ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR POWER STATION (‘NUCLEAR 1’) AND ASSOCIATED INFRASTRUCTURE

BOTANICAL AND DUNE ECOLOGY IMPACT ASSESSMENT FOR THE PROPOSED NUCLEAR 1 SITE AT KOEBERG (DUYNEFONTEIN): REASSESSMENT OF TRANSVERSE DUNES FOR PROPOSED NEW FOOTPRINT

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DECLARATION OF INDEPENDENCE

I, A Barrie Low as duly authorised representative of Coastec, hereby confirm my independence (as well as that of Coastec) as a specialist and declare that neither I nor Coastec have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for worked performed, specifically in connection with the Environmental Impact Assessment for the proposed conventional nuclear power station ('Nuclear 1'). I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in my attached report.

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EXECUTIVE SUMMARY

Findings

Initial assessment of the mobile dune systems at Koeberg (Low, 2011) found that impacts associated with a Nuclear Power Station (NPS) would be too severe. It was recommended that any footprint be located some 1.5 km inland of the coast in order to avoid the sensitive transverse dunes (see Figure 5.1.2 in the botanical EIA report (Low, 2011)).

In the ensuing, seven or so years since this study (field work initially conducted in 2007/8) the transverse dunes have stabilised themselves to such an extent, suggesting they might be amenable to development.

An assessment of the soils, flora and vegetation along a gradient from bare sand through pioneer and successional (fynbos) communities, to climax thicket, showed an increase in plant species, cover and height. Soils under mature thicket displayed greater levels of nutrients and cation exchange capacity, much of this correlated with higher levels of organic carbon which acts as a colloid in sandy soils.

Mapping of a sequence of aerial photographs from 1938 to 2014 indicated that transverse dunes were vegetating at a fair pace. Bare sand showed a loss in extent of 637 ha over this period with a concomitant rise in thicket cover (401 ha). Development accounted for some 265 ha. Not only is the dune system "slowing down" but auto-vegetating of this system has been aided by the decline in sand inputs into the mobile dunes, through the location of Koeberg in the middle of the sand sea supplying the mobile dunes, as well as Melkbosstrand in the main channel of sand supply.

Recommendations

Low (2011) in his report on the dunes and botany of the Koeberg site, recommended a set back line which would place any proposed power station beyond the mobile dune field, i.e. over 1.5 km inland of the coast. That recommendation stands for areas which still contain mobile dunes, but the more recent information entertained in this study suggests a reappraisal of the situation, particularly given the stabilisation of the mobile dunes just north of the existing Power Station.

Two factors are paramount to this debate: (i) the substantial loss in dune mobility due to development in the south, coupled with increases in vegetal cover have meant the dune can no longer function in its pristine state and (ii) development would be localised to vegetated parts of the dune system, permitting the remaining small mobile system in the north to function in the long term, albeit artificially restricted.

Low (2011) comments: "Construction of a nuclear facility would potentially lead to the loss of most of a large transverse dune system, **endemic** to the lower Cape West Coast. This system is poorly represented in the region, although there is a large transverse dunefield to the north-east at Witzand and a similar, but larger, more intact system north of Yzerfontein. The Duynefontein system is remarkable for its size (nearly 1 000 ha) and location at the coast, just above the primary dunes. Despite the present position of the Koeberg Power Station to the south, and at the start of this system, thereby somewhat compromising the supply of sand to the north (the general direction of sand movement), field observations, together with those of the dune geomorphologist, confirm that there is fairly substantial inland sand movement from the south-west, suggesting there has either been somewhat of a "correction" in the system, or the south-western source has been present for some length of time".

In the seven or so years since the first study, it is clear that both development and active planting of the mobile transverse dunes has hampered dune mobility and has led to a "slowing down" of the system. The prognosis for dune stabilisation is that this will continue into the foreseeable future, as sand supply literally dries up, and auto-vegetation accelerates.

This report, therefore recommends that location of the proposed Nuclear-1 footprint be considered for the southern VEGETATED and STABILISED part of the transverse dunes in line with the current preliminary footprint /plant layout of the proposed NPS, but with the provisos dealt with under the next section.

Any losses of the transverse dune should be through an -offset by addition of dune vegetation to the north of the Koeberg Nature Reserve boundary (i.e. Groot Springfontein Farm).

Response of the stabilising transverse dunes to impact

Construction phase of the Nuclear-1 facility

Soils

As plant cover increases, so does the level of organic carbon and most nutrients (see above). Soils under climax dune thicket show disproportionately higher amounts of carbon and nutrients than bare sand and pioneering communities. Of note is the greater cation exchange capacity and nutrient availability which ensures a greater diversity of species and a plant community far more resilient to disturbance. Soil stability is ensured through a) higher amounts of organic matter and therefore soil binding and b) dense canopies which afford sand protection from the wind. Correspondingly, natural transverse dunes are far less vegetated and mobile, being blown in perpendicular waves in the direction of the wind (see below and refer to Illenberger, 2013).

Flora

Some 87 species were encountered on the transverse dunes in this study, 10 more than in Low's (2011) work (see SaSFlora, 1998 – 2015). Both this and Low's (2011) study report five Red List species, all of which are well-distributed in the dunes of the West Coast and elsewhere (*sensu* SaSFlora, 1998 – 2015). Losses to a NPS footprint are thus considered minor.

Vegetation and dune stability

The vegetation of the site is well-represented elsewhere on the West Coast and Cape Flats. However, it is a dynamic system, with an unnatural succession (owing to artificial stabilisation) moving these dunes towards mature thicket. This is the climax vegetation of the adjacent parabolic dunes (Low, 2011), where dense thicket provides far greater stability than the transverse dunes.

Reversal of this process would require removal of vegetation from the dune and even then it would not return to its natural state as the main supply of sand from the south is blocked by Koeberg itself, and to a certain extent, Melkbosstrand. This echoes the situation for the Oyster Bay-Cape St Francis headland bypass system, where development in the former town is preventing sand from feeding this massive dune system (Illenberger, 2010; Low, 2011).

The impacts associated with building a Nuclear facility on dunes which were previously mobile has been dealt with in the main impact assessment (Low, 2011). In this report Low (2011) recommends that there be no development on mobile dunes, in particular the transverse system north of Koeberg, and that such development is shitted inland onto stable parabolic dunes. Clearly the transverse dunes just to the north of the existing power station are now well-stabilised (Figures 23 & 24) and the trajectory of vegetation cover is towards climax dense thicket, now occurring patchily throughout the area (see Low, 2011 for distribution of plant communities).

With the vegetating of the once-mobile transverse dunes, this new stability would imply that development could be considered, but with the migratory measures for parabolic dunes (Low, 2011).

Fine-tuning of footprint

It is vital that no footprint is permitted in the mobile transverse dune system. Rather care must be taken to ensure that the boundary of the footprint is well within stabilised dunes. In addition, there should be at least a 100 m wide buffer between the boundary and any mobile dune.

Operational phase of nuclear facility

Coastal set back and buffers

A key agreement reached between Eskom management and the consulting team was provision of a coastal corridor of 200 m minimum width (see Low, 2011). This should also be applied here and will also ensure that the more sensitive and mobile primary dunes at the coast are avoided.

Low (2011) produced a series of management and rehabilitation guidelines for the operational phase of the project and which have been included here. These are to be adhered to and included as part of the environmental authorisation should permission be granted for another Nuclear facility at Koeberg.

Conservation

In short, the transverse dunes are part of the Cape Flats Dune Strandveld vegetation type which is rated as Endangered (Rouget et al., 2004). This system is well-protected in the 3 000 ha Koeberg Nature Reserve and in various parts of the Cape Flats and West Coast. Low (2011) recognises this as a positive impact in the development of a new nuclear facility: “The continued management of the Koeberg Nature Reserve, which entails the whole of the site outside the present NPS, is considered a positive impact. Current multiple-use of the reserve is extensive and management would continue with the new NPS. Extension of the reserve into good quality dune veld of the Groot Springfontein Farm to the north is also highly desirable, and could be effected by a cooperative conservation agreement. All in all the use of some 200 to 280 ha for a NPS is far outweighed by the 3 000 ha currently under conservation within the Koeberg Nature Reserve". I would add here that a biodiversity offset should be sought for the potential loss of transverse dunes in the south of the site, and that the Groot Springfontein Farm on the northern boundary of the KNR would be a worthy addition, particularly as it lies to the west of the R27, encompasses a relatively pristine coastline and would be directly connected to the Koeberg Nature Reserve.

Key interventions during construction and/ or operational phases (largely from Low, 2011)

Search & rescue

For each phase of construction within natural veld, a search and rescue operation is required which would identify all plants which were either extremely rare (i.e. Endangered or Critically Endangered) or which could be used in site rehabilitation. Red List species likely to be affected if development is carried out on the transverse dunes, are the annual *Capnophyllum africanum, Helichrysum cochleariforme* duineteebossie (Near Threatened - NT), *Psoralea repens* duine-ertjie (NT), the succulent vygie *Ruschia indecora* (Endangered - EN), and *Passerina ericoides* kusgonnabas (Vulnerable - VU) (Red List status in brackets) (see Appendix 2). Such RL species would require to be identified by a specialist botanist who would ensure a plan was in place to remove said plants **prior** to construction's commencing. Plants with a bulb or rootstock have the greatest chance of surviving translocation, whereas most shrubs and many of the graminoids (grasses, sedges, restios), particularly the obligate reseeders, would not translocate successfully. Seed and/or cuttings should be removed from species which will not translocate easily and grown on in the on-site nursery (see below).

Rehabilitation plan

Linked with Search and Rescue above should be a rehabilitation plan which would see that all areas disturbed in the development of the proposed facility are satisfactorily rehabilitated with locally occurring indigenous species. This would include the collection of appropriate plant material prior to construction's commencing, the storage of such material and/or the growing on of suitable material. Plants would need to be at least two to three years old for use in rehabilitation and thus sampling should commence during the construction period, at least three years before commissioning of the NPS plant. A nursery which would accommodate stored and grown on plants would be an absolutely essential requirement for satisfactory rehabilitation. For this purpose a rehabilitation plan needs to be drawn up which will identify suitable species, method of storage and/or propagation, method of planting and maintenance, and monitoring of rehabilitation success (see below). This can be included as a part of the construction and operational EMP.

A comprehensive rehabilitation plan will require the services of a rehabilitation specialist together with a specialist botanist who would identify and locate suitable species; measures must be in place to ensure removal of said plants **prior** to construction's commencing. Seed and/or cuttings should be removed from species which will not translocate easily and grown on in the on-site nursery.

The plan should include the following key elements:

Preparation phase

At least two years before commencement of construction, an on-site nursery with manager needs to be set up at Duynefontein. A list of appropriate species needs to be drawn up and both seed and cuttings collected, planted out and suitably hardened off. This would provide material ready for planting as areas are required to be rehabilitated. In addition certain species could also be translocated into the nursery. The amount of plant material required would be guided by the extent of construction and areas to be disturbed. Both terrestrial and wetland habitats need to be considered.

A list of selected species suitable for rehabilitation is provided.

Topsoil

This is perhaps the most critical part of rehabilitation and would determine to a great extent the ultimate success of any rehabilitation work.

- Topsoil (0 – 300 mm depth) should be removed from any area being disturbed temporarily or permanently, and stockpiled. Piles should be no more than 1.5 to 2 m high to avoid decrease in aeration, but also too rapid decomposition of organic matter, the latter essential for providing a good start for new plants.

- Stockpiles should be placed in previously disturbed areas and should definitely not be located on natural vegetation. This would lead to the death of the latter.

Planting

- Planting of nursery-grown and -translocated species should be undertaken at a density set by the rehabilitation specialist, but generally at no less than 1 m apart. Time of planting should be just prior to the commencement of the rainy season in the Western Cape (April/May) so that plants are provided with good moisture conditions prior to the onset of the summer season some six months later.

Mulching

- Mulch should be strewn over the planted areas and this should shade the soil, and provide a source of organic matter and some nutrients, as well as retention of moisture for new plants. The best source for mulch is locally occurring introduced acacias and these can be mulched on site after cutting. Care should be taken not to clear these woody aliens when they are setting seed (October-November for *Acacia saligna* Port Jackson willow).

Maintenance

- Newly planted areas should be regularly weeded. Where plant death occurs, dead specimens should be replaced with material from the nursery. Plants should also be irrigated during the first summer season. For this purpose a simple above ground irrigation system would prove useful if not essential.
- All woody aliens should be removed once they reach knee height (for ease of pulling).

Coastal corridor and buffers

The negative aspects of locating a nuclear facility at the coast (i.e. on the high water mark) have been discussed by Low (2008) for the proposed PBMR plant (since discounted as an option) and historically have existed for the Koeberg Nuclear Power Station. "These habitats are extremely sensitive and fragile and demand great circumspect if both the habitat as well as issues such as maintenance of structures are to be satisfactorily dealt with. A setback line should be implemented ......"
The EIA corridor should be separated from the high-water mark by a coastal corridor and adequate buffer to the sensitive mobile dunes, whichever is the greater. Such a corridor should be underpinned by the following ecological rules or criteria:

- 200 m wide ecological corridor as a minimum width for serving as a conduit for pollinating and fruit-translocating fauna and an enabling area for essential ecological processes, such as dune mobility and pollination, and preservation of major communities. At Koeberg this will be far wider if recommendations for avoiding the sensitive, rare and endemic transverse dune system are upheld;
- Avoidance of the sensitive primary dunes at the coast;
- Avoidance of the sensitive limestone cliffs, in the north of the area;
- Whichever setback line is the furthest from the HWM, an additional buffer of 100 m should be set to protect the sensitive systems discussed above from any long-term impacts the development could have on such systems; and
- All setback lines would need to be accurately surveyed before the footprint was fine-tuned.

Impact of development on the coast could compromise the existing, albeit *de facto,* corridor along the Cape West Coast, which locally stretches several kilometres inland. The recommended 200 m setback maintains such a West Coast coastal corridor (Low, 2011).

Monitoring

(i) Rehabilitation

Goal: to ensure that rehabilitation with indigenous species is carried out effectively and has long-term sustainability

a Uninvaded areas

Where habitats have been unnaturally disturbed but are not invaded by *Acacia cyclops* rooikrans, rehabilitation with indigenous species is to be implemented. Such rehabilitation must follow a plan put together by a rehabilitation specialist, assisted by a specialist botanist with a good working knowledge of the local flora, and using locally occurring indigenous species. Details of the plan are presented in section (v) above. Rehabilitation success must be monitored on a three monthly basis for the first year, and then six monthly until acceptable species densities and cover are achieved.

b Invaded areas

Areas invaded by *Acacia cyclops* rooikrans or *Acacia saligna* Port Jackson willow should be cleared and rehabilitated as per the recommendations in (v) above. Rehabilitation should only be implemented if thicket species do not naturally return to a desired cover and species complement. The latter two factors should be monitored by a specialist botanist and targets set for both these two criteria; this should be included in the rehabilitation plan.

Whilst it is strongly recommended that rooikrans be cleared manually – for both social as well as ecological reasons – individuals removing acacias should be subject to a code of conduct which would govern behaviour on site. Key issues would include damage to plants and animals, toilets, fire, and general behaviour to be consistent with that of a nature reserve. Activities of these individuals need to be monitored by the on-site supervisor or conservation manager (see below).

(ii) Coastal corridor

Goal: to ensure a coastal corridor is created in an appropriate manner and is maintained in the long-term

Implementation of a coastal corridor must be a key goal of the development of the nuclear facility. Monitoring must be implemented to ensure that the coastal corridor is maintained in as natural a state as possible. This would include monitoring the rehabilitation of areas which have been excavated for the inlet and outlet pipes and the area immediately alongside the nuclear structure. Rehabilitation with indigenous species should be undertaken following the rehabilitation plan discussed above.

(iii) Relocation and/or growing on of Red List species

Goal: to ensure that where possible all Red List species in particular those on the Vulnerable and Endangered categories affected by development are relocated or successfully grown on in a nursery and returned to the wild.

Relocation and/or growing on of Red List species should be included in the site's rehabilitation plan. Key performance criteria include the reintroduction of RL species into protected areas, either on the site or in nearby nature reserves, or the growing on of such species for introduction into natural habitats through the rehabilitation plan. The bottom line would be to ensure there would not be a reduction in the natural densities and populations in each RL species.

(iv) State of conservation area

Goal: to ensure that the natural areas of Duynefontein/Koeberg Private Nature Reserve are maintained in a state consistent with that of a well-managed nature reserve

Koeberg should continue with its present management programme and ensure that that a management plan for the area is implemented. Key performance areas would be: woody alien eradication, rehabilitation, creation of a trail system for the public, control of access and use of the area, control of vehicles entering the area.

Conclusions

From this study, major changes were recorded in the transverse dune system to the north of the existing Koeberg Nuclear facility.

Mapping of aerial photographs over a 76 year period showed conclusively the once-mobile transverse dunes are vegetating at a fairly rapid rate and have lost their mobility in the south. This was demonstrated through a decline in bare sand (mobility) and increases in the cover of thicket and other plant communities (loss of mobility).

Accompanying the above, was an increase in species number and vegetation cover, as one moved along a succession from pioneer to mature, climax thicket.

Soils showed concomitant changes along the gradient, with appreciable increases in organic carbon, total nitrogen and several cations, as well as cation exchange capacity. The latter was closely correlated with organic carbon, which in these sandy soils acts as a colloid in the place of clay.

Recommendations

Given the rapidly stabilising transverse dune system at Koeberg, it is recommended that consideration be afforded the location of a new Nuclear facility within the transverse dune directly **north** of the existing NPS. This is in line with the proposed footprint shown in Figure 24 However, this should be accompanied by strict measures which ensure proper fine-tuning of the footprint, creation of a buffer between development and presently mobile dunes, and implementation of an effective management plan during both the construction and operational phases. This plan would include, among other, effective rehabilitation and monitoring, and the enhancement of the Koeberg Nature Reserve through addition of land in the north.

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1. ABBREVIATIONS

E or EN	Endangered (of vegetation type or plant species rarity)
EMP	Environmental Management plan/Programme
HWM	high water mark
LT	Least Threatened (of vegetation type rarity)
MDS	multi-dimensional non-parametric scaling (analysis)
NT	Near Threatened (of plant species rarity)
NPS	Nuclear Power Station
RL	Red List (plant species)
SANBI	South African National Biodiversity Institute
TD	Transverse dune
V or VU	Vulnerable (of vegetation type or plant species rarity)

2. 2. GLOSSARY

Alkaline (soli)	Soil with a high pH (>7)
Buffer	A narrow strip protecting a conservation area or ecological ***corridor***; often permitting green use but not necessarily comprising natural ***vegetation***
Calcareous	Containing calcium, invariably calcium carbonate (e.g. of rock or sand)
Cation	A positively charged ion, for example Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}
Cation exchange capacity	The degree to which a soil can adsorb and exchange ***cations***. It is also a measure of the ***colloida***l nature of a soil. The higher the proportion of ***colloids***, the higher the CEC
Climax community	The stage at which a ***plant community*** reaches maturity. For ***dunes***, this would be thicket
Colloid	Minute particle in the soil responsible for adsorbing water and important nutrients. In a soil derived from shale or granite, this would be in the form of clay. In a sandy soil, organic matter then takes over this role
Colluvial	Transported by gravity, often referring to soil as it slips down a steep slope
Corridor	A tract of (usually) natural ***vegetation*** linking two or more natural remnants
Dune	A hill, mound or ridge of sand which is composed of particles transported and heaped up into accumulations by the wind
Ecosystem	A system, or a group of interconnected elements, formed by the interaction of a community of organisms with their environment. The ecosystem is the basic functional unit in ecology, and includes both biotic (organisms) and abiotic (non-living) components
Embryo dunes	Primary dunes normally associated with the coast line and usually formed at the coast by sand being blown up above the high water mark. These dunes tend to be bare or with poor plant cover of pioneering plant species, reflecting the generally harsh conditions (strong winds and salt spray) of this habitat. Dunes generally tend to lie perpendicular to the direction of the prevailing winds
Endemic	(Of a plant species) confined to a ***habitat*** (habitat endemic) or region (bioregional endemic)
Flora	Assemblage of plant species in a particular area
Graminoid	Grass-like, including the grasses (Poaceae), reeds (Restionaceae), rushes (Juncaceae) and sedges (Cyperaceae)
Habitat	essentially the place where an organism lives; this is informed by the geology, soil, moisture (amount and seasonality), place in the landscape; relationship with other plants and animals
Headland bypass (dune)	***dunes*** which cross the headland plain to feed the shoreline of the embayment opposite with sand, thereby avoiding the headland itself

Hummock dune	A form of ***primary dune***, where the form of the dunes is a hummock. Bare sand or sparsely vegetated
MDS	Non-metric multidimensional scaling: a measure of the relationship of the Euclidean distance between items, and the location of each item in two-dimensional space, usually as a scatterplot
Mulch	Used in the context of this study, mulch is a layer of organic material applied to the surface of the soil. In this case we consider mulch to be chipped plant material (leaves, shoots) applied to the soil surface during the process of ***rehabilitation***
Obligate reseeder	A plant which can only regenerate from seed (usually following fire)
Off set	This is an approach used to compensate for loss of natural systems associated with development. It involves the acquisition of land for conservation, either within the area being developed or elsewhere, for example in a similar system
Parabolic dune	A tongue of advancing sand with a rounded nose that migrates with the direction of the wind. The crescentic nose is opposite to that of a barchan ***dune*** (crescentic, with crests orientated transversely to the wind direction)***.*** Parabolics also produce two trailing edges (the two "legs" of "hairpin parabolics"). Can be unvegetated but generally stabilised by vegetation
Pioneer	Generally referring to a plant species or ***community*** which represents the "advance guard" in hostile habitats or after a major intervention such as fire
Plant community	A plant community is any assemblage of plants found growing together and which possesses a distinctive species composition and cover (compared with other communities)
Plot	The specific size and shape of a site used to subsample ***vegetation***. Shape tends to be square and no larger than 5 m x 5 m for ***dune thicket***
Quaternary	relating to or denoting the most recent period in the Cenozoic era (65.5 to 2.6 million years (my) before present (BP)), comprising the Pleistocene (2.6 my to 11 700 years BP) and Holocene (11 700 year BP to present) epochs
Red List[1]	List of rare species released by SANBI, and with the following **rankings: Critically Endangered -** a species is Critically Endangered when the best available evidence indicates that it meets any of the criteria for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild; **Endangered -** a species is Endangered when the best available evidence indicates that it meets any of the criteria for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild; **Vulnerable -** a species is Vulnerable when the best available evidence indicates that it meets any of the criteria Vulnerable, and it is therefore considered to be facing a high risk of extinction in the

[1] Go to link *IUCN Red List* Categories and *Criteria*: Version 3.1 - red list for more information

wild; **Near Threatened –** a species is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future; **Rare –** species Taxa with limited distribution ranges within South Africa and/or known from very few subpopulations, but that are not threatened are included on the national list as species of conservation concern. In this report these species have been given the same status as NT; **Least Concern –** a species taxon is of Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category

Rehabilitation The process whereby an area is repaired with (indigenous) plant species following degradation; the aim is not to return the area to its original state (i.e. restoration)

Resistance (soil) measured in a saturated paste and gives a rough indication of the quantity of soluble salts in the soil, and therefore also an inverse indication of soil nutrient availability

Setback line Setback lines are used to control and prevent insensitive, inappropriate and non-sustainable development in sensitive coastal environments. These are also used to protect coastal processes and to minimise human impacts at the coast and to to reduce the risk posed by climate change

Succession The natural stages of a developing plant community, from immature (often fire-induced) to mature or ***climax***. Succession is a key part of post-fire regeneration in fynbos, and can also apply to dune vegetation after disturbance such as wind removal of dune cover

Thicket ***Vegetation*** characterised by a closed canopy consisting of an impenetrable tangle of shrubs, and low trees usually interwoven by woody climbers. Thicket is by and large impenetrable!

Transverse dune A large, strongly asymmetrical, elongated dune lying at right angles to the prevailing wind direction; invariably sinusoidal in shape along its length

Tukey's test This method is a single-step multipole comparison procedure and statistical test and can be used on raw data to find means that are significantly different from each other. It compares all possible pairs of means of every treatment to the means of every other treatment and identifies any difference between two means that is greater than the expected standard error

Vegetation Presence and abundance (cover) of plant species in a particular area

3. INTRODUCTION

1.1 Background

1.1.1 Description of Proposed Project

Eskom proposes constructing a Nuclear Power Station (NPS), with a power generation capacity of up to 4000 MW, at one of three sites; Duynefontein adjacent to the existing Koeberg Power Station, Bantamsklip near the town of Hermanus and Thyspunt near Cape St. Francis. This report deals only with the transverse dune system at the Duynefontein/ Koeberg site. In the botanical and dune ecology impact assessment of the site, Low (2011) recommended the proposed footprint for the facility should not be located in the sensitive mobile transverse dunes just to the north of the existing Koeberg faculty, but rather should be positioned inland, on stable, well-vegetated dunes.

Given the seven year time lapse since the earlier botanical and dune work was undertaken (2007-8), and following recent discussions with GIBB and Eskom, a possible review of the location of a Nuclear Power Station (NPS) was suggested, where stabilised and stabilising transverse dunes could well be developed.

Consequently, Coastec was appointed to investigate the sensitivity of the dune system directly north of the Koeberg NPS and with the following terms of reference:

a) Flora & vegetation

Assess the flora and vegetation of the site with a view to determining site resilience with respect to:

- The disturbance of species, habitats and ecosystem functioning through activities associated with construction; and
- The disturbance of species, habitats and ecosystem functioning through activities associated with the operational phase of the NPS.

b) Dune systems

Assess the transverse dune system for the site, providing an indication of increasing or decreasing stability over a time line stretching back some 70 years.

1.1.2 Methods and analysis

a. Soils

Topsoils (0 – 15 cm depth) were sampled along a continuum from bare sand, through pioneer vegetation to dense dune thicket, as part of the stabilising gradient. All soils were air-dried and sent to BemLab for the following analyses: pH (1M KCl); resistance; total and Bray no.2 phosphorus; exchangeable cations; total carbon; total nitrogen; cation exchange capacity; texture (stone; sand, silt, clay).

b. Dunes and vegetation: mapping

Establish a study area which incorporates the historically mobile dunes of the southern Koeberg-Witsand transverse dune complex as depicted in Low (2011). Establish vegetation patterning (bare sand, lightly vegetated sand, densely vegetated sand, etc.) from the aerial photographs and map the various categories. Assess changes in community distribution and extent over the period 1938 - 2014.

c. Flora

Sample plant species from three approximately 20 m x 10 m plots in the vicinity of the vegetation plots (below). Where possible, identify plant specimens in the field or from Coastec's field herbarium, otherwise process specimens (dry and label) and submit for identification to specialists at Kirstenbosch and elsewhere. Input all flora data into the SaSFlora database (SaSFlora, 1998 – 2015). Analyse data to illustrate successional trends on the transverse dunes and establish patterns which might indicate an increase in dune stability.

d. Vegetation

Place triplicate plots (2 m x 2 m to 5 m x 5 m in size) within major plant communities found in the site and record species presence and cover-abundance according to the Braun-Blanquet technique (see Low, 2011). Sampling to include a range of cover and species dominance from pioneer (*Cladoraphis cyperoides*, *Osteospermum incanum*), through successional vegetation (*Morella cordifolia, Metalasia muricata*) to mature thicket (*Searsia glauca*) on the transverse dunes, and climax, dense thicket on the edge of this system (*Searsia glauca*). Input plot data into Coastec's SaSFlora database (SaSFlora, 1998 – 2015). Analyse data to illustrate successional stages of the vegetation colonisation of the transverse dune and relate to dune stability.

e. Product

Provide an analysis of site botany and dune ecology, indicating soil, flora and vegetation patterns which might indicate increasing dune stability. From this comment on whether the transverse dunes system north of Koeberg could accept development in the longer term.

1.1.3 Assumptions and limitations

It is assumed that the correct sequence of aerial photographs can be sourced and that photographic resolution, particularly of earlier imagery, is sufficient for accurate mapping of the required parameters.

A few plant specimens had not been identified by the time of writing but this will have no material effect on the findings and recommendations.

4. STUDY APPROACH (METHODOLOGY)

2.1 General

The site (Figure 1) was visited on 2 and 28 October 2014. Several major habitats were sampled: bare sand (soil only), *Cladoraphis cyperoides* (hummock and transverse dune) and *Osteospermum incanum* (no soil) pioneer communities, *Morella cordifolia* and *Metalasia muricata* successional communities, and *Searsia glauca* climax community. An older dune thicket (*Searsia glauca*) community on the edge of the site was also sampled. This gave a total of eight sites, seven vegetated.

2.2 Soils

In each of the above sites (with the exception of *Osteospermum incanum*) three soil samples (15 cm deep) were collected from three bulked subsamples, to give a sample of about 1 kg in mass, and then air dried. All samples were then sent to BemLab, Somerset West, for analysis of the following parameters: pH, resistance, total phosphorous, Bray no. 2 phosphorus, exchangeable cations (Ca, Mg, K, Na, total cations), total nitrogen, total carbon, cation exchange capacity, bulk density and texture. These parameters were chosen as they provide a profile of relevant and measurable soil changes across a continuum of vegetation succession.

2.3 Flora

At each of the five vegetated sites, all plant species were sampled from three homogeneous areas of approximately 20 m x 10 m in each broad plant community identified above (see Table 1). Where possible, species were identified in the field or, if not known, pressed and labelled, and dried for later naming. Specimens not identified in the field or not being suitable for submission (e.g. lacking suitable flowering material) were ignored in a minority of cases. Dried specimens prepared in this way were labelled and submitted to Kirstenbosch (most plant groups) or to other specialists.

Species names were entered into Coastec's SaSFlora site and species database for the Cape and Karoo floras (SaSFlora, 1998 – 2015), with each plant community sample(s) representing a different site.

2.4 Vegetation

2.4.1 Mapping

Detailed mapping of bare sand and plant communities was undertaken using a sequence of black and white and colour photographs from between 1938 and 2014, a period of 76 years. The area of interest lay between the Sout River (south) and the Springfontein cliffs in the north of the Koeberg Nature Reserve, and the coastline inland to the R27, in a line stretching from Melkbosstrand to the north of the KNR, on the R27.

Aerial photographs from 1938, 1960, 1977, 1985, 1997, and 2014 were ordered from the Chief Directorate: National Geospatial Information, National Department of Rural Development (NGI). The earliest aerial imagery captured for the region (1938) marks the start of the time series. The dates following 1938 were selected to ensure that the state of the dune system prior to the construction of Koeberg, and the changes thereafter were adequately captured. Eskom had 2007 specifically flown for the original Nuclear Sites study (high res colour aerials), commenced in that year. Table 2 shows the imagery used in the study, the date of capture and type of processing required.

The imagery was geo-referenced to the Transverse Mercator Projection working with 19°E Meridian and WGS84 Datum and using recent digital ortho-corrected imagery as a reference. The residual error of the 1938 and 1960 geo-referencing was 10 m – 12 m, 1985 was 3 m and from 1997 the error was less than 1m.

The geo-referenced imagery was loaded into ARCGIS and seven categories mapped, ranging from bare sand, through various densities of vegetation to development (Table 3). Each category was mapped using an on-screen heads-up process at a scale of between 1: 2000 and 1:5000.

Figure 1. Location of Koeberg on the West Coast, north of Cape Town

Table 1. Habitats and plant communities occurring along the vegetation succession on the transverse dunes at Koeberg

Plant community	Description	Soil sample	Flora sample	Vegetation (plot) sample
KTDBS	Bare sand in north of site, occasional small clumps of grass (*Ehrharta villosa* or *Ammophila arenaria*)	Yes	No	No
KTDCC	Pioneer grass dominated by *Cladoraphis cyperoides*	Yes	Yes	Yes
KTDHD	Hummock dune community dominated by *Cladoraphis cyperoides*	Yes	Yes	Yes
KTDOI	Pioneer community near the coast dominated by *Osteospermum incanum*	No	Yes	Yes
KTDMC	Mid succession fynbos type vegetation dominated by *Morella cordifolia*	Yes	Yes	Yes
KTDMM	Mid succession fynbos dominated by *Metalasia muricata*	Yes	Yes	Yes
KTDSG	Climax thicket vegetation dominated by *Searsia glauca* and other dune thicket species	Yes	Yes	Yes
KTDDTM	Mature, climax dune thicket on edge of transverse dune system, dominated by thicket species including *Searsia glauca*, *Euclea racemosa* and *Olea exasperata*	Yes	Yes	Yes

Table 2. Aerial photographs used in the mapping of the study area			
Date	**Scale**	**Job #**	**Process**
1938	1:30 000	126	B/W negative scanned at 1200 dpi. Geo-referencing in Global Mapper 14.1 - based on recent orthophotos (NGI)
1960	1:30 000	454	B/W negative scanned at 1200 dpi. Geo-referencing in Global Mapper 14.1 - based on recent orthophotos (NGI)
1977	1:30 000	786	B/W negative scanned at 1200 dpi. Geo referencing in Global Mapper 14.1 - based on recent orthophotos (NGI)
1985	1:50 000	498_225	B/W negative scanned at 1200 dpi. Geo-referencing in Global Mapper 14.1 - based on recent orthophotos (NGI)
1997	1:20 000	Orthophoto Series	B/W scanned and Geo-referenced Orthophotos (1: 10 000) (NGI)
2007	1: 5000	ESKOM	High resolution ortho-corrected digital aerial imagery flown by Eskom
2014	1:10 000	CD: NGI	High resolution ortho-corrected digital aerial imagery (NGI)

NGI: Chief Directorate: National Geospatial Information, National Department of Rural Development

2.4.2 Field sampling

In parallel with the flora sampling (above), three plots or relevés were placed within each of the broad plant communities. Plots were generally 2 m x 2 m (pioneer) to 5 m x 5 m (climax) in size and these were found to be suitable for capturing the diversity and cover-abundance of individual species comprising each community. In each plot all species were recorded and a cover-abundance rating ascribed for the individual species, based upon the Braun-Blanquet scale (r = barely present, odd individuals); + = present but <1% cover); 1 = 1 to 5 % cover, or many individuals with lower cover; 2 = 6 to 25% cover; 3 = 26 to 50% cover; 4 = 51 to 75% cover; 5 = 76 to 100% cover. All plot data were entered into the SaSFlora database (SaSFlora (1998 – 2015).

Table 3. Mapping categories for aerial photos: Koeberg dunes	
Category	**Description**
1. Bare sand and mobile dunes	Bare sand - vegetation cover <5%
2. Pioneer	Sand with scattered and very sparse vegetation, usually shrubs < 30% cover
3. Pioneer Grass	Sand with grey mottled to even appearance, mainly attributable to *Ammophila arenaria* marram grass (introduced and sometimes invasive) and the greyer *Ehrharta villosa* pypgras (indigenous). Both are aggressive pioneers. Some shrubs and sand visible
4. Shrub & Sand	Small shrubs (usually darker grey due to limited shadows) with ~ 30-75 % sand matrix)
5. Thicket & Sand mosaic	Larger shrubs/ bushes (usually darker grey-black) with ~ 30 - 75% vegetation cover); mainly thicket but also including localised fynbos clumps
6. Thicket	Dense thicket vegetation including thicket, fynbos, (vegetation cover >75%)
7. Developed	Mainly Koeberg Nuclear Power Station and Melkbosstrand

2.4.3 Statistical analysis

Comparisons for floristic and vegetation (plot) data were made using the PRIMER statistical package of Clarke & Warwick (1994). By and large site and species/ plot data tables were created in SaSFlora (1998 – 2015) and then taken into PRIMER for cluster and multidimensional scaling analysis (MDS).

Comparisons of differences between communities were made for soil parameters and species totals using a simple t-test or the Tukey method.

5. DESCRIPTION OF AFFECTED ENVIRONMENT

3.1 Background and general description

The geology of the study site is relatively simple, being underlain by calcareous Quaternary sands (*sensu* Theron *et al*., 1992; Galliers, 2000; see Figure 4.1.1 in Low (2011). Recent to Tertiary sands dominate the geology of the West Coast, north of Cape Town (Galliers, 2000) and have a strong influence on vegetation distribution (see below). Calcareous sands, chiefly of the Witzand Formation, are represented by dune cordons which run the length of the site in a south-north direction (Figure 2). According to Low & Pond (2004), most of the site comprises dunes, chiefly of the parabolic, transverse and undulating sheet (deflated parabolic) types, whilst all dune soils are sandy and calcareous.

Some of the largest parabolic dunefields are found at Yzerfontein and in the Koeberg-Witzand area (Tinley, 1985). Many of these have been converted (locally) to complex dune types, with bare transverse dunes replacing the vegetated parabolics. In other words there has been an extensive remobilisation of sand as the parabolic dunes have become destabilised by the wind.

Low (2011) provides this background to the mobile and semi-mobile transverse dunes at Koeberg (his Community K3).

Three major dune types were recognised: embryo or primary dunes at the coast, parabolic dunes (as deflated parabolics occupy a relatively small proportion of the total dune area - only one parabolic category was mapped, and these dominate the dune systems of this section of the West Coast) and finally transverse dunes, which largely represent reworked parabolic dunes (Tinley, 1985).

Parabolic dunes comprise the greatest extent of dunes in the subregion, together with transverse and embryo. Of major significance is the presence in the Duynefontein-Witzand area of the largest transverse dune system on the lower West Coast (*sensu* Tinley, 1985; Low & Pond, 2006b. This system extends inland to beyond Atlantis and is some 15 km from the coast.

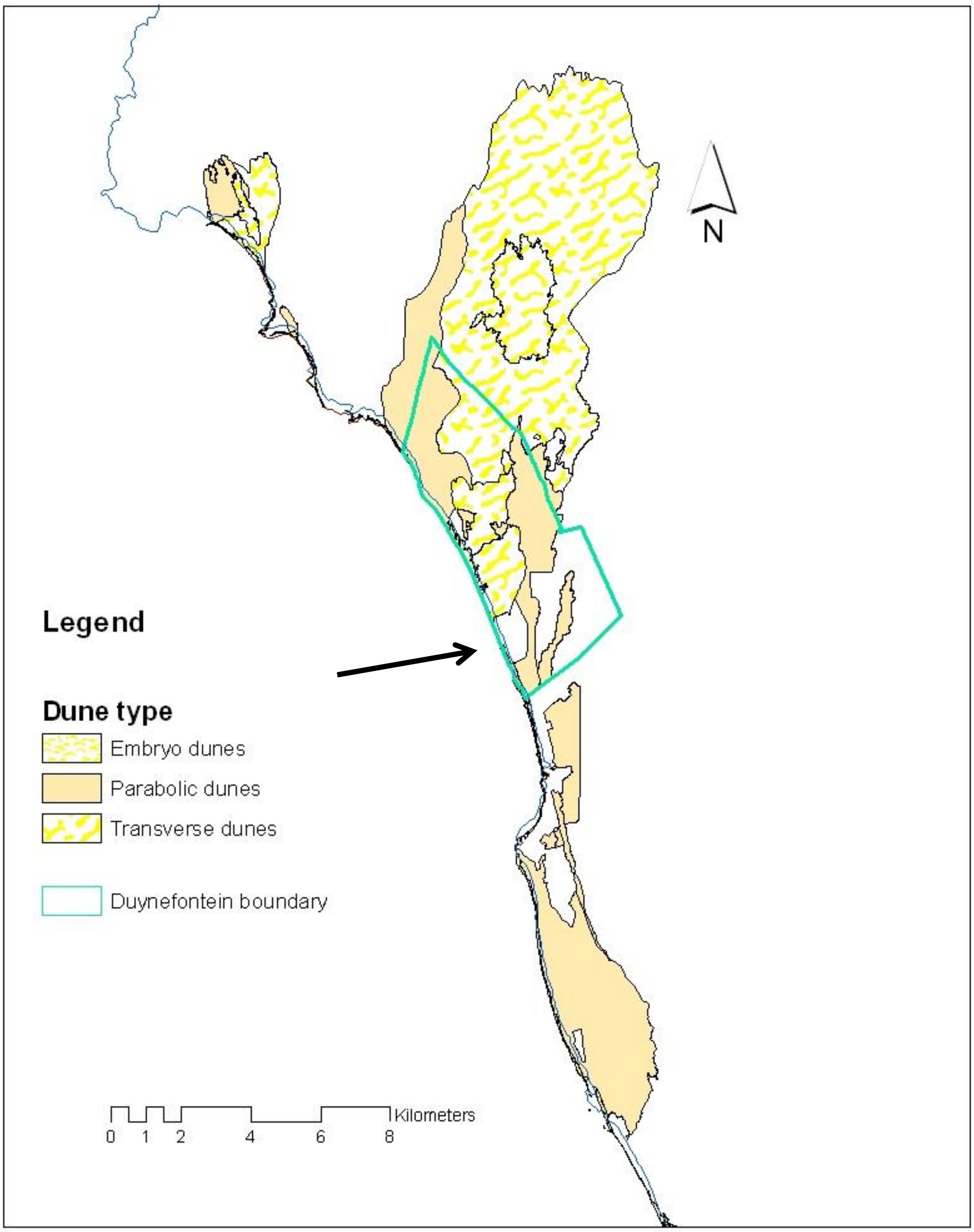

Figure 2. Distribution of dune systems between Melkbosstrand and Bokbaai. Note the predominance of transverse dunes to the north of the Koeberg Power Station (arrowed). From Low (2011, Fig. 4.1.2)

3.2 Geomorphology of transverse dunes at Koeberg

This presents a brief summary of Illenberger's (2010) findings. The Duynefontein (Koeberg) system lies at the southern end of the Atlantis dunefield. Two major dune systems are present: vegetated parabolic dunes and transverse dunes which are largely unvegetated. He recognises four dune types or varieties: currently active transverse dunes, artificially stabilised transverse dunes, older Mid Holocene parabolic dunes, and younger Late Holocene parabolic dunes. The mobile transverse dunes are thought to move at about 5 to 8 m per year, with heights of between 8 and 12 m above the surrounding landscape.

Illenberger (2010) comments on the negative impact that the mobile transverse dunes would have on infrastructure recommending that such dunes be artificially stabilised. He however also contends that they are not sensitive and thus can be developed. This is at odds with Low's (2011) findings that all the mobile dunes are ecologically sensitive and are prone to disturbance. The ability of a dune to tolerate disturbance is proportionate to how well vegetated the system is. Thus a dune covered by thicket vegetation is less sensitive than one with bare sand.

3.3 Flora & vegetation in the study area

Low (2011) recorded 408 plant species from the entire Koeberg site, of which only 51 occurred on the transverse dunes. Four of these are on the Red List (*sensu* Low, 2011).

The vegetation of the transverse dunes is classified as Dune Thicket (Daines & Low, 1993; Low, 2000) or Cape Flats Dune Strandveld (Mucina & Rutherford, 2006).

"Like their primary and foredune counterparts, this plant community is pioneering, is found inland of the coast, and as would be expected, displays close linkages with the coastal primary dunes and foredunes discussed above". Again vegetation is successional to dune thicket, but only if the sand stabilises. Plant height reaches 2 m, but in general tends to be low (0.5 to 1 m) (Low, 2011).

A transition between transverse and parabolic dunes is also recognised and is included in the successional stages recognised in this study; it contains elements of both communities. This transitional community comprises elements of both mobile/semi-mobile transverse dunes, and the more stable parabolics abutting the former.

6. FINDINGS & DISCUSSION

4.1 Soils

Results of the soils analysis are shown in Table 4. All soils are alkaline, with a slight decrease this parameter as one moves inland, but with the lowest value recorded in mature dune thicket (Figure 3). This tends to be associated with an increase in organic acids leaking from plant litter and roots (*sensu* Brady, 1974), but can also be linked with the leaching of calcium from older dune sands (Schloms et al., 1983).

There is usually a close correlation between elevated levels of calcium and high pH (Brady, 1974), but this relationship is fairly weak for the soils examined (Figure 4). This is probably due to above average concentrations of calcium in dune sands and the localised concentration of calcium and other mineral elements in the original sand depositional process.

Sodium shows a general decrease as one moves to the mature communities, but does display a small peak in the *Cladoraphis* pioneer site (Figure 5). This is due to close proximity to the coast and the deposition of aerosols high in this and other elements such as chlorine. Magnesium shows a marked increase in the climax vegetation, with amount of potassium slightly elevated in this community.

Total cations (T value) are closely correlated with exchangeable calcium (Figure 6), indicating this element to be the dominant cation in these soils, regardless of position along the gradient.

A fundamental feature of sandy soils (all soils in the study sites comprised more than 90% sand – Table 4) which tend to be somewhat infertile is the strong link between organic matter and cation exchange capacity. In the absence of clay, organic carbon takes on the role of colloid (*sensu* Brady, 1974) leading to a close correlation between the two parameters. This is true for the soils of this study (Figure 7), with an additional close correlation between organic carbon and a key plant nutrient, total nitrogen (Figure 8). Thus, in a build-up of organic matter (here measured indirectly as organic carbon), there is a concomitant increase in many plant important nutrients through the gradient. Highest values were found in thicket sites, where litter layer was the greatest and therefore contribution to the organic carbon fraction in the soil the highest (pers.obs.).

Along with nitrogen, phosphorus is crucial for plant nutrition (Brady, 1974; Witkowski and Mitchell, 1986). However amounts of this element appear to be linked to pedogenetic processes rather than plant cover, as there is negative correlation between this element and CEC.

Increases in CEC, and total carbon and nitrogen are shown in Figure 10, with all highest in the climax thicket community.

Table 4. Analysis of selected topsoils from the transverse dunes at Koeberg. Community descriptions in Tables 1 & 3														
Plant community	**pH**	**Resistance (Ohm)**	**Total P (mg/kg)**	**Bray no.2 P**	**Exchangeable cations (cmol/kg)**				**Total N (%)**	**Total C (%)**	**CEC (cmol/kg)**	**Texture**		
					Na	**K**	**Ca**	**Mg**				**Clay (%)**	**Silt (%)**	**Sand (%)**
KTDBS1	8.9	7400	718	30	0.09	0.01	10.90	0.17	0.030	0.20	1.25	6	4	90
KTDBS2	8.5	1870	927	35	0.17	0.02	11.50	0.23	0.010	0.12	1.11	6	2	92
KTDBS3	9.2	6820	715	25	0.10	0.01	11.59	0.14	0.030	0.24	1.34	4	2	94
KTDCC1	8.5	2370	1347	65	0.18	0.02	10.68	0.27	0.010	0.34	1.24	6	0	94
KTDCC2	8.9	1260	1026	68	0.24	0.03	9.88	0.31	0.020	0.28	1.16	6	2	92
KTDCC3	8.6	2030	907	46	0.19	0.03	10.55	0.27	0.010	0.42	1.19	6	0	94
KTDMC1	8.7	3100	1136	76	0.14	0.03	11.05	0.27	0.010	0.41	1.22	6	2	92
KTDMC2	8.7	2910	1282	66	0.11	0.03	10.30	2.20	0.010	0.42	1.32	6	2	92
KTDMC3	8.7	2470	1519	62	0.13	0.03	11.46	0.22	0.020	0.53	1.17	6	2	92
KTDMM1	8.8	2740	817	76	0.15	0.04	10.41	0.21	0.030	0.32	1.32	6	2	92
KTDMM2	8.8	3410	974	79	0.08	0.03	9.95	0.22	0.020	0.30	1.26	6	2	92
KTDMM3	8.8	2170	753	77	0.09	0.03	10.12	0.19	0.020	0.49	1.16	6	2	92
KTDSG1	8.2	2750	990	76	0.09	0.05	10.58	0.46	0.030	0.68	1.60	6	0	94
KTDSG2	7.9	2180	816	76	0.12	0.06	12.51	0.72	0.030	1.05	2.61	6	0	94
KTDSG3	7.9	2750	847	73	0.09	0.04	11.57	0.42	0.030	0.56	1.83	6	0	94
KTDDTM1	7.6	2300	677	139	0.10	0.09	13.36	0.64	0.140	1.24	2.54	6	2	92
KTDDTM2	7.4	2050	571	205	0.11	0.20	14.51	1.58	0.130	1.68	4.11	6	2	92
KTDDTM3	7.2	2260	454	164	0.12	0.12	11.65	1.11	0.120	1.35	3.66	4	4	92

pH – measured in 1M KCl; P - phosphorus; Na - sodium; K - potassium; Ca - calcium; Mg - magnesium; N - nitrogen; C - carbon. Plant community descriptions are shown in Table 3.

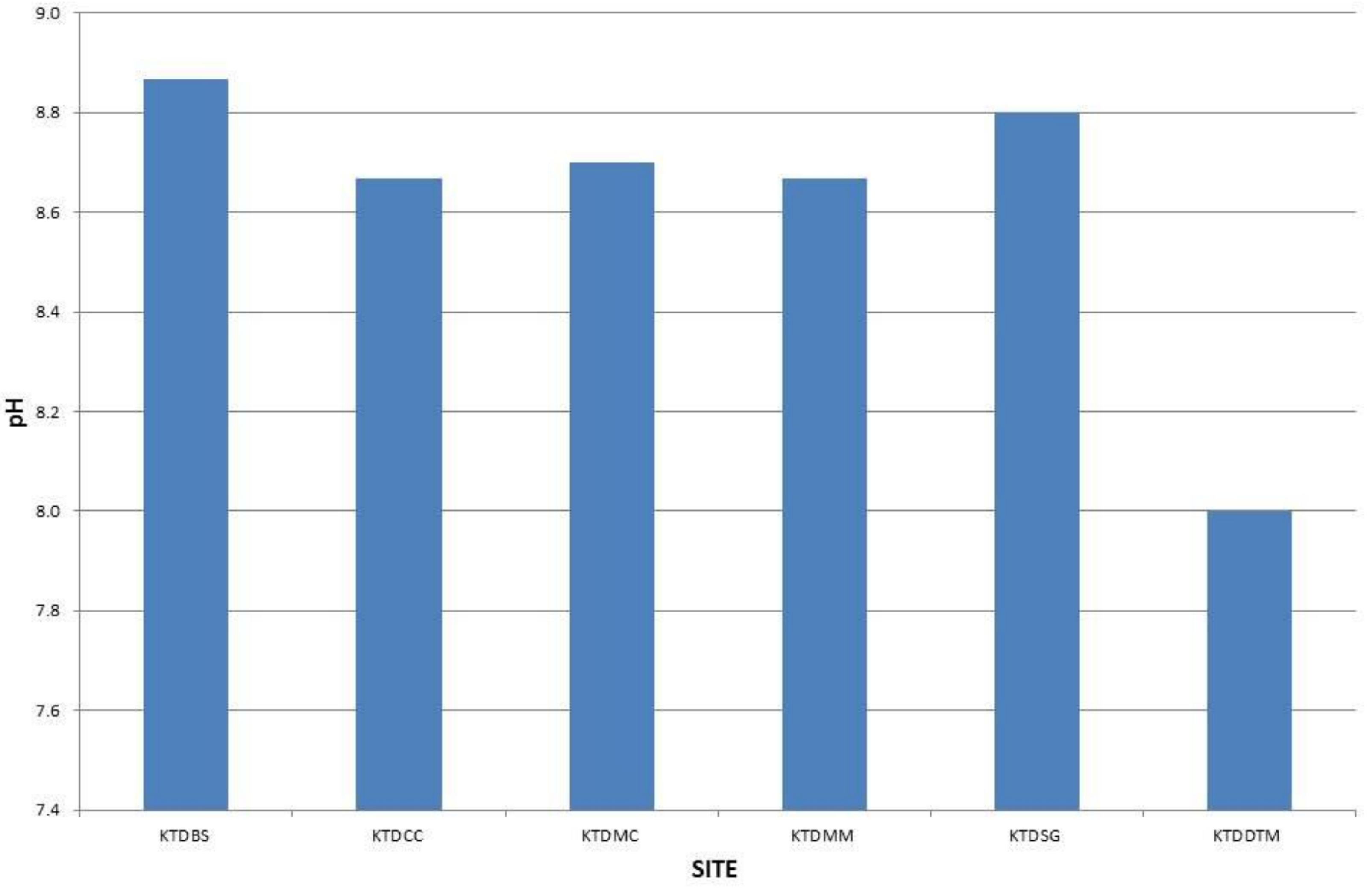

Figure 3. Change in pH as one moves along a gradient from bare sand (left) to climax thicket vegetation (right). Site abbreviations explained in Tables 1 and 3

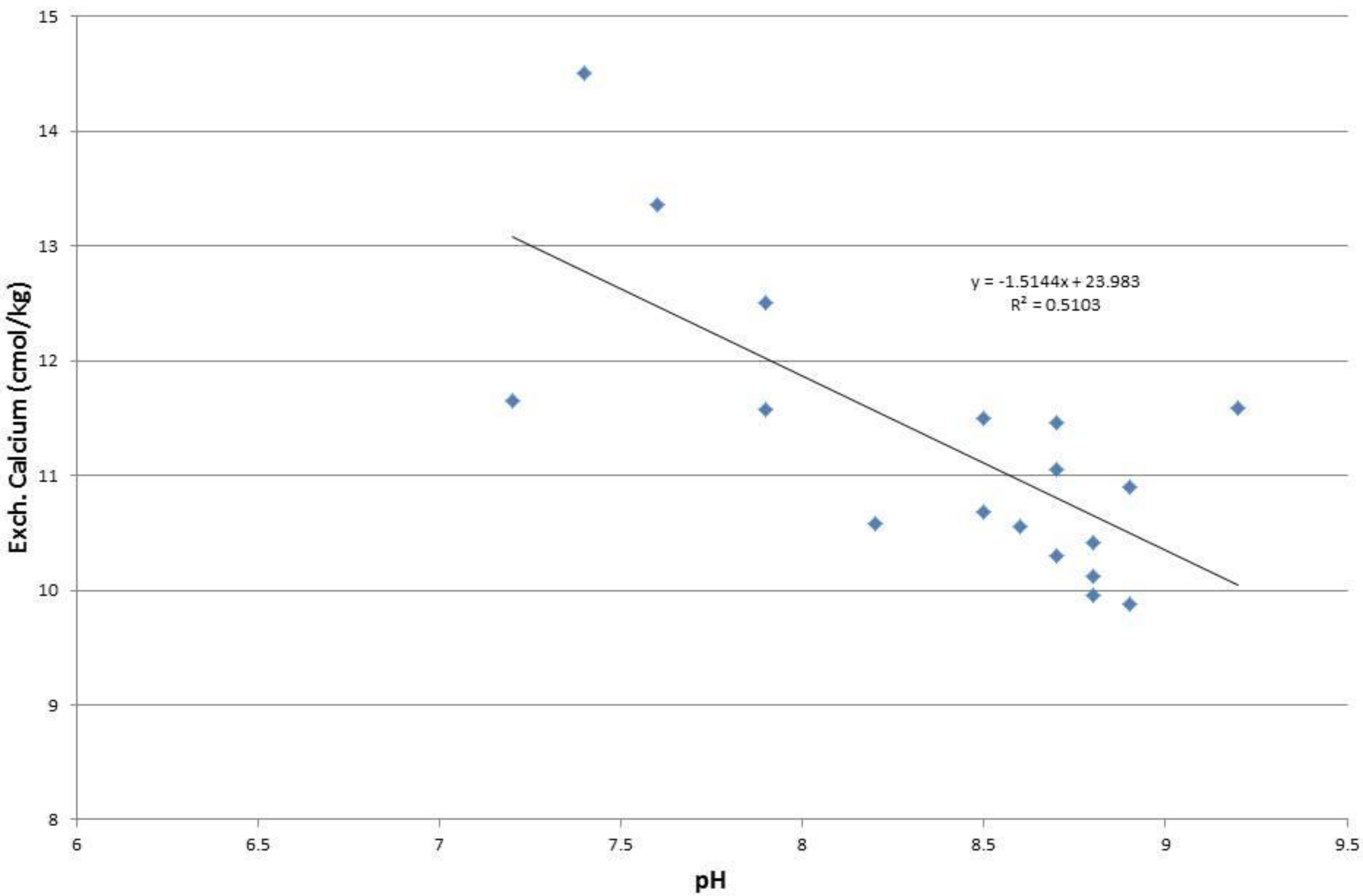

Figure 4. Relationship between exchangeable calcium and pH along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. There is a generally negative but not significant correlation between the two

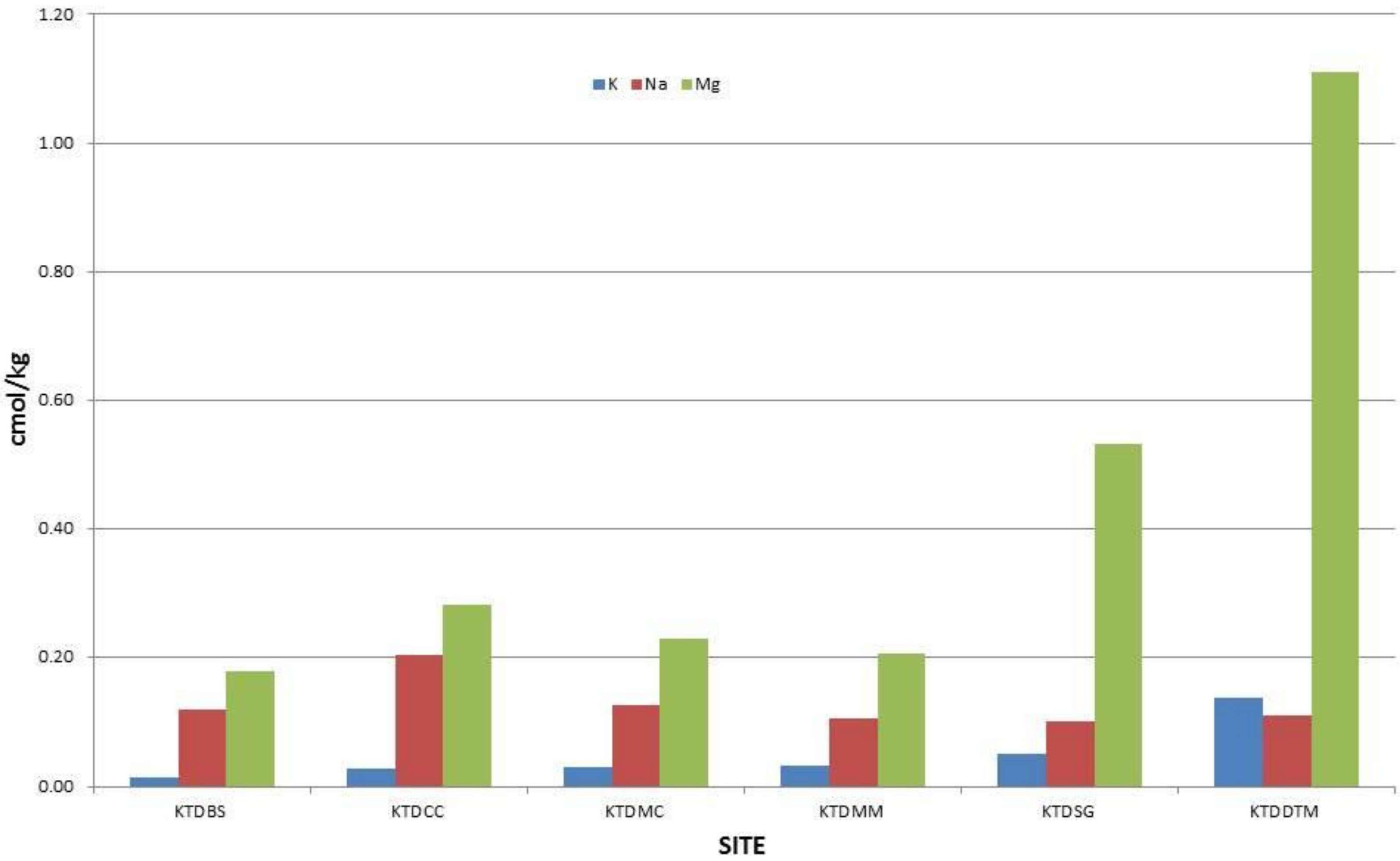

Figure 5. Relationship amongst exchangeable potassium, sodium and magnesium along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. Both K and Mg show increases in the climax vegetation, unlike Na which shows a slight peak in the *Cladoraphis* community near the coast. Site abbreviations explained in Tables 1 and 3

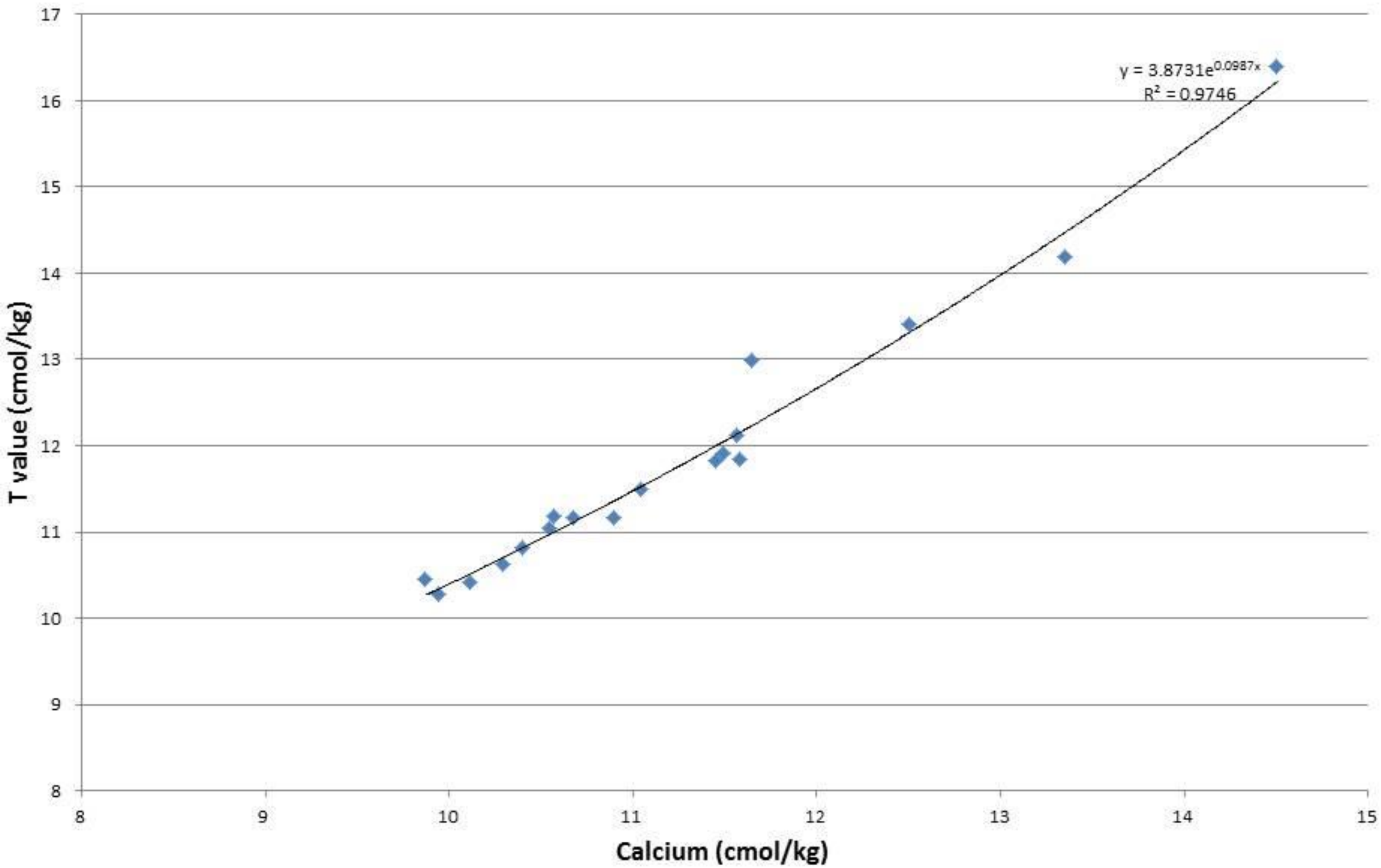

Figure 6. Relationship between exchangeable calcium and T value (total cations) along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. There is a strongly significant positive correlation between the two indicating calcium to be the dominate cation in these soils

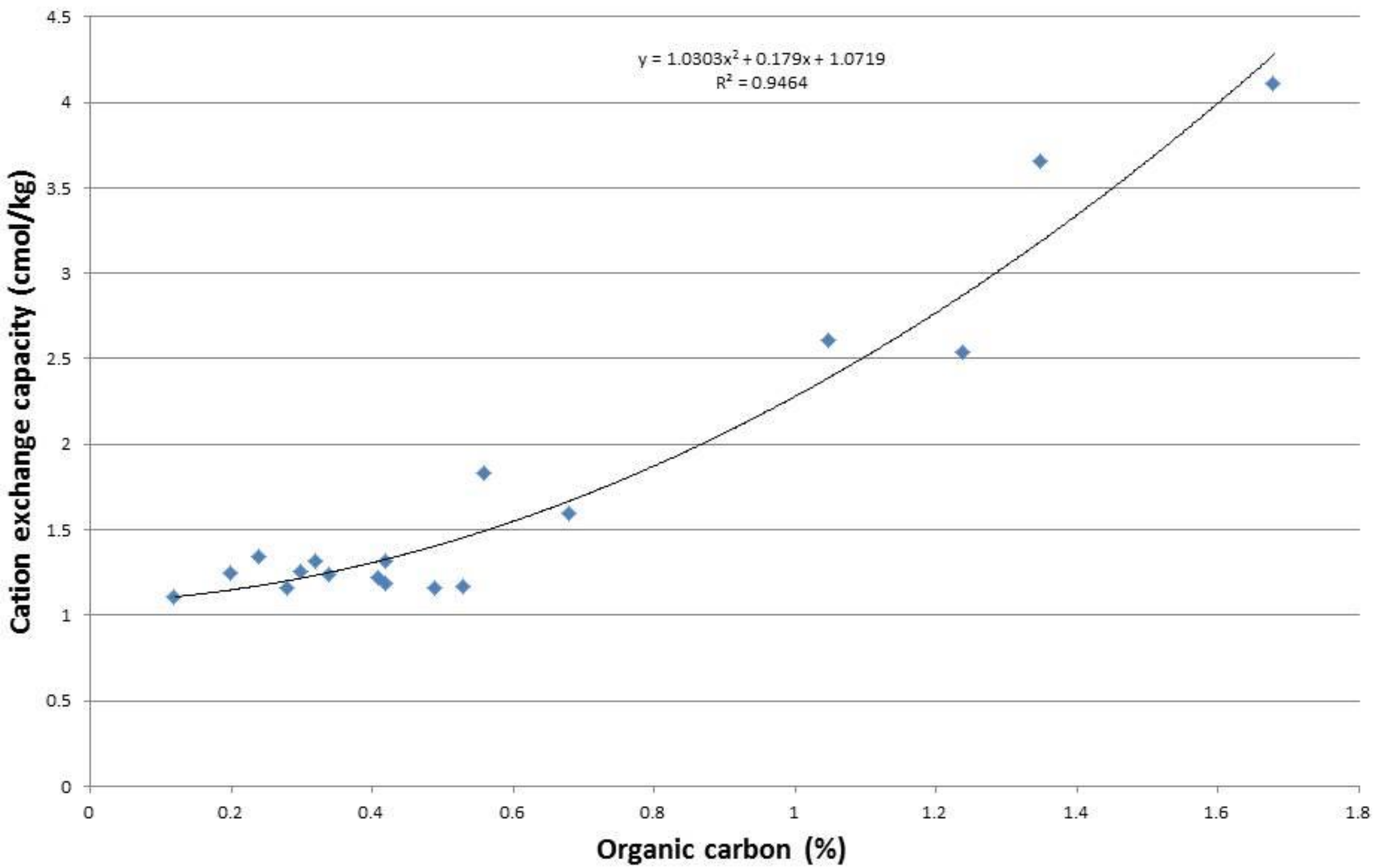

Figure 7. Relationship between organic carbon and cation exchange capacity along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. There is a strongly significant positive correlation between the two underscoring the role carbon plays as a colloid in the absence of clay in these sandy soils. Carbon and CEC levels are highest under thicket

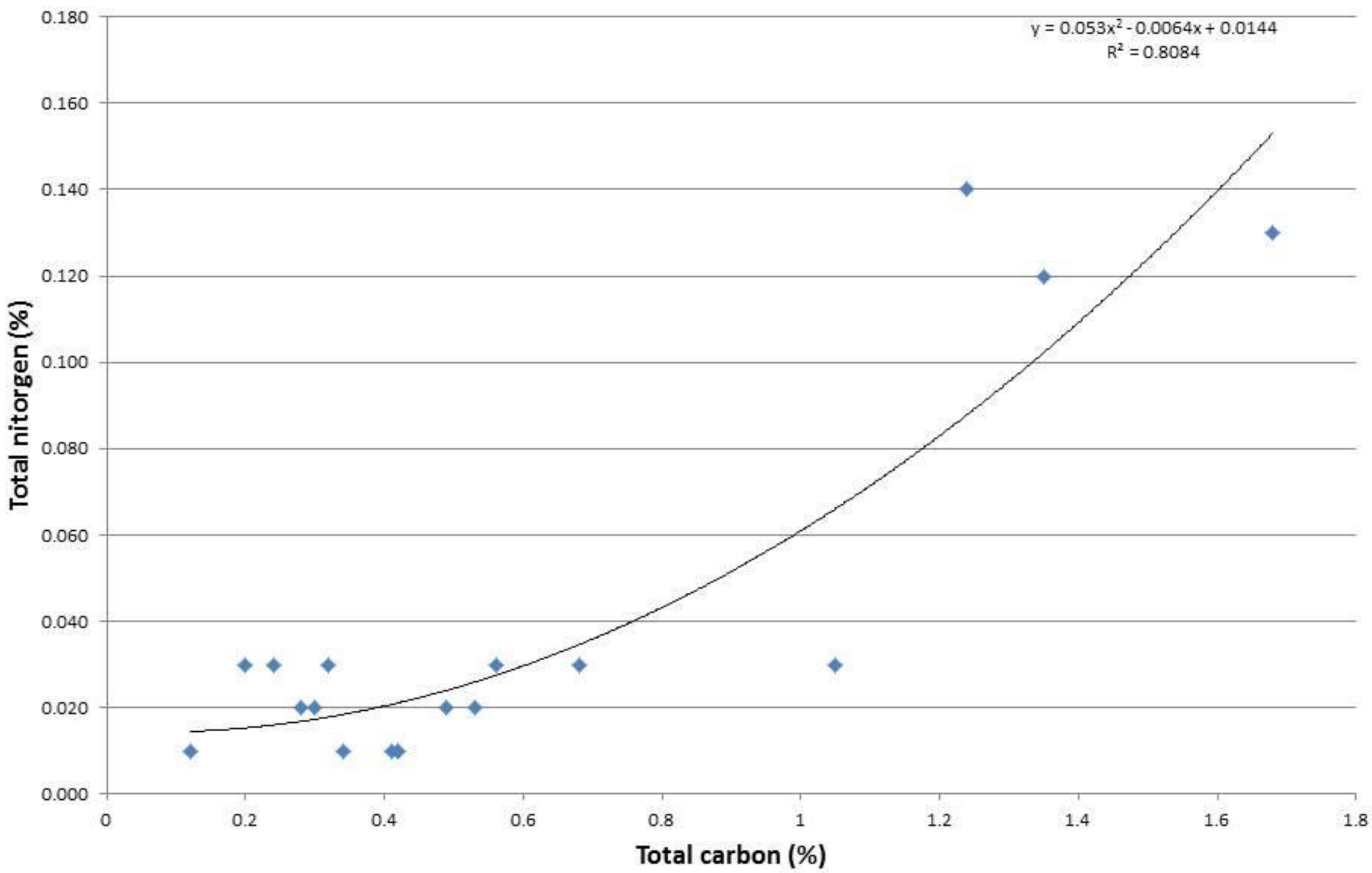

Figure 8. Relationship between organic carbon and total nitrogen along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. There is a fairly significant positive correlation between the two, underscoring the role carbon plays in influencing the nutrient status of sandy soils in particular. Carbon and nitrogen levels are highest under thicket

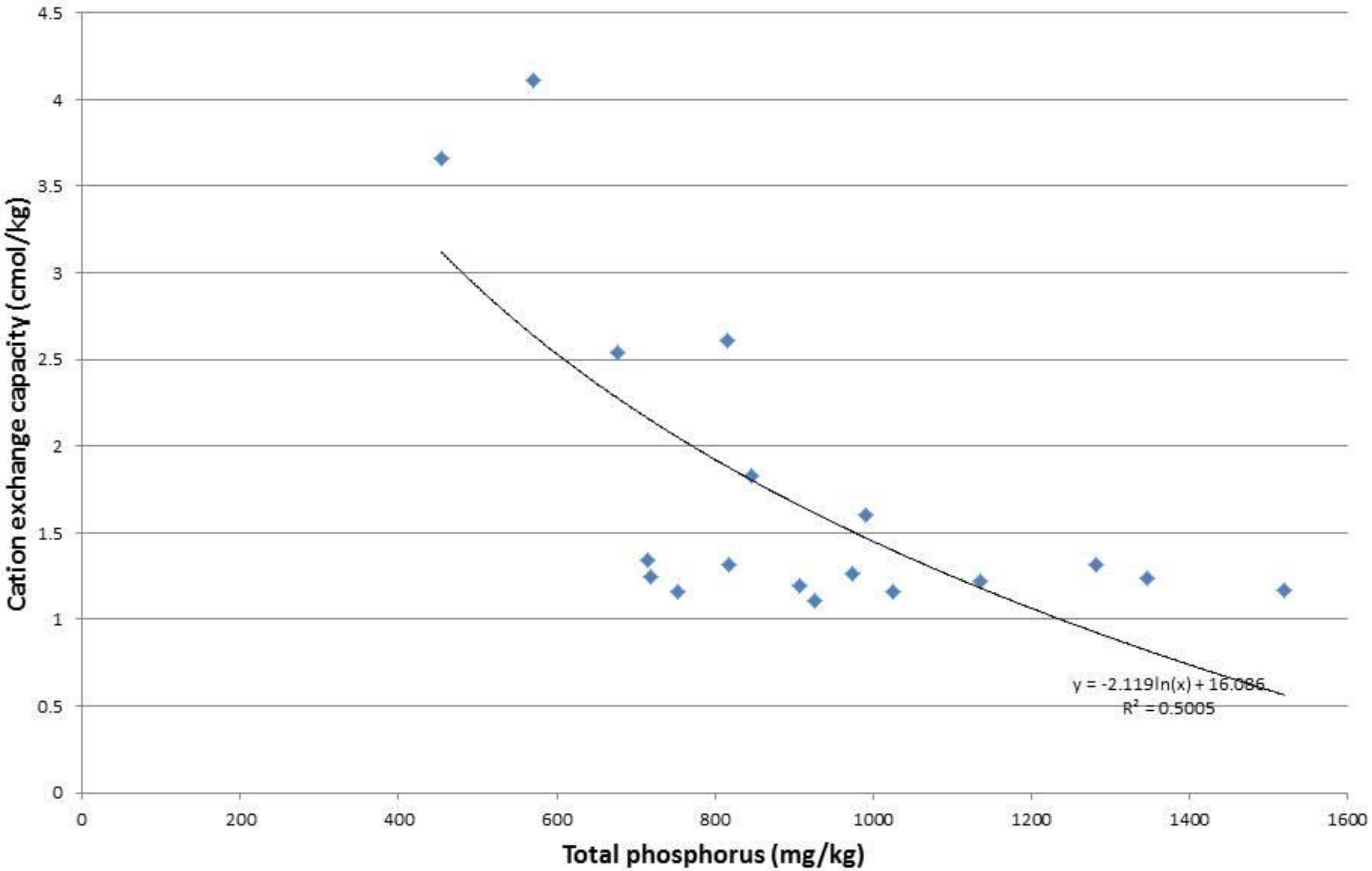

Figure 9. Relationship between total phosphorus and cation exchange capacity along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. There is a generally negative correlation between the two, suggesting phosphorous levels are influenced by pedogenetic factors rather than deposition of organic matter by plants

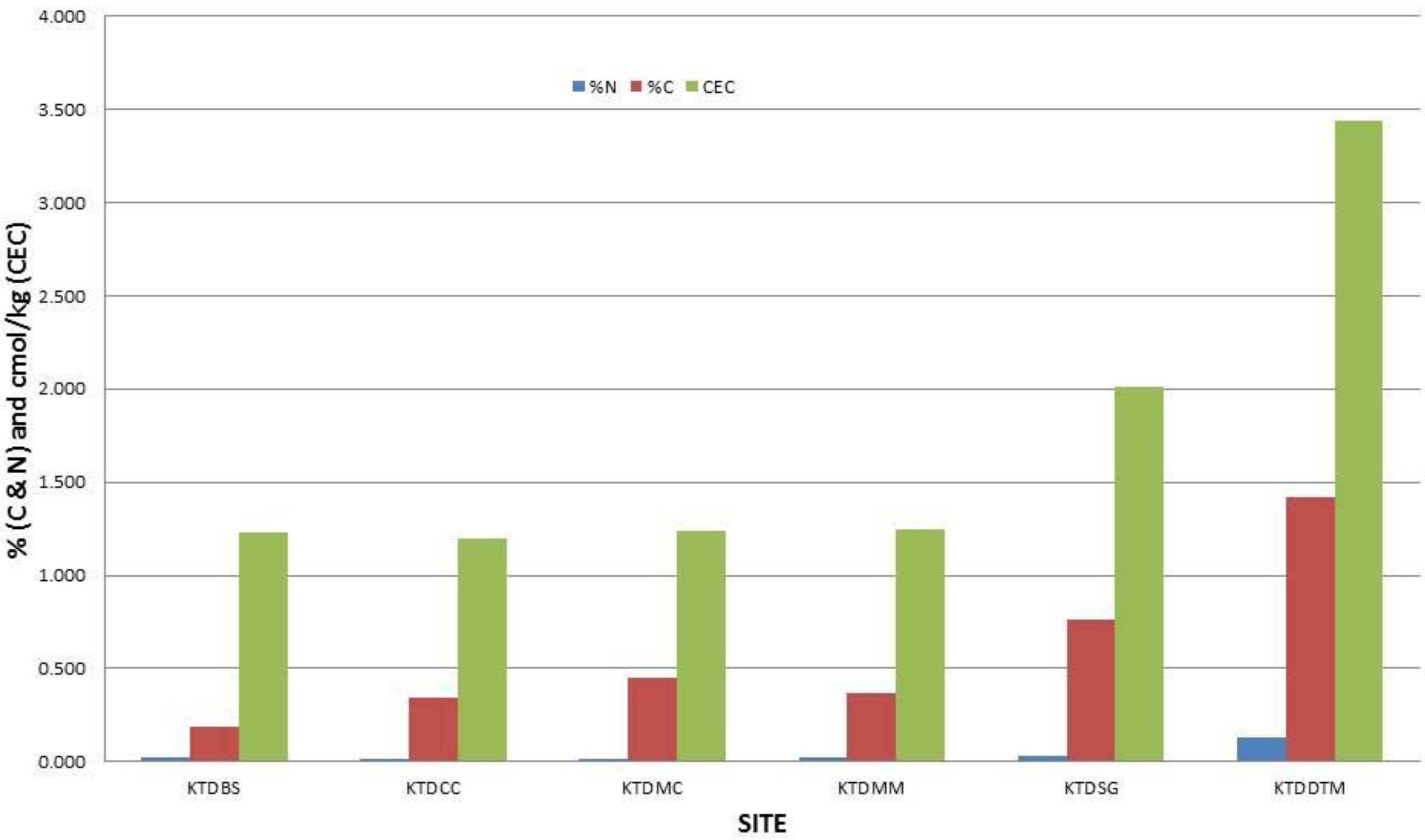

Figure 10. Increase in cation exchange capacity, organic carbon and nitrogen along a gradient from bare sand to dense thicket on transverse dunes at Koeberg. Levels in all these parameters are highest in the the two thicket communities (right hand of plot). Site abbreviations explained in Tables 1 and 3

4.2 Flora

Species lists for each of the broad communities are shown in Appendix 1 (individual) and 2 (composite). Species numbers are low for pioneer (8 to 18) and successional (17 to 28) communities, but considerably higher for dune thicket (45 to 48) (Appendix 1). The composite list (87) indicates plant diversity lying between pioneer and thicket communities, with the latter reaching a total of 108) (Low, 2011).

Analysis of transverse dune flora plots confirms differentiation of sites into three broad associations (three pioneer communities: (*Ehrharta villosa, Cladoraphis cyperoides* and *Osteospermum incanum*), two successional fynbos types (*Morella cordifolia, Metalasia muricata*), and two thicket communities (*Searsia glauca)* (Figure 11).

Mean species numbers for 20 m x 10 m plots increase as one moves along the gradient from pioneer to thicket (Table 5; Figure 12). A simple t-test (two-tailed probability) indicates the pioneer and successional communities are not significantly different, but the successional and climax, and the pioneer and climax are, at a 1% probability level.

Using the Tukey test to compare triplets (i.e. each set of three flora plots against each other), we find the following (Table 6): significant differences at $p<0.01$ for HD vs MM; HD vs DTM; CC vs SG; CC vs DTM; OI vs SG; OI vs DTM; MC vs SG; MC vs DTM; MM vs DTM). At <0.05 differences were found for HD vs MM; MM vs DTM. In short, dune thicket, and to a certain extent *Metalasia* fynbos, show significant differences from the other communities. Figure 12 shows a rapid rise in total species numbers, from the *Morella* community through the *Metalasia* community to dune thicket.

Table 5. Total species numbers for 20 m x 10 m plots in major communities occurring along a gradient in the transverse dunes at Koeberg

Plant community	Species number
KTDHD1	8
KTDHD2	7
KTDHD3	5
KTDCC1	12
KTDCC2	13
KTDCC3	14
KTDOI1	18
KTDOI2	9
KTDOI3	11
KTDMC1	11
KTDMC2	10
KTDMC3	12
KTDMM1	18
KTDMM2	17
KTDMM3	21
KTDSG1	32
KTDSG2	25
KTDSG3	30
KTDDTM1	27
KTDDTM2	41
KTDDTM3	32

Table 6. Significance of total species differences amongst different plant communities on the Koeberg transverse dunes. ** p<0.01; * p<0.05)

	HD	CC	OI	MC	MM	SG	DTM
HD					*	**	**
CC						**	**
OI						**	**
MC						**	**
MM	*					*	**
SG	**	**	**	**	*		
DTM	**	**	**	**	**		

Pioneer: HD = Ehrharta villosa hummock dune; CC = Cladoraphis cyperoides; OI = Osteospermum incanum
Successional/ fynbos: MC = Morella cordifolia; MM = Metalasia muricata
Thicket: SG = Searsia glauca; DTM = mature Searsia glauca thicket on edge of transverse dunes

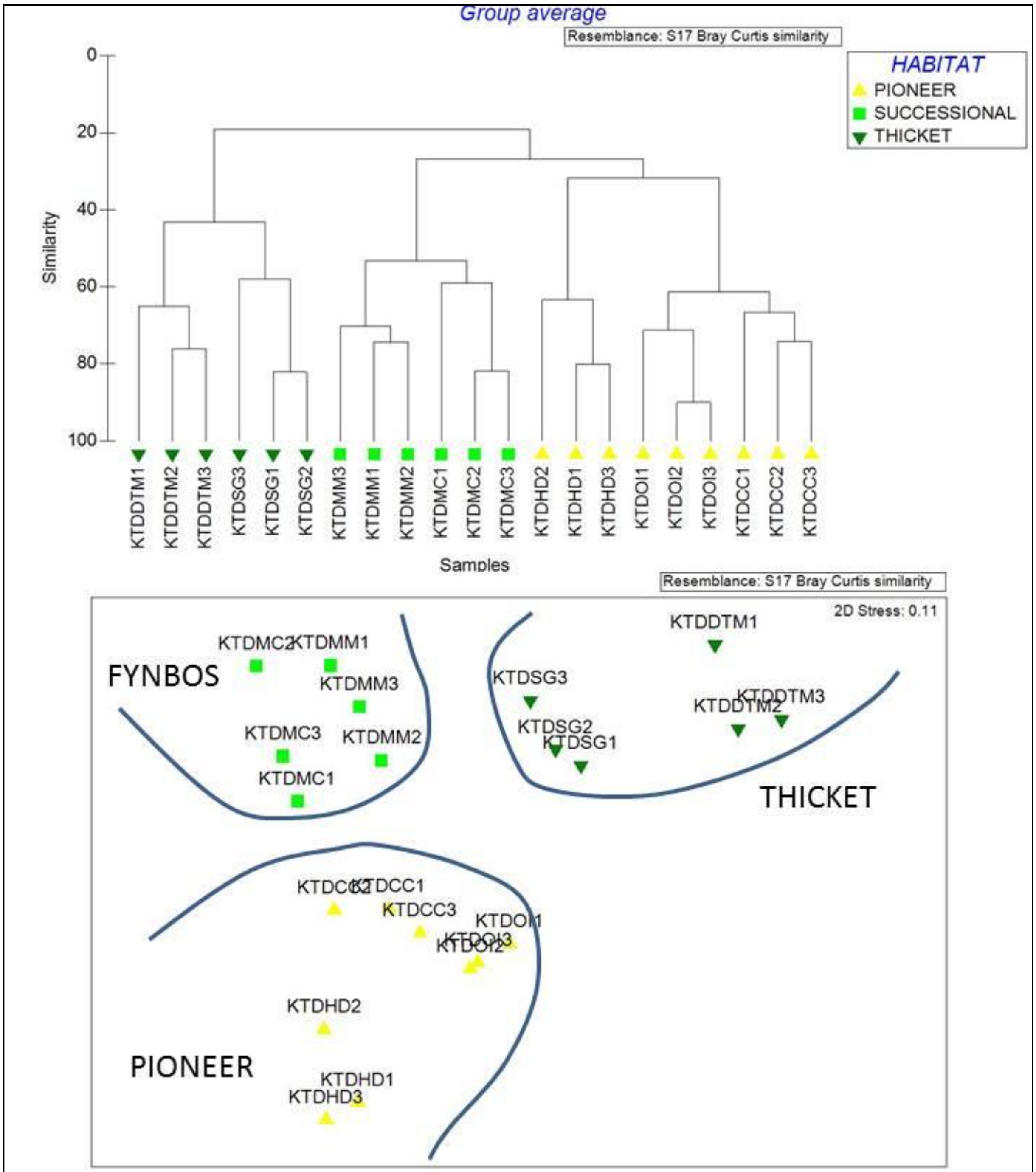

Figure 11. Cluster (top) and MDS (bottom) analysis of Koeberg transverse dune floras. Note clear separation into three broad associations, with pioneer communities in bottom right hand and thicket in top right hand of plot. Site abbreviations as per Table 3

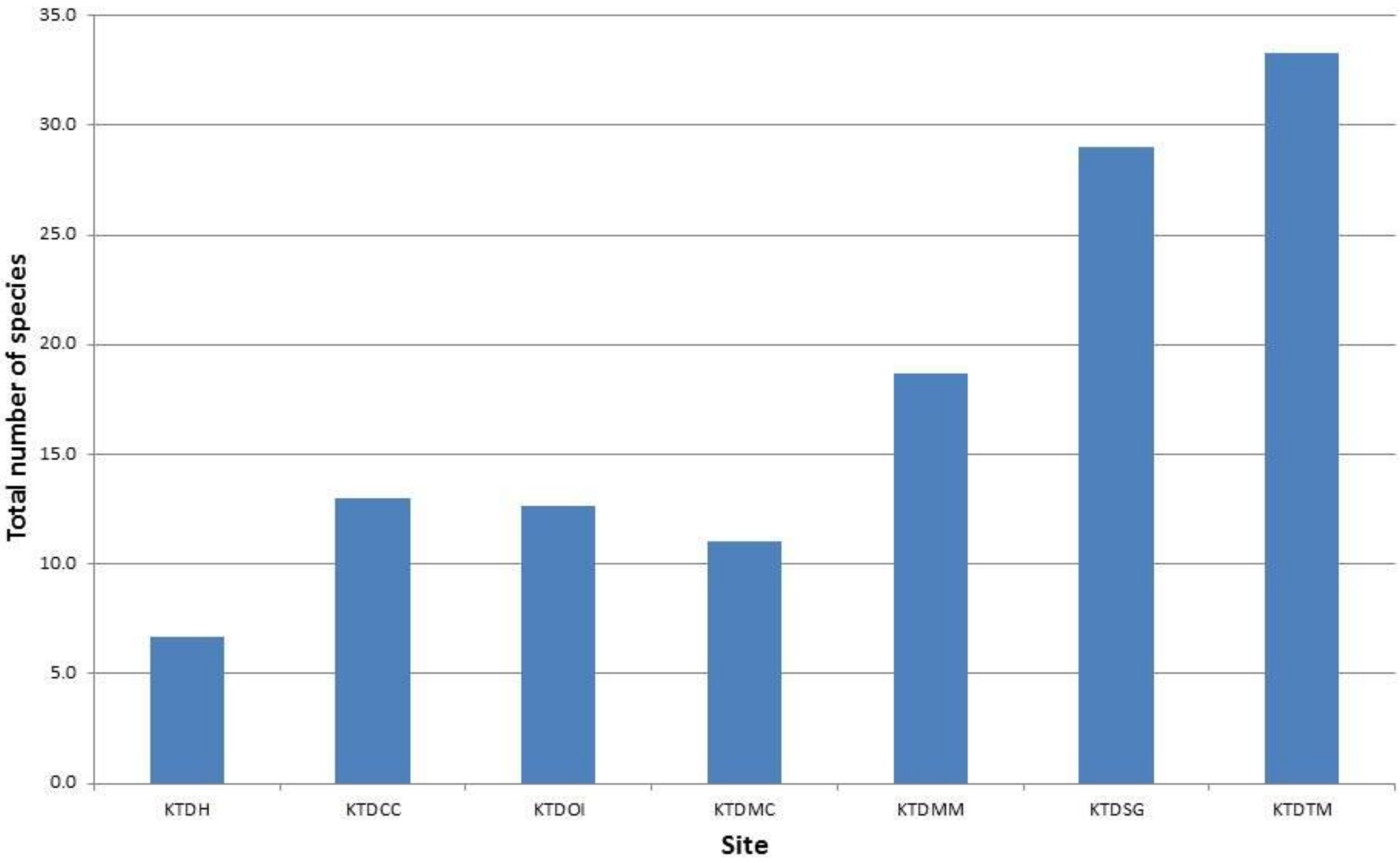

Figure 12. Change in total number of plant species (mean of three 20 m x 10 m plots) along a gradient from pioneer to mature thicket vegetation on the transverse dunes at Koeberg. Site abbreviations in Table 4. Note the rapid change from fynbos (MC/MM) to dune thicket (SG/DTM). Data from Table 5. Site abbreviations explained in Tables 1 and 3

4.3 Vegetation

Brief descriptions of the plant communities are presented in Table 7 and show a general increase in cover and height as one progresses along the gradient from pioneer to climax vegetation. Images for the different communities are shown in Plates 1 to 6.

An analysis of plot data is shown in Figure 13 displays clear separation into Pioneer, Successional (Fynbos) and Thicket associations, emphasising the gradient displayed in the floristic analysis (Figure 11). This echoes the pattern shown for the Koeberg vegetation (Low, 2011, Figure 4.1.10) and confirms the succession from lightly vegetated dunes to dense thicket. This finding needs to be read in conjunction with the vegetation mapping (below) where transverse dunes become less mobile as vegetal cover increases (*sensu* Low, 2011).

4.4 Mapping

Results of the mapping exercise are shown in Figures 14 (1938), 15 (1960), 16 (1977), 17 (1985), 18 (1997), 19 (2007) and 20 (2014). Figure 21 groups years 1938, 1977, 1997 and 2014 to show the major increases in vegetation cover and subsequent loss of dune mobility over the intervening 76 years.

These changes are quantified in Table 8 and a summary of the findings presented graphically in Figure 22. Over the 76 year period of assessment, there is a major loss of bare sand and therefore dune mobility (637 ha). This is coupled with a concomitant gain in vegetated dunes, mainly thicket (401 ha), but also development in the south, principally Melkbosstrand (265 ha). Fluctuations in Pioneer vegetation and shrub and sand categories are understandable as this reflects natural dune dynamics.

Table 7. Description of plant communities occurring along a succession on the transverse dunes at Koeberg

Site	Description
PIONEER	
KTDHD	Hummock dunes on mobile sand in early succession. Cover 50 – 55%. Short grass and occasional shrubs to 50 cm in height; low succulence Dominant: *Cladoraphis cyperoides*
KTDCC	Edge of transverse dunes, semi-mobile sand. Cover 70 – 80% but often less. Low grass and some shrubs to 50 cm in height; low succulence. Dominant: *Cladoraphis cyperoides*
KTDOI	Edge of transverse dunes at coast, just north of Koeberg. Disturbed site. Cover 90 – 95%. Low shrubs and fairly marked succulence to 60 cm in height; moderate succulence. Dominant: *Osteospermum incanum*
KTDMC	Successional fynbos on more stable sand. Cover 85 – 90%. Medium height shrubs, occasionally very dense monospecific stands to 1 m in height; low succulence. Dominant: *Morella cordifolia*
KTDMM	Successional fynbos on more stable sand, often in dune slacks. Cover 90 – 95%. Medium height shrubs to 2.5 m in height; low succulence. Dominant: *Metalasia muricata*
KTDSG	Immature dune thicket on stable dune. Cover 98 – 100%. Tall shrubs in dense thicket, but localised and in clumps to 3 m in height; low succulence. Dominant: *Searsia glauca*
KTDDTM	Mature climax dune thicket on the stable sands in the transition between parabolic and transverse dunes. Cover 98 – 100%. Tall shrubs in dense thicket with occasional openings supporting fynbos, to 3 m in height. Dominant: *Searsia glauca*

Plate 1. *Cladoraphis cyperoides* steekriet hummock dunes amongst bare dunes of the northern mobile transverse dunes at Koeberg

Plate 2. *Cladoraphis cyperoides* pioneer community at edge of transverse dunes

Plate 3. *Metalasia* successional (fynbos) community in dune slack

Plate 4. *Morella* successional fynbos community in dune slack

Plate 5. *Searsia* clumps (darker green in mid-distance) in developing vegetation on stabilising transverse dune

Plate 6. *Searsia-Euclea* climax thicket community at stable edge of transverse dunes. Note greater density and species richness compared with the vegetation in Plate 5

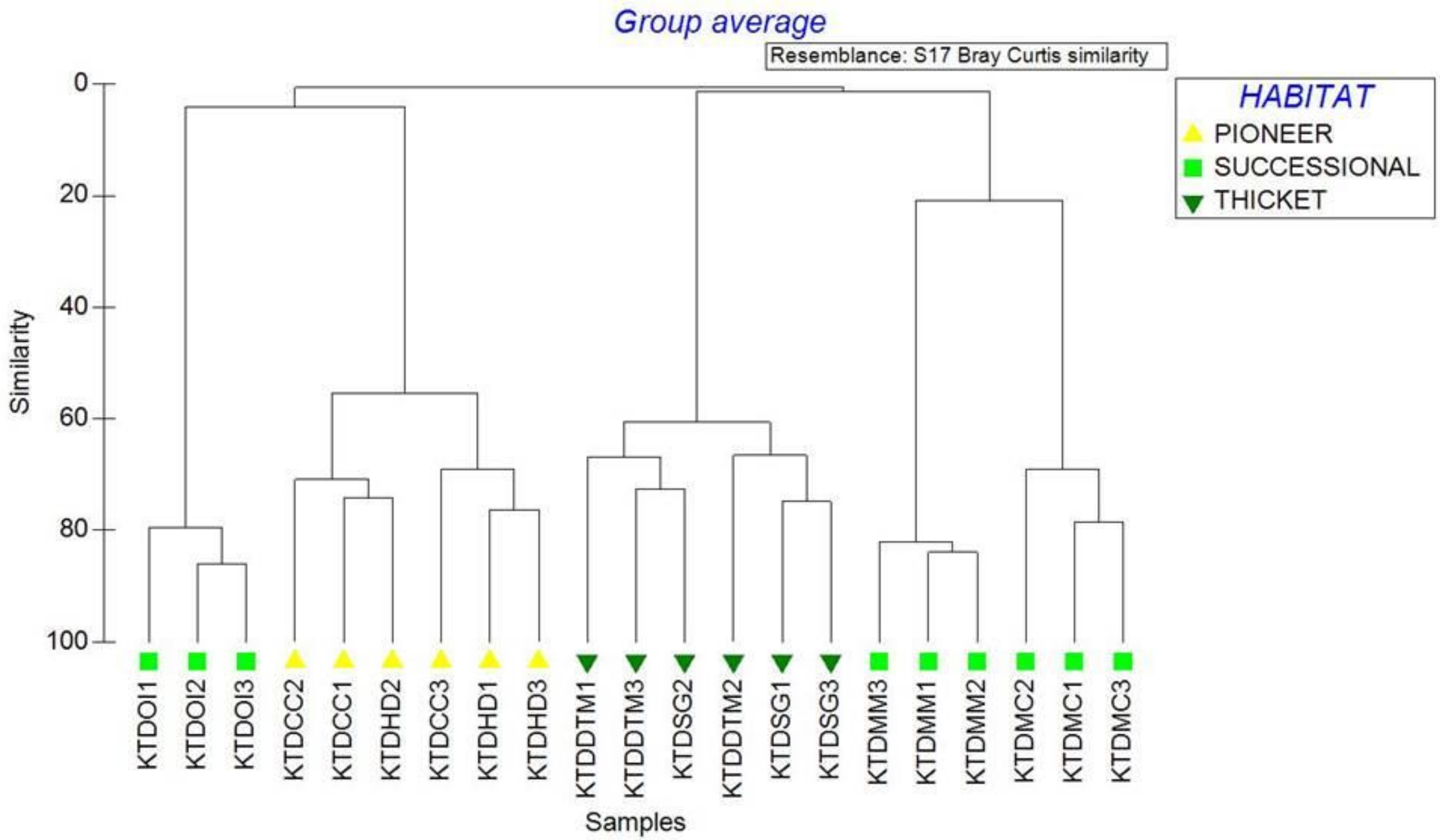

Figure 13. Cluster analysis of vegetation plots from the Koeberg transverse dunes. Note distinct separation into Pioneer, Successional (Fynbos) and Thicket communities

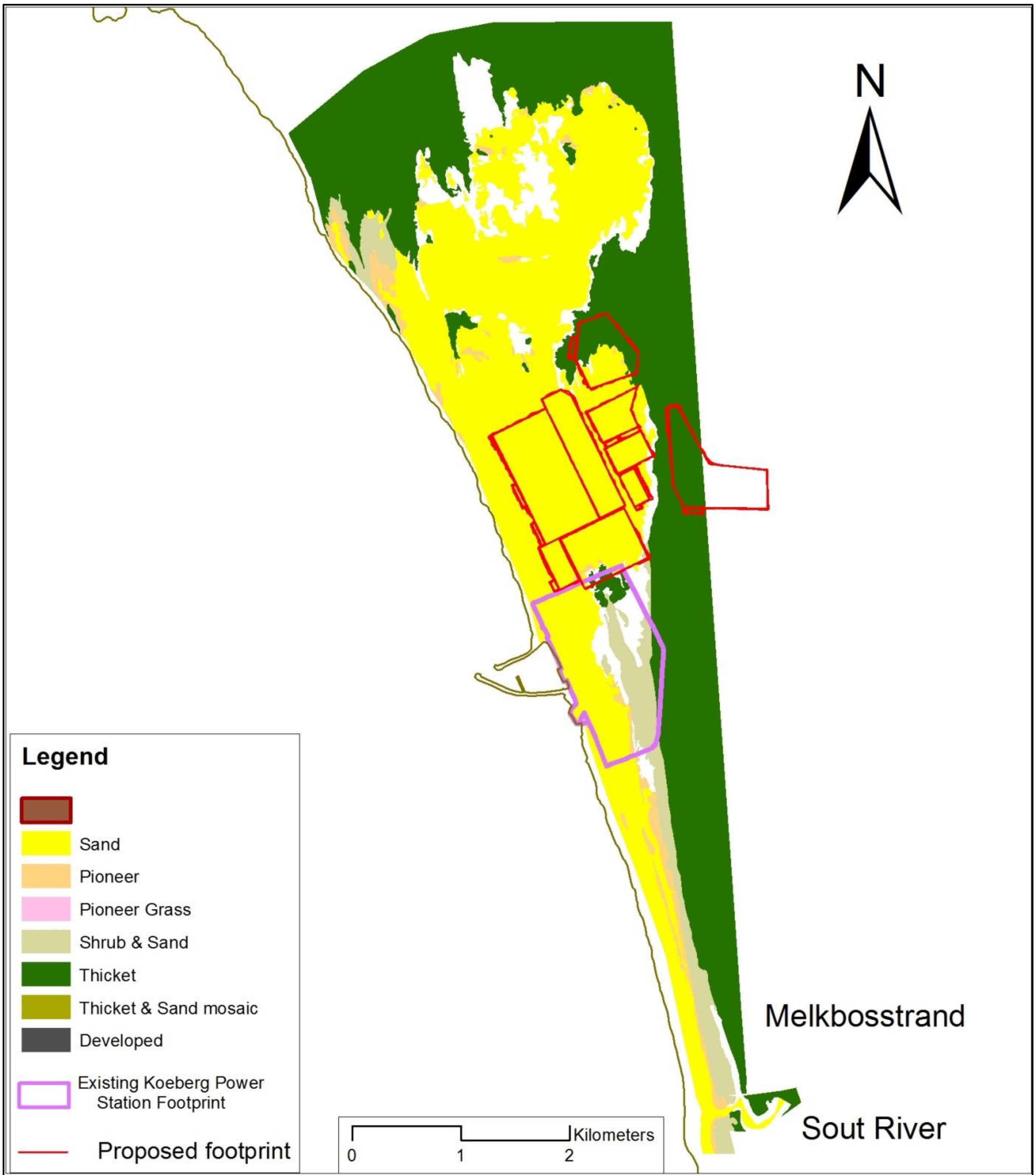

Figure 14. Koeberg: mapping of 1938 aerial photographs. Note dominance of bare sand on transverse dunes north and south of the existing Power Station, and dense thicket, probably mostly invasive acacias,to the east

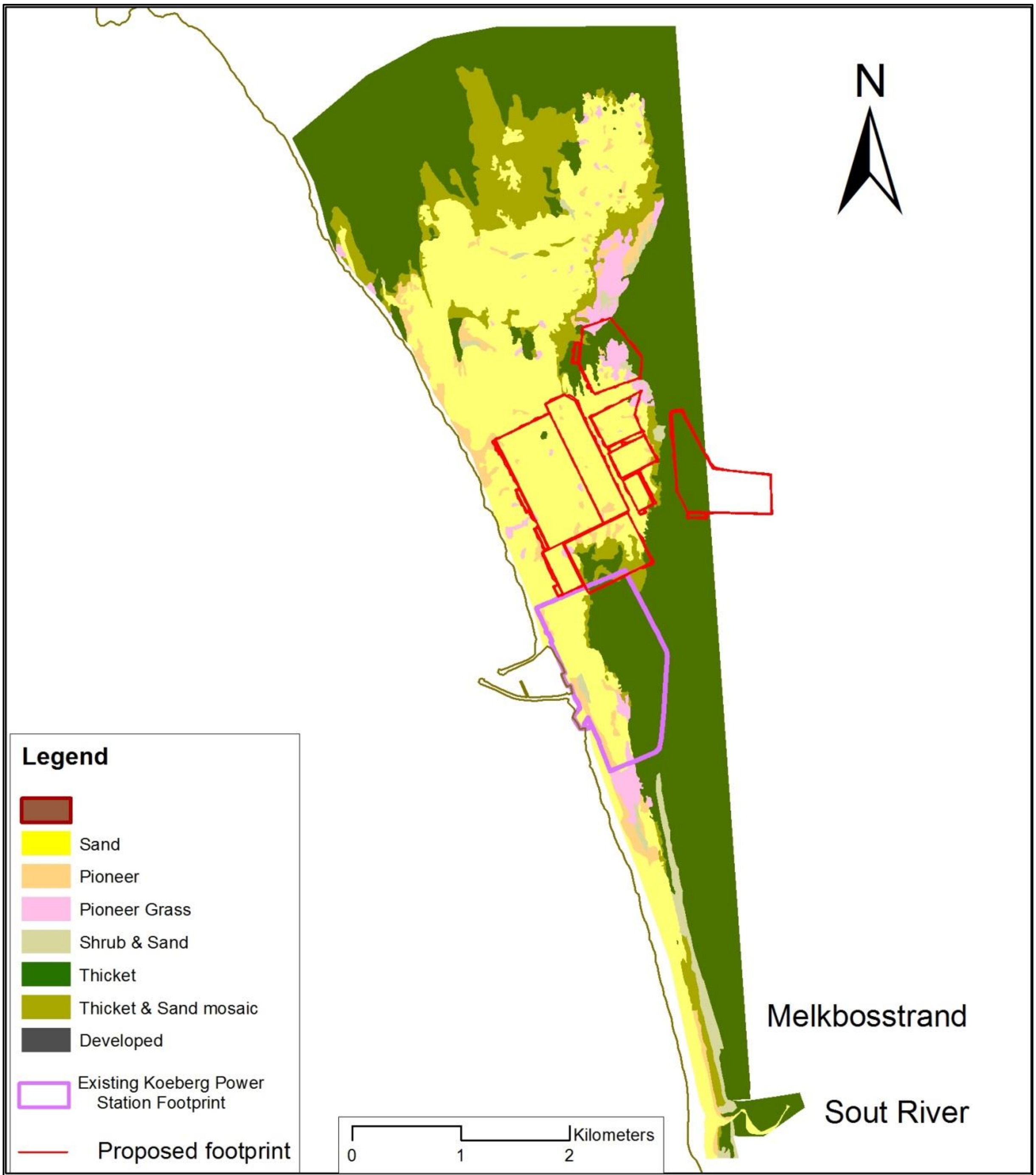

Figure 15. Koeberg: mapping of 1960 aerial photographs. There is still a dominance of bare sand on transverse dunes north and south of the existing Power Station, and dense thicket, probably mostly invasive acacias, to the east. The thicket-sand mosiac is increasing, chiefly in the north

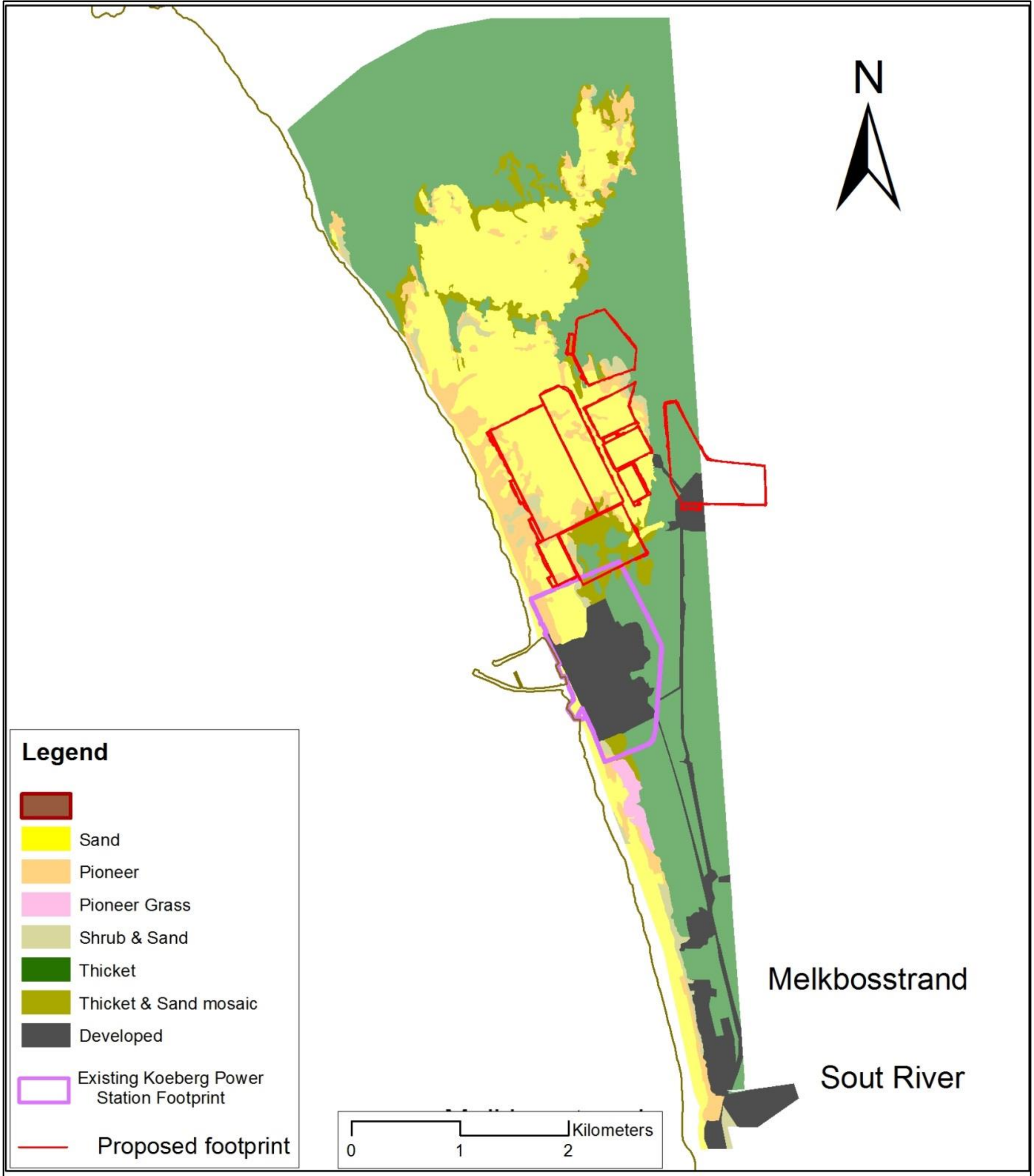

Figure 16. Koeberg: mapping of 1977 aerial photographs. The Power Station has been constructed. Much of the bare sand from the 1938 and 1960 photos has been vegetated, although mobile transverse dunes are still prominet north of the NPS. There is far greater cover from thicket, probably mostly invasive acacias

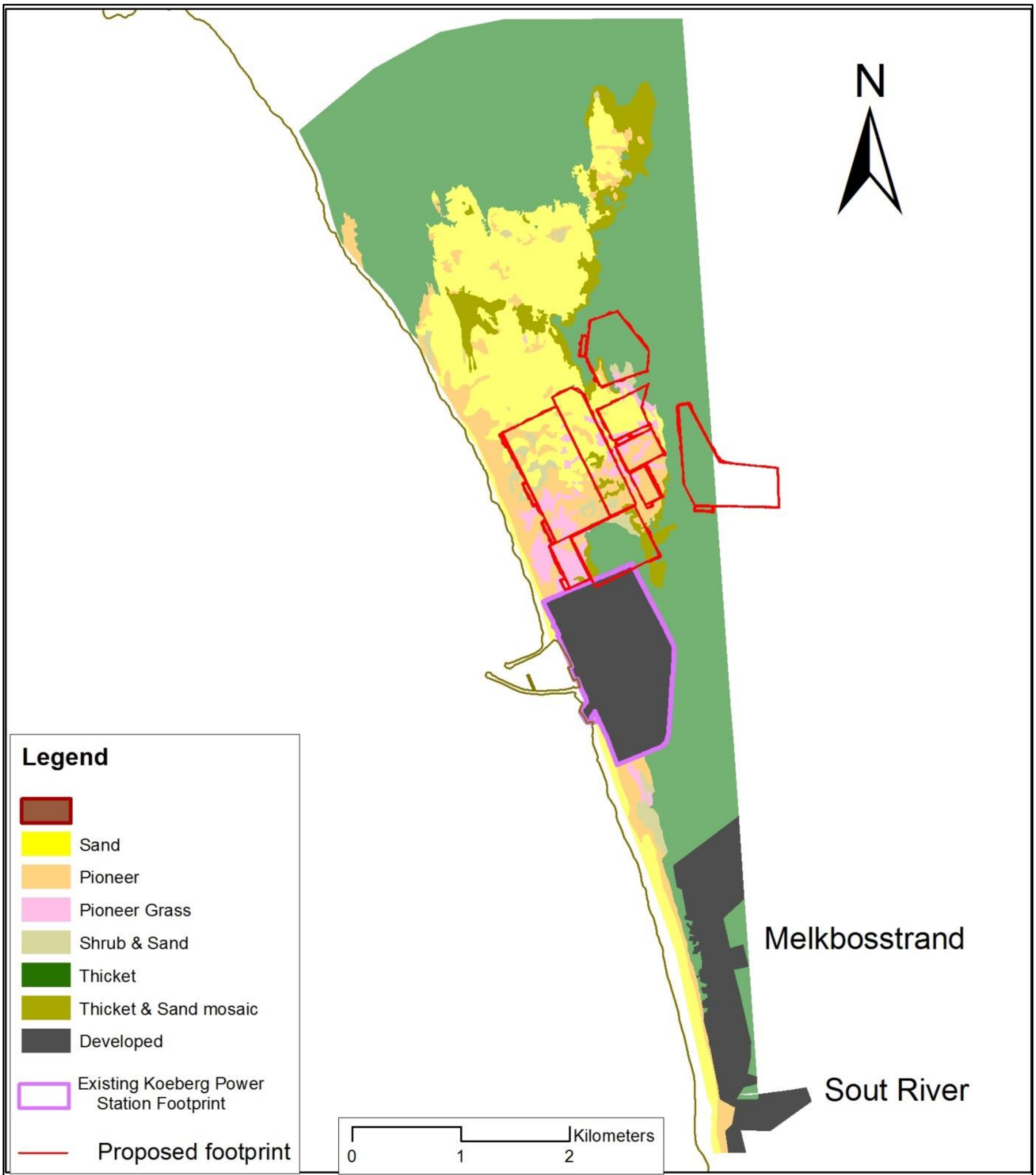

Figure 17. Koeberg: mapping of 1985 aerial photographs. Most of the transverse dunes north of the Power Station have been vegetated, although there is still some mobility. Thicket, probably mostly invasive acacias, now dominates the area. Development, in particular around Melkbosstrand, has accelerated

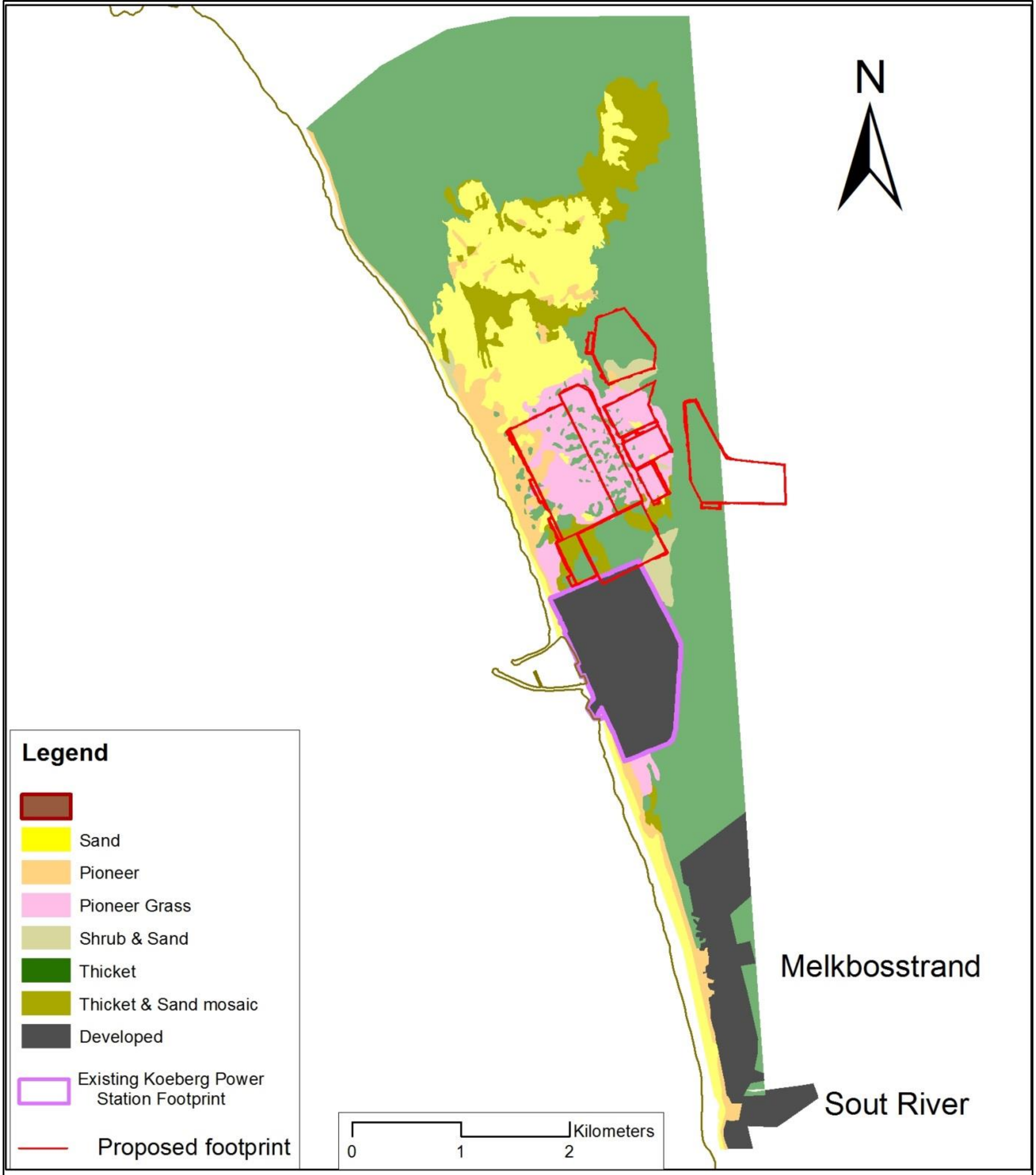

Figure 18. Koeberg: mapping of 1997 aerial photographs. Most of the transverse dunes north of the Power Station have been colonised by pioneer vegetation, particulary the introduced marram grass, which was actively planted. Mobility is now confined to a much smaller area in the north. Thicket, probably mostly acacias, continues to dominate the dune vegetation. Development still marked in the south

Figure 19. Koeberg: mapping of 2007 aerial photographs. The transverse dunes north of the Power Station continue to show an increase in vegetation cover, with both the pioneer, and thicket and sand mosaic forms dominating. Dune mobility is now severely reduced and is some distance from the Power Station. Thicket, probably mostly acacias, continues to dominate. Development marked in the south

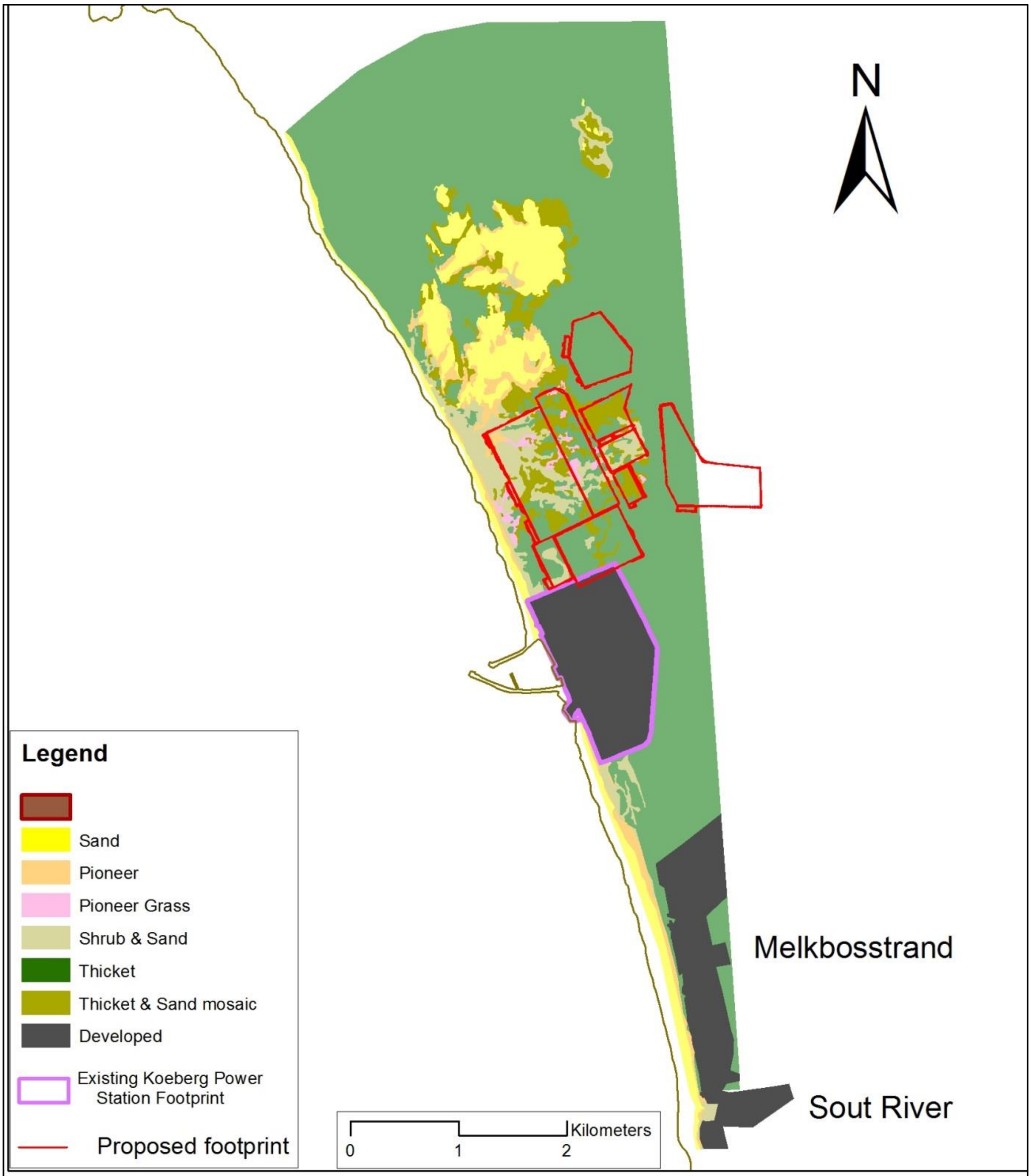

Figure 20. Koeberg: mapping of 2014 aerial photographs. The transverse dunes north of the Power Station show an increase in more stable shrub and thicket vegetation, although mobility has decreased only slightly. Thicket, probably mostly acacias, continues to dominate. Development marked in the south

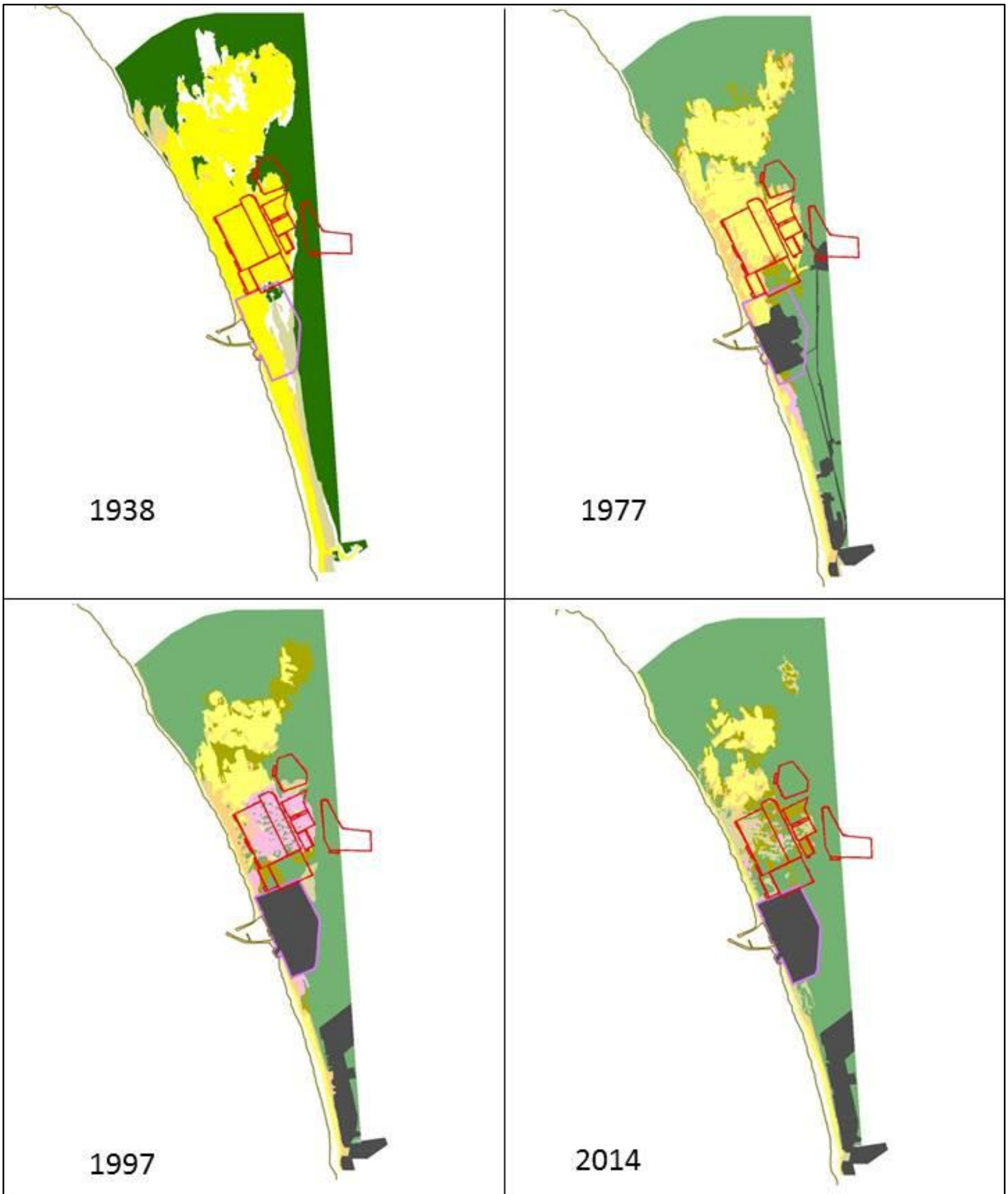

Figure 21. Sequential mapping at Koeberg, showing marked changes in vegetal cover between 1938 and 2014. The decrease in mobile dunes (yellow) is offset by increases in green (shrub and thicket vegetation)

Table 8. Change in bare sand and vegetation cover between 1938 and 2014 for the Koeberg dunes. Extent in hectares								
	1938	**1960**	**1977**	**1985**	**1997**	**2007**	**2014**	**Net change**
Bare sand	793	629	475	332	243	187	156	-637
Pioneer (grass)	1	51	11	49	128	36	12	+11
Pioneer (shrubs)	46	60	118	146	86	32	49	+3
Shrubs & sand	99	44	33	29	25	137	98	-1
Thicket & sand	153	190	83	85	129	109	117	-36
Thicket	809	943	1016	1002	1028	1135	1210	+401
Developed	1	1	165	259	262	266	266	+265
Total	**1902**	**1917**	**1901**	**1902**	**1901**	**1902**	**1908**	

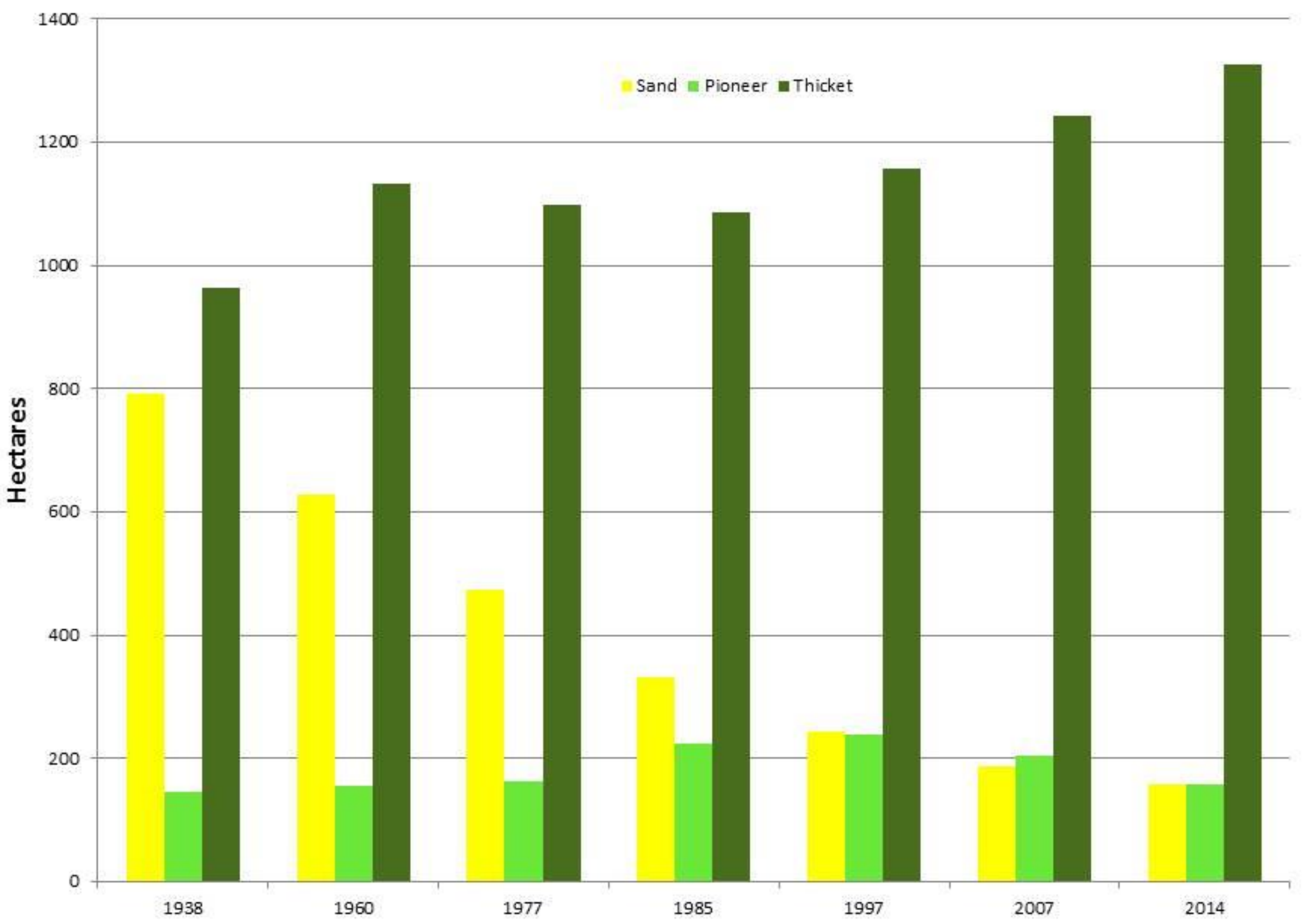

Figure 22. Mapped change in dune vegetation cover at Koeberg: 1938 to 2014. A decline in bare sand is accompanied by an increase in thicket cover

7. SYNTHESIS OF FINDINGS

The above findings present an account of a major change in dune dynamics in the Koeberg area. The construction of the Koeberg Power Station itself commenced in the mid to late 1970’s, so that by 1985 (Table 8; Figure 17), bare sand had declined from 475 to 332 ha, some 30%. However, it is important to note that prior to any development in the area, there had be a natural “slowing down” of the dune, as bare sand decreased in extent by 318 ha (a significant 40%) between 1938 and 1977 (Table 8; Figures 14 & 16), during a period in which there was no development in the area. This “slowing down” has been markedly exacerbated through the construction of Koeberg in a virtual sea of sand over 30 years ago. Coupled with the development of Melkbosstrand in the south, particularly around the Sout River mouth, this led to a decline in sand supply to the mobile transverse dunes north of here, and the onset of stabilisation.

A parallel for this scenario can be found in the Thyspunt dunes, where Illenberger (2013) investigated the change in dune behaviour between 1942 and 2011, a period of 69 years. Illenberger (2013) found that the headland-bypass dunefields between Oyster Bay and Cape St Francis had been cut off from their source beaches by the former development. Despite this, he contends that with the removal of alien vegetation the dunes will revert to their natural mobility, moving at a rate of some 10 to 30 m per year. Nevertheless, sand supply from the west has been permanently compromised so sand inputs into the system have slowed to almost a negligible amount. This suggests a net loss of sand as the headland-bypass system continues to move eastwards, and therefore a crucial loss in natural dune functioning.

Illenberger (2013) found dune mobility to decrease due to stabilisation through vegetation by 30% between 1942 to 1985 (43 years) and a further 30% between 1985 and 2011 (26 years). Most of the stabilisation has been artificial, with the Department of Forestry’s commencing with active planting of the mobile dunes by acacias between Oyster Bay and Thyspunt carried out from 1917 (Keet, 1936). Dune stabilisation was started at Cape St Francis in about 1960, with the Santamerene dunefield vegetated during the 1970’s and 1980’s to permit development. Much dune mobility has been lost to development, such as the golf links in the west of Cape St Francis. Thus development in the path of the sand source has had a negative impact on sand supply and resultant dune mobility.

In the Koeberg case, development, particularly of the Power Station, was accompanied by active stabilisation of the mobile system directly north of Koeberg. Here *Ammophila arenaria* marram grass was planted between 1979 and 1983 (Gert Greeff, pers.comm.) in the area shown in Figure 23. Although there appear to be no records of method of stabilisation, it is clear that the approach was successful as is attested by the loss of bare sand between 1977 and 1985, and with the concomitant gain in vegetal cover (Table 8).

Prognosis for transverse dune mobility? The major source of sand supply has been irrevocably lost due to development of both the Koeberg Power Station as well as Melkbosstrand. Although Illenberger (2010) correctly attests to the main winds at Koeberg being southerly, Low (2011) does point out that sand is fed from the primary dunes on the coast, when the wind turns to the south-west. In my opinion, this has kept part of the transverse dune system mobile. However, as a system, and echoing the fate of the headland-bypass system at Oyster Bay-Cape St Francis, the mobile dunes at Koeberg no longer function as they would have pre-1980’s, when Koeberg was constructed. Following active stabilisation, the dunes are now “auto-vegetating” as is evidenced in Table 8. The rate of “slowing down” of the mobile system, initially rapid between 1938 and 1977 (461 ha or 58%) (Table 8), has levelled off slightly with only 31 ha or 16.6% being lost between 2007 and 2014. However, the trajectory is one of constant loss of bare sand and gain of plant cover, and it is likely that dune mobility will continue declining in the foreseeable future.

Figure 23. Transverse dune system just north of the existing Koeberg Power Station and actively planted with marram grass between 1979 and 1983. Supplied by Mr Gert Greeff of Eskom

8. RECOMMENDATIONS

Low (2011) in his report on the dunes and botany of the Koeberg site, recommended a set back line which would place any proposed power station beyond the mobile dune field, i.e. over 1.5 km inland of the coast. That recommendation stands for areas which still contain mobile dunes, but the more recent information entertained in this study suggests a reappraisal of the situation, particularly given the stabilisation of the mobile dunes just north of the existing Power Station.

Two factors are paramount to this debate: (i) the substantial loss in dune mobility due to development in the south, coupled with increases in vegetal cover have meant the dune can no longer function in its pristine state and (ii) development would be localised to vegetated parts of the dune system, permitting the remaining small mobile system in the north to function in the long term, albeit artificially restricted.

Low (2011) comments: "Construction of a nuclear facility would potentially lead to the loss of most of a large transverse dune system, **endemic** to the lower Cape West Coast. This system is poorly represented in the region, although there is a large transverse dunefield to the north-east at Witzand and a similar, but larger, more intact system north of Yzerfontein. The Duynefontein system is remarkable for its size (nearly 1 000 ha) and location at the coast, just above the primary dunes. Despite the present position of the Koeberg Power Station to the south, and at the start of this system, thereby somewhat compromising the supply of sand to the north (the general direction of sand movement), field observations, together with those of the dune geomorphologist, confirm that there is fairly substantial inland sand movement from the south-west, suggesting there has either been somewhat of a "correction" in the system, or the south-western source has been present for some length of time".

In the seven or so years since the first study (Low, 2011), it is clear that both development and active planting of the mobile transverse dunes has hampered dune mobility and has led to a "slowing down" of the system. The prognosis for dune stabilisation is that this will continue into the foreseeable future, as sand supply literally dries up, and auto-vegetation accelerates.

It is therefore the recommendation of this report, that location of the proposed Nuclear-1 footprint be considered for the southern ~~southern~~ VEGETATED and STABILISED part of the transverse dunes (see Figures 23 & 24), but with the provisos dealt with under the next section (in section 7?).

Any losses of the transverse dune should be offset by addition of dune vegetation to the north of the Koeberg Nature Reserve boundary (i.e. Groot Springfontein Farm).

9. TREATMENT OF THE STABILISING TRANSVERSE DUNES IN RESPONSE TO IMPACT

7.1 Construction phase of Nuclear-1 facility

9.1.1 Soils

As plant cover increases, so does the level of organic carbon and most nutrients (see above). Soils under climax dune thicket show disproportionately higher amounts of carbon and nutrients than bare sand and pioneering communities. Of note is the greater cation exchange capacity and nutrient availability which ensures a greater diversity of species and a plant community far more resilient to disturbance. Soil stability is ensured through a) higher amounts of organic matter and therefore soil binding and b) dense canopies which afford sand protection from the wind. Correspondingly, natural transverse dunes are far less vegetated and mobile, being blown in perpendicular waves in the direction of the wind (see below and refer to Illenberger, 2013).

9.1.2 Flora

Some 87 species were encountered on the transverse dunes in this study, 10 more than in Low's (2011) work (see SaSFlora, 1998 – 2015). Both this and Low's (2011) study report five Red List species, all of which are well-distributed in the dunes of the West Coast and elsewhere (*sensu* SaSFlora, 1998 – 2015). Losses to a NPS footprint are thus considered minor.

9.1.3 Vegetation and dune stability

The vegetation of the site is well-represented elsewhere on the West Coast and Cape Flats. However, it is a dynamic system, with an unnatural succession (owing to artificial stabilisation) moving these dunes towards mature thicket. This is the climax vegetation of the adjacent parabolic dunes (Low, 2011), where dense thicket provides far greater stability than the transverse dunes.

Reversal of this process would require removal of vegetation from the dune and even then it would not return to its natural state as the main supply of sand from the south is blocked by Koeberg itself, and to a certain extent, Melkbosstrand. This echoes the situation for the Oyster Bay-Cape St Francis headland bypass system, where development in the former town is preventing sand from feeding this massive dune system (Illenberger, 2010; Low, 2011).

The impacts associated with building a Nuclear facility on dunes which were previously mobile has been dealt with in the main impact assessment (Low, 2011). In this report Low (2011) recommends that there be no development on mobile dunes, in particular the transverse system north of Koeberg, and that such development is shitted inland onto stable parabolic dunes. Clearly the transverse dunes just to the north of the existing power station are now well-stabilised (Figures 23 & 24) and the trajectory of vegetation cover is towards climax dense thicket, now occurring patchily throughout the area (see Low, 2011 for distribution of plant communities).

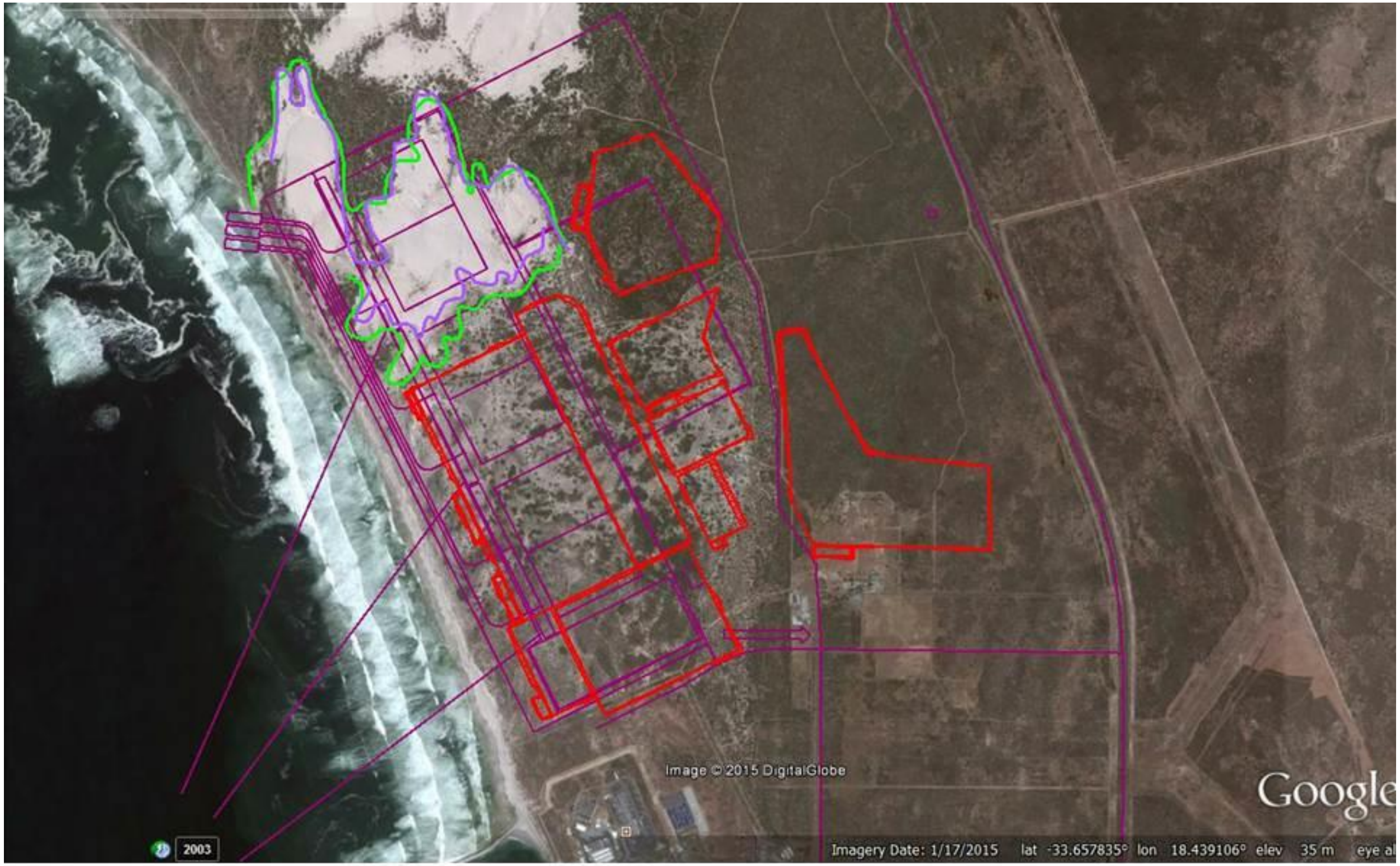

Figure 24. Google image (17 January 2015) showing Koeberg Power Station in the south, with the transverse dunes to the north. The proposed new Nuclear Power Station footprint (red) lies over vegetated transverse dunes. It is this area which was actively stabilised between 1979 and 1983. Shrinkage of the mobile dunes is shown by comparing the edge of bare sand between 2003 (green) and 2014 (mauve). Initial footprint (purple) shown for comparison (see Figure 5.1.2 in botanical EIA)

With the vegetating of the once-mobile transverse dunes, this new stability would imply that development could be considered, but with the migratory measures for parabolic dunes (Low, 2011).

9.1.4 Fine-tuning of footprint

It is vital that no footprint is permitted in the mobile transverse dune system. Rather care must be taken to ensure that the boundary of the footprint is well within stabilised dunes. In addition, there should be at least a 100 m wide buffer between the boundary and any mobile dune.

7.2 Operational phase of nuclear facility

7.2.1 Coastal set back and buffers

A key agreement reached between Eskom management and the consulting team was provision of a coastal corridor of 200 m minimum width (see Low, 2011). This should also be applied here and will also ensure that the more sensitive and mobile primary dunes at the coast are avoided.

Low (2011) produced a series of management and rehabilitation guidelines for the operational phase of the project and which have been included here. These are to be adhered to and included as part of the record of decision should permission be granted for another Nuclear facility at Koeberg.

7.2.2 Conservation

In short, the transverse dunes are part of the Cape Flats Dune Strandveld vegetation type which is rated as Endangered (Rouget et al., 2004). This system is well-protected in the 3 000 ha Koeberg Nature Reserve and in various parts of the Cape Flats and West Coast. Low (2011) recognises this as a positive impact in the development of a new nuclear facility: “The continued management of the Koeberg Nature Reserve, which entails the whole of the site outside the present NPS, is considered a positive impact. Current multiple-use of the reserve is extensive and management would continue with the new NPS. Extension of the reserve into good quality dune veld of the Groot Springfontein Farm to the north is also highly desirable, and could be effected by a cooperative conservation agreement. All in all the use of some 200 to 280 ha for a NPS is far outweighed by the 3 000 ha currently under conservation within the Koeberg Nature Reserve”. I would add here that a biodiversity offset should be sought for the potential loss of transverse dunes in the south of the site, and that the Groot Springfontein Farm on the northern boundary of the KNR would be a worthy addition, particularly as it lies to the west of the R27, encompasses a relatively pristine coastline and would be directly connected to the Koeberg Nature Reserve.

7.3 Key interventions during construction and/ or operational phases (largely from Low, 2011)

7.3.1 Search and rescue

For each phase of construction within natural veld, a search and rescue operation is required which would identify all plants which were either extremely rare (i.e. Endangered or Critically Endangered) or which could be used in site rehabilitation. Red List species likely to be affected if development is carried out on the transverse dunes, are the annual *Capnophyllum africanum, Helichrysum cochleariforme* duineteebossie (Near Threatened - NT), *Psoralea repens* duine-ertjie (NT), the succulent vygie *Ruschia indecora* (Endangered - EN), and *Passerina ericoides* kusgonnabas (Vulnerable - VU) (Red List status in brackets) (see Appendix 2). Such RL species would require to be identified by a specialist botanist who would ensure a plan was in place to remove said plants **prior** to construction's commencing. Plants with a bulb or rootstock have the greatest chance of surviving translocation, whereas most shrubs and many of the graminoids (grasses, sedges, restios), particularly the obligate reseeders, would not translocate successfully. Seed and/or cuttings should be removed from species which will not translocate easily and grown on in the on-site nursery (see below).

7.3.2 Rehabilitation plan

Linked with Search and Rescue above should be a rehabilitation plan which would see that all areas disturbed in the development of the proposed facility are satisfactorily rehabilitated with locally occurring indigenous species. This would include the collection of appropriate plant material prior to construction's commencing, the storage of such material and/or the growing on of suitable material. Plants would need to be at least two to three years old for use in rehabilitation and thus sampling should commence during the construction period, at least three years before commissioning of the NPS plant. A nursery which would accommodate stored and grown on plants would be an absolutely essential requirement for satisfactory rehabilitation. For this purpose a rehabilitation plan needs to be drawn up which will identify suitable species, method of storage and/or propagation, method of planting and maintenance, and monitoring of rehabilitation success (see below). This can be included as a part of the construction and operational EMP.

A comprehensive rehabilitation plan will require the services of a rehabilitation specialist together with a specialist botanist who would identify and locate suitable species; measures must be in place to ensure removal of said plants **prior** to construction's commencing. Seed and/or cuttings should be removed from species which will not translocate easily and grown on in the on-site nursery.

The plan should include the following key elements:

<u>*Preparation phase*</u>
At least two years before commencement of construction, an on-site nursery with manager needs to be set up at Duynefontein. A list of appropriate species needs to be drawn up and both seed and cuttings collected, planted out and suitably hardened off. This would provide material ready for planting as areas are required to be rehabilitated. In addition certain species could also be translocated into the nursery. The amount of plant material required would be guided by the extent of construction and areas to be disturbed. Both terrestrial and wetland habitats need to be considered.

A list of selected species suitable for rehabilitation can be found in Table 9.

Topsoil

This is perhaps the most critical part of rehabilitation and would determine to a great extent the ultimate success of any rehabilitation work.

- Topsoil (0 – 300 mm depth) should be removed from any area being disturbed temporarily or permanently, and stockpiled. Piles should be no more than 1.5 to 2 m high to avoid decrease in aeration, but also too rapid decomposition of organic matter, the latter essential for providing a good start for new plants.

- Stockpiles should be placed in previously disturbed areas and should definitely not be located on natural vegetation. This would lead to the death of the latter.

Planting

- Planting of nursery-grown and -translocated species should be undertaken at a density set by the rehabilitation specialist, but generally at no less than 1 m apart. Time of planting should be just prior to the commencement of the rainy season in the Western Cape (April/May) so that plants are provided with good moisture conditions prior to the onset of the summer season some six months later.

Mulching

- Mulch should be strewn over the planted areas and this should shade the soil, and provide a source of organic matter and some nutrients, as well as retention of moisture for new plants. The best source for mulch is locally occurring introduced acacias and these can be mulched on site after cutting. Care should be taken not to clear these woody aliens when they are setting seed (October-November for *Acacia saligna* Port Jackson willow).

Maintenance

- Newly planted areas should be regularly weeded. Where plant death occurs, dead specimens should be replaced with material from the nursery. Plants should also be irrigated during the first summer season. For this purpose a simple above ground irrigation system would prove useful if not essential.
- All woody aliens should be removed once they reach knee height (for ease of pulling).

Table 9. Selected plant species useful for rehabilitation at Koeberg (adapted from Low, 2011, Table 5.1.3)

Family	Species	Common name	Broad habitat	Form
Dicotyledones				
AIZOACEAE	*Tetragonia decumbens*	kinkelbossie	Pioneer on primary dunes	groundcover
ANACARDIACEAE	*Rhus crenata*	duinekraaibessie	Stable dunes	Shrub
ANACARDIACEAE	*Rhus lucida*	blinktaaibos	Stable dunes	Shrub
ASTERACEAE	*Arctotheca populifolia*	Sea pumpkin	Pioneer on primary dunes	Groundcover
ASTERACEAE	Chrysanthemoides monilifera	bietou	Successional and stable dunes	Shrub
ASTERACEAE	*Didelta carnosa* subsp. *tomentosa*	seegousblom	Pioneer on primary dunes	Low shrub
ASTERACEAE	*Metalasia muricata*	blombos	Successional dunes	Shrub
EBENACEAE	*Euclea racemosa*	seeghwarrie	Stable dunes	Shrub
FABACEAE	Otholobium bracteolatum	Skaapbostee	Successional dunes	Shrub
FABACEAE	Psoralea repens	duine-ertjie	Pioneer on primary dunes	Groundcover
GERANIACEAE	Pelargonium capitatum	rose-scented pelargonium	Successional dunes	Low shrub
LAMIACEAE	Salvia africana-lutea	Bruinsalie	Successional and stable dunes	Shrub
MESEMBRYANTHEMACEAE	*Carpobrotus acinaciformis*	Sour fig	Pioneer and successional dunes	Groundcover
POLYGALACEAE	Nylandtia spinosa	skilpadbessie	Successional and stable dunes	Shrub
RHAMNACEAE	*Phylica ericoides*		Successional dunes	Shrub
Monocotyledones				
ARACEAE	*Zantedeschia aethiopica*	Arum lily	Successional and stable dunes	Bulb
ASPHODELACEAE	*Trachyandra divaricata*	duinekool	Pioneer and successional dunes	Bulb
POACEAE	*Cladoraphis cyperoides*	Steekriet	Pioneer on primary dunes	Grass
RESTIONACEAE	*Thamnochortus spicigerus*	duineriet	Successional and stable dunes	Restio

7.3.3 Coastal corridor and buffers

The negative aspects of locating a nuclear facility at the coast (i.e. on the high water mark) have been discussed by Low (2008) for the proposed PBMR plant (since discounted as an option) and historically have existed for the Koeberg Nuclear Power Station. “These habitats are extremely sensitive and fragile and demand great circumspect if both the habitat as well as issues such as maintenance of structures are to be satisfactorily dealt with. A setback line should be implemented ......”

The EIA corridor should be separated from the high-water mark by a coastal corridor and adequate buffer to the sensitive mobile dunes, whichever is the greater. Such a corridor should be underpinned by the following ecological rules or criteria:

- 200 m wide ecological corridor as a minimum width for serving as a conduit for pollinating and fruit-translocating fauna and an enabling area for essential ecological processes, such as dune mobility and pollination, and preservation of major communities. At Koeberg this will be far wider if recommendations for avoiding the sensitive, rare and endemic transverse dune system are upheld;
- Avoidance of the sensitive primary dunes at the coast;
- Avoidance of the sensitive limestone cliffs, in the north of the area;
- Whichever setback line is the furthest from the HWM, an additional buffer of 100 m should be set to protect the sensitive systems discussed above from any long-term impacts the development could have on such systems; and
- All setback lines would need to be accurately surveyed before the footprint was fine-tuned.

Impact of development on the coast could compromise the existing, albeit *de facto,* corridor along the Cape West Coast, which locally stretches several kilometres inland. The recommended 200 m setback maintains such a West Coast coastal corridor (Low, 2011).

7.3.4 Monitoring

(i) Rehabilitation

Goal: to ensure that rehabilitation with indigenous species is carried out effectively and has long-term sustainability

a Uninvaded areas

Where habitats have been unnaturally disturbed but are not invaded by *Acacia cyclops* rooikrans, rehabilitation with indigenous species is to be implemented. Such rehabilitation must follow a plan put together by a rehabilitation specialist, assisted by a specialist botanist with a good working knowledge of the local flora, and using locally occurring indigenous species. Details of the plan are presented in section (v) above. Rehabilitation success must be monitored on a three monthly basis for the first year, and then six monthly until acceptable species densities and cover are achieved.

b Invaded areas

Areas invaded by *Acacia cyclops* rooikrans or *Acacia saligna* Port Jackson willow should be cleared and rehabilitated as per the recommendations in (v) above. Rehabilitation should only be implemented if thicket species do not naturally return to a desired cover and species complement. The latter two factors should be monitored by a specialist botanist and targets set for both these two criteria; this should be included in the rehabilitation plan.

Whilst it is strongly recommended that rooikrans be cleared manually – for both social as well as ecological reasons – individuals removing acacias should be subject to a code of conduct which would govern behaviour on site. Key issues would include damage to plants and animals, toilets, fire, and general behaviour to be consistent with that of a nature reserve. Activities of these individuals need to be monitored by the on-site supervisor or conservation manager (see below).

(ii) Coastal corridor

Goal: to ensure a coastal corridor is created in an appropriate manner and is maintained in the long-term

Implementation of a coastal corridor must be a key goal of the development of the nuclear facility. Monitoring must be implemented to ensure that the coastal corridor is maintained in as natural a state as possible. This would include monitoring the rehabilitation of areas which have been excavated for the inlet and outlet pipes and the area immediately alongside the nuclear structure. Rehabilitation with indigenous species should be undertaken following the rehabilitation plan discussed above.

(iii) Relocation and/or growing on of Red List species

Goal: to ensure that where possible all Red List species in particular those on the Vulnerable and Endangered categories affected by development are relocated or successfully grown on in a nursery and returned to the wild.

Relocation and/or growing on of Red List species should be included in the site's rehabilitation plan. Key performance criteria include the reintroduction of RL species into protected areas, either on the site or in nearby nature reserves, or the growing on of such species for introduction into natural habitats through the rehabilitation plan. The bottom line would be to ensure there would not be a reduction in the natural densities and populations in each RL species.

(iv) State of conservation area

Goal: to ensure that the natural areas of Duynefontein/Koeberg Private Nature Reserve are maintained in a state consistent with that of a well-managed nature reserve

Koeberg should continue with its present management programme and ensure that that a management plan for the area is implemented. Key performance areas would be: woody alien eradication, rehabilitation, creation of a trail system for the public, control of access and use of the area, control of vehicles entering the area.

10. CONCLUSIONS

From this study, major changes were recorded in the transverse dune system to the north of the existing Koeberg Nuclear facility.

Mapping of aerial photographs over a 76 year period showed conclusively the once-mobile transverse dunes are vegetating at a fairly rapid rate and have lost their mobility in the south. This was demonstrated through a decline in bare sand (mobility) and increases in the cover of thicket and other plant communities (loss of mobility).

Accompanying the above, was an increase in species number and vegetation cover, as one moved along a succession from pioneer to mature, climax thicket.

Soils showed concomitant changes along the gradient, with appreciable increases in organic carbon, total nitrogen and several cations, as well as cation exchange capacity. The latter was closely correlated with organic carbon, which in these sandy soils acts as a colloid in the place of clay.

Recommendations

Given the rapidly stabilising transverse dune system at Koeberg, it is recommended that consideration be afforded the location of a new Nuclear-1 facility within the transverse dune directly north of the existing NPS. This is in line with the current preliminary foot print/plant lay out of the proposed new NPS. However, this should be accompanied by strict measures which ensure proper fine-tuning of the footprint, creation of a buffer between development and presently mobile dunes, and implementation of an effective management plan during both the construction and operational phases. This plan would include, among other, effective rehabilitation and monitoring, and the enhancement of the Koeberg Nature Reserve through addition of land in the north.

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- Identification of plant specimens was undertaken n\by staff at the Compton Herbarium Kirstenbosch and the Bolus Herbarium, University of Cape Town

- Comments from a number of reviewers (from Gibb?).

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APPENDIX 1. KOEBERG NEW FOOTPRINT: PLANT SPECIES RECORDED FROM FLORA AND VEGETATION PLOTS – INDIVIDUAL LISTS IN ORDER OF SUCCESSION, FROM PIONEER TO CLIMAX THICKET

EX = Extinct, EW = Extinct in the wild, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient, LC = Least Concern, NE = Not Evaluated

CLADORAPHIS CYPEROIDES HUMMOCK DUNE PIONEER COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

ASTERACEAE
- Didelta
  - carnosa var. tomentosa LC
- Senecio
  - elegans
- Stoebe
  - plumosa NE

FABACEAE
- Lessertia
  - frutescens
- Psoralea
  - repens NT

Division: Anthophyta **Class:** Monocotyledones

ASPHODELACEAE
- Trachyandra
  - divaricata LC

POACEAE
- Cladoraphis
  - cyperoides LC
- Ehrharta
  - villosa

Total named species:	**8**
Total genera:	**8**
Total families:	**4**
Total red data species:	**1**

CLADORAPHIS CYPEROIDES TRANSVERSE DUNE PIONEER COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

APIACEAE
Capnophyllum
cf. africanum NT
ASTERACEAE
Helichrysum
niveum
patulum LC
Metalasia
muricata LC
Nidorella
foetida LC
Osteospermum
incanum LC
Senecio
elegans
littoreus
CRASSULACEAE
Crassula
cf. glomerata LC
FABACEAE
Lessertia
frutescens
Psoralea
repens NT
GENTIANACEAE
Orphium
frutescens LC
MESEMBRYANTHEMACEAE
Amphibolia
laevis LC
Carpobrotus
edulis
MYRICACEAE
Morella
cordifolia LC
THYMELAEACEAE
Passerina
ericoides VU

Division: Anthophyta **Class:** Monocotyledones

ASPHODELACEAE
Trachyandra
divaricata LC
POACEAE
Cladoraphis
cyperoides LC

Total named species:	**18**
Total genera:	**16**
Total families:	**10**
Total red data species:	**3**

OSTEOSPERMUM INCANUM PIONEER COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

ANACARDIACEAE
  Searsia
    glauca
ASTERACEAE
  Helichrysum
    niveum
    revolutum LC
  Nidorella
    foetida LC
  Osteospermum
    incanum LC
  Senecio
    elegans
    littoreus
CRASSULACEAE
  Crassula
    cf. glomerata LC
FABACEAE
  Lessertia
    frutescens
  Psoralea
    repens NT
GERANIACEAE
  Pelargonium
    capitatum LC
MESEMBRYANTHEMACEAE
  Amphibolia
    laevis LC
  Carpobrotus
    edulis
  Jordaaniella
    dubia LC
  Ruschia
    macowanii LC
SANTALACEAE
  Thesidium
    fragile LC

Division: Anthophyta **Class:** Monocotyledones

ASPHODELACEAE
  Trachyandra
    divaricata LC
POACEAE
  Cladoraphis
    cyperoides LC

Total named species:	**18**
Total genera:	**16**
Total families:	**9**
Total red data species:	**1**

MORELLA CORDIFOLIA SUCCESSIONAL (FYNBOS) COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

APIACEAE
  Annesorhiza
    macrocarpa LC
ASTERACEAE
  Helichrysum
    cochleariforme NT
    niveum
    patulum LC
  Metalasia
    muricata LC
  Senecio
    elegans
    halimifolius LC
GENTIANACEAE
  Chironia
    baccifera LC
GERANIACEAE
  Pelargonium
    capitatum LC
MYRICACEAE
  Morella
    cordifolia LC
POLYGALACEAE
  Muraltia
    spinosa LC
THYMELAEACEAE
  Passerina
    cf. paleacea LC

Division: Anthophyta **Class:** Monocotyledones

ASPHODELACEAE
  Trachyandra
    divaricata LC
POACEAE
  Cladoraphis
    cyperoides LC
  Ehrharta
    villosa
  Pentameris
    cf. pallida LC
RESTIONACEAE
  Thamnochortus
    spicigerus LC

Total named species: **17**
Total genera: **14**
Total families: **10**
Total red data species: **1**

METALASIA MURICATA SUCCESSIONAL (FYNBOS) COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

ANACARDIACEAE
  Searsia
    laevigata
ASTERACEAE
  Helichrysum
    cochleariforme NT
    niveum
    patulum LC
  Metalasia
    muricata LC
  Nidorella
    cf. foetida LC
  Osteospermum
    incanum LC
  Senecio
    burchellii LC
    elegans
    halimifolius LC
FABACEAE
  Lessertia
    frutescens
  Otholobium
    bracteolatum LC
  Psoralea
    repens NT
GERANIACEAE
  Pelargonium
    capitatum LC
MESEMBRYANTHEMACEAE
  Carpobrotus
    acinaciformis LC
  Jordaaniella
    dubia LC
MYRICACEAE
  Morella
    cordifolia LC
POLYGALACEAE
  Muraltia
    spinosa LC
RUBIACEAE
  Galium
    tomentosum LC
SANTALACEAE
  Thesidium
    fragile LC
  Viscum
    capense LC

Division: Anthophyta **Class:** Monocotyledones

ASPHODELACEAE
  Trachyandra
    cf. divaricata LC
CYPERACEAE
  Ficinia
    lateralis LC
  Hellmuthia
    membranacea LC
POACEAE
  Cladoraphis
    cyperoides LC
  Ehrharta
    villosa
  Pentameris
    cf. pallida LC
RESTIONACEAE
  Thamnochortus
    spicigerus LC

Total named species:	**28**
Total genera:	**24**
Total families:	**13**
Total red data species:	**2**

SEARSIA GLAUCA TRANSVERSE DUNE THICKET COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

ANACARDIACEAE
  Searsia
    glauca
    laevigata
APOCYNACEAE
  Cynanchum
    cf. africanum LC
    obtusifolium LC
ASTERACEAE
  Cineraria
    geifolia LC
  Helichrysum
    niveum
    revolutum LC
  Metalasia
    muricata LC
  Osteospermum
    incanum LC
  Othonna
    coronopifolia LC
  Senecio
    arenarius LC
    burchellii LC
    elegans
CRASSULACEAE
  Crassula
    cf. glomerata LC
EBENACEAE
  Euclea
    racemosa
LAMIACEAE
  Salvia
    africana-lutea LC
  Stachys
    cf. aethiopica LC
MESEMBRYANTHEMACEAE
  Carpobrotus
    acinaciformis LC
  Ruschia
    macowanii LC
POLYGALACEAE
  Muraltia
    spinosa LC
RUBIACEAE
  Anthospermum
    prostratum LC
  Galium
    tomentosum LC
SANTALACEAE
  Thesidium
    fragile LC
  Thesium
    aggregatum LC
  Viscum
    capense LC
SCROPHULARIACEAE
  Lyperia
    lychnidea LC
  Manulea
    cheiranthus LC
    cf. rubra LC
  Zaluzianskya
    villosa LC
SOLANACEAE
  Solanum
    cf. guineense LC
THYMELAEACEAE
  Passerina
    cf. paleacea LC
URTICACEAE
  Didymodoxa
    capensis
ZYGOPHYLLACEAE
  Roepera
    flexuosa LC
    morgsana LC

Division: Anthophyta **Class:** Monocotyledones

ASPARAGACEAE
  Asparagus
    capensis
    cf. lignosus LC
ASPHODELACEAE
  Trachyandra
    divaricata LC
CYPERACEAE
  Ficinia
    dunensis LC
  Isolepis
    marginata LC
HYACINTHACEAE
  Albuca
    cf. canadensis LC
IRIDACEAE
  Melasphaerula
    cf. ramosa LC
POACEAE
  Cladoraphis
    cyperoides LC
  Ehrharta
    villosa

Pentameris
cf. pallida LC
RESTIONACEAE
Thamnochortus
spicigerus LC

Total named species:	**45**
Total genera:	**37**
Total families:	**22**
Total red data species:	**0**

SEARSIA GLAUCA MATURE DUNE THICKET COMMUNITY

Division: Anthophyta **Class:** Dicotyledones

AIZOACEAE
  Tetragonia
    cf. fruticosa LC
ANACARDIACEAE
  Searsia
    glauca
    laevigata
APIACEAE
  Torilis
    cf. arvensis NE
APOCYNACEAE
  Cynanchum
    obtusifolium LC
ASTERACEAE
  Cineraria
    geifolia LC
  Helichrysum
    cf. revolutum LC
  Osteospermum
    incanum LC
    moniliferum
  Senecio
    arenarius LC
    burchellii LC
    elegans
BRASSICACEAE
  Heliophila
    coronopifolia LC
CARYOPHYLLACEAE
  Silene
    cf. undulata LC
CELASTRACEAE
  Putterlickia
    pyracantha LC
CRASSULACEAE
  Crassula
    dichotoma
    cf. glomerata LC
EBENACEAE
  Euclea
    racemosa
EUPHORBIACEAE
  Clutia
    daphnoides LC
  Euphorbia
    mauritanica
FABACEAE
  Indigofera
    cf. procumbens LC
  Lessertia
    cf. tomentosa LC
GERANIACEAE
  Pelargonium
    gibbosum LC
LAMIACEAE
  Salvia
    africana-lutea LC
  Stachys
    cf. aethiopica LC
MENISPERMACEAE
  Cissampelos
    capensis LC
MESEMBRYANTHEMACEAE
  Ruschia
    cf. indecora EN
    macowanii LC
OLEACEAE
  Olea
    exasperata LC
PLUMBAGINACEAE
  Limonium
    perigrinum
RUBIACEAE
  Galium
    tomentosum LC
SANTALACEAE
  Viscum
    capense LC
SCROPHULARIACEAE
  Manulea
    cheiranthus LC
  Nemesia
    affinis LC
  Zaluzianskya
    villosa LC
SOLANACEAE
  Solanum
    cf. guineense LC
URTICACEAE
  Didymodoxa
    capensis
ZYGOPHYLLACEAE
  Roepera
    morgsana LC

Division: Anthophyta **Class:** Monocotyledones

AGAVACEAE
  Chlorophytum
    cf. triflorum LC
ASPARAGACEAE
  Asparagus
    capensis

ASPHODELACEAE
  Trachyandra
    divaricata   LC
CYPERACEAE
  Ficinia
    dunensis   LC
  Isolepis
    marginata   LC
IRIDACEAE
  Ferraria
    cf. crispa
  Melasphaerula
    cf. ramosa   LC
POACEAE
  Ehrharta
    calycina   LC
    villosa
RESTIONACEAE
  Thamnochortus
    spicigerus   LC

Total named species:	**48**
Total genera:	**41**
Total families:	**31**
Total red data species:	**1**

APPENDIX 2. KOEBERG NEW FOOTPRINT: PLANT SPECIES RECORDED FROM FLORA AND VEGETATION PLOTS – COMPOSITE LIST

EX = Extinct, EW = Extinct in the wild, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient, LC = Least Concern, NE = Not Evaluated

Division: Anthophyta **Class:** Dicotyledones

AIZOACEAE
  Tetragonia
    fruticosa LC
ANACARDIACEAE
  Searsia
    glauca
    laevigata
APIACEAE
  Annesorhiza
    macrocarpa LC
  Capnophyllum
    africanum NT
  Torilis
    arvensis NE
APOCYNACEAE
  Cynanchum
    africanum LC
    obtusifolium LC
ASTERACEAE
  Cineraria
    geifolia LC
  Didelta
    carnosa var. tomentosa LC
  Helichrysum
    cochleariforme NT
    niveum
    patulum LC
    revolutum LC
  Metalasia
    muricata LC
  Nidorella
    foetida LC
  Osteospermum
    incanum LC
    moniliferum
  Othonna
    coronopifolia LC
  Senecio
    arenarius LC
    burchellii LC
    elegans
    halimifolius LC
    littoreus
  Stoebe
    plumosa NE
BRASSICACEAE
  Heliophila
    coronopifolia LC
CARYOPHYLLACEAE
  Silene
    undulata LC
CELASTRACEAE
  Putterlickia
    pyracantha LC
CRASSULACEAE
  Crassula
    dichotoma
    glomerata LC
EBENACEAE
  Euclea
    racemosa
EUPHORBIACEAE
  Clutia
    daphnoides LC
  Euphorbia
    mauritanica
FABACEAE
  Indigofera
    procumbens LC
  Lessertia
    frutescens
    tomentosa LC
  Otholobium
    bracteolatum LC
  Psoralea
    repens NT
GENTIANACEAE
  Chironia
    baccifera LC
  Orphium
    frutescens LC
GERANIACEAE
  Pelargonium
    capitatum LC
    gibbosum LC
LAMIACEAE
  Salvia
    africana-lutea LC
  Stachys
    aethiopica LC
MENISPERMACEAE
  Cissampelos
    capensis LC
MESEMBRYANTHEMACEAE
  Amphibolia
    laevis LC
  Carpobrotus
    acinaciformis LC
    edulis
  Jordaaniella
    dubia LC
  Ruschia
    indecora EN
    macowanii LC
MYRICACEAE
  Morella
    cordifolia LC

OLEACEAE
  Olea
    exasperata LC
PLUMBAGINACEAE
  Limonium
    perigrinum
POLYGALACEAE
  Muraltia
    spinosa LC
RUBIACEAE
  Anthospermum
    prostratum LC
  Galium
    tomentosum LC
SANTALACEAE
  Thesidium
    fragile LC
  Thesium
    aggregatum LC
  Viscum
    capense LC
SCROPHULARIACEAE
  Lyperia
    lychnidea LC
  Manulea
    cheiranthus LC
    rubra LC
  Nemesia
    affinis LC
  Zaluzianskya
    villosa LC
SOLANACEAE
  Solanum
    guineense LC
THYMELAEACEAE
  Passerina
    ericoides VU
    paleacea LC
URTICACEAE
  Didymodoxa
    capensis
ZYGOPHYLLACEAE
  Roepera
    flexuosa LC
    morgsana LC

Division: Anthophyta **Class:** Monocotyledones
AGAVACEAE
  Chlorophytum
    triflorum LC
ASPARAGACEAE
  Asparagus
    capensis
    lignosus LC
ASPHODELACEAE
  Trachyandra
    divaricata LC
CYPERACEAE
  Ficinia
    dunensis LC
    lateralis LC
  Hellmuthia
    membranacea LC
  Isolepis
    marginata LC
HYACINTHACEAE
  Albuca
    canadensis LC
IRIDACEAE
  Ferraria
    crispa
  Melasphaerula
    ramosa LC
POACEAE
  Cladoraphis
    cyperoides LC
  Ehrharta
    calycina LC
    villosa
  Pentameris
    pallida LC
RESTIONACEAE
  Thamnochortus
    spicigerus LC

Total named species:	**87**
Total genera:	**66**
Total families:	**36**
Total red data species:	**5**