's Kop 215**, in the north western corner of farm name lying north of the Sishen-Saldanha railway and west of the N7, is a fantastic benchmark reserve of what quartz fields should look like in the absence of grazing ungulates (Figure 21 site 6). The reserve borders Rooiberg and every attempt should be made to include this reserve in the core area of the reserve.

Knersvlakte north of the N7

The quartz fields and quartzite mountain to the north of the N7 have for the most part not been included in the proposed reserve. Significant extents of these habitats exist in this region (see scenario 1, Figure 13). A major distinction between the northern Knersvlakte and central and southern area, though, is the degree or extent of threatening processes. The north is significantly less threatened by land transformation (Figures 4-6), thus the need to formally conserve areas is less urgent. The presence of unique features in the landscape - quartz fields and quartzite mountains - warrants the implementation of conservation orientated land management practices such as through a nature conservancy.



Knersvlakte Reserve Design Project

Figure 21

Location of sites of interest not explicitly considered by targets.

Appendix 3 A list of 370 farm numbers, names and areas that fall within the planning domain.

Key field	Farm name	Area (ha)	Key field	Farm name	Area (ha)
541	DOOD DRINK 406	6578	993	798	449
543	NUWEFONTEIN 6	11712	994	HOLRIVIER 179	1657
561	OBEEB 8	11706	997	246	8023
569	REM NIEUWEFONTEIN CLW. O. 8.8	83	998	249	233
575	UITKYK 9	11578	999	HOLRIVIER 317	5710
576	RIETMOND 24	9373	1000	633	1592
581	DAAUWS 404	6508	1001	250	328
585	AASVOGEL KOP 403	7271	1002	317	6958
590	HAARBEEN 23	10540	1003	DROOGE RIVIER 243	2452
595	KOKER BOOM KRAAL 13	6437	1004	DIE KAMP 447	5124
604	DE PUT 69	6716	1005	330	820
608	GROOT KLIP 16	16871	1006	799	502
609	ROODE KLOOF 14	2409	1007	246	2332
615	LIESLAP 21	8587	1008	260	306
617	BRAKFONTEIN A 30	3238	1009	621	1774
625	BEZONDERHEID 61	4180	1011	KLEIN KOBE 335	3514
627	LANGEDAM 35	6968	1012	256	8589
628	TAFELBERG 64	13635	1013	282	1969
635	VOLSRUISFONTEIN 34	4723	1014	VARCHE RIVIER 260	4288
636	WIELSPOOR 73	1929	1015	317	330
640	BESONDERHEID A 63	5921	1016	PALMIET FONTEIN 331	1811
641	SAMUELS VLAKTE 81	3214	1017	?	48
645	ROODE SLOOT VLAKTE 123	4899	1024	DUINEN 258	1068
646	UILKLIP	4748	1025	RASKRAAL 255	5090
648	ROODE WAL 74	3054	1026	617	1980
653	ZUID GROOT KLIP 18	2446	1028	318	1948
654	LANG DAM EXTENSION 36	1442	1030	THE CAMP 329	671
657	BEEST VLAKTE 60	2425	1031	334	149
658	SPRINGBOKVLAKTE 82	2990	1032	VOGELSSTRUISVLAKTE 188	2289
659	TAFELBERG EXTENSION NO 1 60	1610	1033	?	87
662	TAFELBERG EZTENSION NO 2 67	1511	1034	553	106
663	DROOGE HOUTS BERG FLATS 331	6786	1035	DROOGE RIVIER EXTENSION 328	1246
664	LEEUW KUIL 75	2869	1037	618	2561
665	WOLVEGAT 39	5899	1040	341	589
669	DROOGE HOUTS BERG VLAKTE 83	7963	1041	TIGER BERG 342	2420
670	ROODE KLOOF 57	2951	1042	?	20
671	ALEWYN VLAKTE 79	2813	1043	DIEPE KLOOF 332	2353
672	KRUISPAD 72	2530	1046	TROE TROE 259	2431
674	GOUD VALLEI 50	2887	1047	245	164
675	TOONJES VALLEI 51	2364	1048	KOBE 333	9834
677	BUSHMANS GRAAF WATER 68	2827	1049	0	184
678	VLENNIES KRAAL 56	2592	1050	EBENEZER KOLONIE 187	18225
679	MENSCHLEIF 52	2388	1054	ZANDKRAAL A 180	462

685	KLEIN BANKEN 59	2390
686	EEN KOKER BOOM VLAKTE 76	2842
690	BANKEN 58	2957
691	STEENKAMPS KRAAL 70	2168
692	ONDER BLAAUW KRANTZ 53	2002
693	DUIKER VLAKTE 78	3948
694	KALK GAT VLAKTE 84	7246
696	MELKBOSCH VLAKTE 71	4111
697	KANAKIES 332	8115
698	BAKOONDKOLK 285	3455
699	BRANDEWYNS KRAAL 69	2981
704	BREEKTAND 55	3288
705	HINGS VALLEI 49	3261
707	ZOOVOORBY 77	4236
708	VLERMUIS GAT 104	2661
711	NABEEB 103	2924
712	BITTERFONTEIN 47	4339
713	KRANTZ KRAAL 48	2971
714	OORST VLAKTE 103	3658
717	?	3964
718	THIAARTS VLEY 117	3952
719	DROOGTE KRAAL 100	3790
723	HELPMEKAAR 101	2323
725	STINK FONTEIN 461	10634
726	KLIP GAT NOORD 91	3642
728	VINKELS KOLK 118	2548
729	NIEUWHOUDIS NAAUWTE 119	2634
730	STRUISVOGEL VLAKTE 105	3143
734	GRAAITJIES GAT 107	4191
735	BITTERFONTEIN 47	7878
736	KALK GAT 85	6121
738	BIESJES VLEY 116	3474
739	JAKKALS DRAAI 92	5065
741	DRIE KUIL 120	2451
743	ROODE BERG 121	1899
744	SPITS BERG 115	3191
749	TREKKERS DRAAI 109	4912
752	UITKYK 107	4065
757	SPRINGHAANS KLOOF 124	1681
759	KLIP GAT ZUID 90	2484
762	KAREE BERG 113	4543
763	462	1934
766	KLIPDRIFT EXTENSION 93	3892
767	KLIPDRIFT 94	2197
769	GEMBOK RIVIER OOST 86	4326
770	PERDEKRAAL 464	5273
772	QUAGGA S KOP 125	10075
773	ERT VARK GAT 122	1244
774	EENZAAMHEID 108	4225

1055	BAKKELY PLAATS 282	1203
1057	257	484
1060	ZOETVLAKTE 189	473
1061	BAKLEIPLAAS B	2032
1062	615	2828
1063	SWARTRUG 190	1232
1064	?	490
1065	RONDERUG EXTENSION 320	2634
1066	189	412
1067	321	473
1068	BAKLEIPLAAS F 278	486
1070	BETJIES KRAAL 254	607
1071	BAKKELEY PLAATS 282/5	1082
1074	VREDENDAL'292	5709
1075	MELKBOOMSDRIFT 184	499
1079	268	614
1080	ROOI KRAAL 323	1023
1084	BAKLEIPLAAS A 182	1134
1085	?	70
1086	ALDERTON 281	230
1087	346	383
1088	ATIES EXTENTION 261	1688
1090	ZANDKRAAL A 180	541
1091	259	262
1092	KLIPFONTEIN 349	2151
1094	VREDENDAL ALLOTMENT AREA	445
1095	THE POINT 267	1925
1098	RONDERUG 316	4515
1100	322	180
1101	KATMAKOEP 279	4800
1102	PLAT PLAATS 280	42
1104	282/ 66	13
1105	282/62	30
1106	VADERLANDSCHE RIETKUIL 308	7526
1107	BLAAUW POORT 353	1443
1108	KATMAKOEP 183	1005
1112	WIDOUW 309	8209
1113	WESPOORT 294	2687
1114	KLIPFONTEIN A 352	765
1115	VREDENDAL 292	508
1118	SPES BONA 297	7
1119	295	115
1120	KAROO VLAKTE 299	708
1121	KYS 301	1124
1123	SPES BONA 297	167
1124	ANNEX WIDOUW A 311	950
1125	ANNEX MOOIHOEK 295	11
1128	LOT 823	474
1129	GROOT DRAAIHOEK	4611

775	UITSPANRUG 110	4083	1130	OORLOGSFONTEIN A 351	820
777	GEMBOK RIVIER WEST 89	4433	1131	OORLOGS FONTEIN 350	2742
778	DE TOEKOMST 126	3028	1132	ELANDSKLOOF 313	1818
780	DOUSE THE GLIM EXTENSION 99	4330	1133	314	380
781	OOR-KRAAL 114	9964	1136	SANDRIVIER B 319	368
788	BUSHMANS GRAVE 112	3989	1138	OP DE ZOOM 315	31
796	DOUSE THE GLIM 95	2054	1139	SANDRIVIER A 318	280
797	ZWELLENGREBE 465	3078	1140	PAPENDORP 269	793
798	THE RACE COURSE 96	2557	1141	ANNEX RONDERUG 317	884
799	SPRINGBOK VLAKTE E 88	5213	1142	GIDEONS OORD 303	1299
800	KLEINFONTEIN RIVIER 87	2712	1143	AAN DE OLIFANTS RIVIER 305	1900
802	FLAMINT VLAKTE 111	10749	1144	DE BOOM 273	8265
803	ZANDKRAAL 98	6313	1146	ZUUR VLEY 354	2588
805	OOST VARSBRAK 131	3247	1147	RONDERUG 316	888
808	KLEIN FONTEIN HOEK 466	1396	1152	MATSIEKAMMA 361	4924
809	POTKLEY 127	14634	1154	WINDHOEK 449	4076
813	BOKKEFONTEIN 635	997	1155	KLEINFONTEIN 312	1776
817	GROOT GRAAF WATER 210	10582	1156	306	1028
819	WILLEMSKOP 639	1574	1158	ANNEX WIDOUW C 310	314
820	ZANDKRAAL A 97	5810	1160	OP DE ZOOM 315	29
824	ELANDSFONTEIN 128	528	1161	NAAUWKOES 300	280
825	ENGELSCHE PUNT 636	1303	1162	AAN DIE OLIFANTS RIVIER 305	1699
828	INHOEK 637	564	1164	HOLLEBAKS STRANDFONTEIN 270	6369
829	ENGELSCHE PONT EXTENTION 221	3238	1165	VERSIG 452	1263
830	KERSBOSVLEI 133	5375	1166	RONDERUG HOOGTENS 369	1338
833	SPRINGBOK VLAKTE D 220	3664	1167	?	13
852	638	247	1168	VOETPADS KLOOF 358	395
854	ZANDKRAAL B 217	3428	1169	357	117
857	644	327	1170	?	22
861	LUIPERS KOP 211	7022	1172	WAGENBOOMS KLOOF 356	1185
862	QUAGGA 'S KOP 213	7930	1175	ANNEX GIFTBERGEN 370	2775
863	KROMVLEI 224	8439	1176	RICHTEIN 391	1039
864	MOSTERT KOP 209	6412	1178	BAIE VLEI 360	1390
865	SPRINGBOK VLAKTE C 219	4037	1179	AAN DIE OLIFANTS RIVIER 305	49
867	305	1206	1180	453/NAAUWKOES 300	188
873	CLOUDSKRAAL 644	2240	1181	ANNEX WIDOUW A 382	274
874	301	1296	1182	KALIEKAMMA 392	118
876	QUAGGA KOP EXTENSION 216	3318	1186	BIRD FIELD 306	3308
877	SPRINGBOK VLAKTE B 218	2829	1187	BYNESLAAGTE 274	1610
880	304	946	1189	GIDEONS OORD 303	5773
881	297	775	1190	SNORKFONTEIN NW 377	660
883	301	950	1192	SNORKFONTEIN 378	820
886	WOLVENEST 212	5064	1193	ANNEX WIDOUW B 372	1199
893	?	46	1194	GRAAFWATER 394	4377
895	646	307	1196	WAGENPADS KLOOF 363	5958
898	ELANDS FOOTHPATH RIVIER 223	2813	1197	ANNEX GIFTBERGEN B 371	951
899	DEELWATER 446	6863	1199	VAN DER STEL 389	2082
900	308	783	1204	KLAWER	632
902	308	1198	1207	PALEIS 395	1262

904	KOPPIESVELD 234	10327	1211	PLATKLIP 272	834
905	309	1354	1214	GIFBERG 2 380	1459
907	QUAGGA 'S KOP 215	4870	1216	KIKFORSTFONTEIN 364	2001
911	VIERFONTEIN 240	10328	1217	NAAUWKOES 300	1254
915	307	1277	1219	GIFBERG 374	5204
920	ROOIBERG 255	4231	1225	392	222
923	OLIFANTS RIVIER NEDERSETTING 309	1733	1226	399	359
927	?	19	1228	398	397
928	650	283	1229	DAMOENS FONTEIN	171
929	MOEDVERLOREN 208	7357	1231	KLIPHOEK 397	2999
930	GRASDUIN 315	3415	1232	CARLTON HILL 307	444
931	VALSCHE RIVIER EXTENSION A227	5034	1234	MELKBOOM 384	5552
936	LEEUKLOOF 658	665	1235	KLEIN HOLBAT 406	1045
937	OLIFANTS RIVIER NEDERSETTING 312	2270	1238	KLIPHEUVEL 390	551
938	314	773	1239	MELKBOOM 384	6585
940	311	332	1244	BYNEST KLIP 411	815
941	314	840	1247	TENT KILP 408	1721
942	KLIPDRIFT EXTENSION 207	3164	1248	RIETRYLAAGTE 385	2578
943	OLIFANTS R. SETTLEMENT 316 BERGP	3677	1249	VAALVLEI 401	1461
946	626	7460	1251	BLAAUWKLIP 407	803
947	DE DAM 655	800	1253	HARDE VLAKTE KLIPHEUWEL 405	8672
951	?	213	1259	?	52
953	624	5087	1266	KLIPHEUVEL 390	1562
954	HALFPAD RIVIER 231	2604	1271	KOEVLEI 400	761
955	HARDEVELD 231	2411	1272	402	199
959	653	313	1278	GROOT HOEK 407	921
962	VARSCHE RIVIER EXTENTION B 226	3271	1304	LEKKERVLEY 284 4974 /1962	25
965	656	567	1305	ZANDKRAAL A 180/21	16
968	630	1847	1306	CONCORDIA 283	344
971	247	3433	1307	VREDENDAL ALLOTMENT AREA	481
972	DROESSAND 248	3402	1309	292/ 116 121 212 113	173
975	796	541	1310	?	35
976	ZOUTFONTEIN 178	6264	1311	181	110
978	0	73	1312	293/1 +293/4	77
979	ZANDVELD 244	2367	1313	??	31
980	GELUKSPUT 241	1013	1314	DRAAI RIVIER 185	256
984	620	5629	1315	316	5
985	VUUR FONTEIN EXTENSION 242	1615	1316	SANDVELD KAPEL	188
986	631	1716	1317	TOLHOEK 387	114
987	DAMLAAGTE 252	628	1318	BIRD FIELD 306?	727
988	797	1295	1319	KAROO VLAKTE 299	1216
989	?	1874	1332	299	916
990	634	1776	1333	744	1132
991	ZOUTFONTEIN 178	3346	1335	BERG-OP-KLIP 392	664