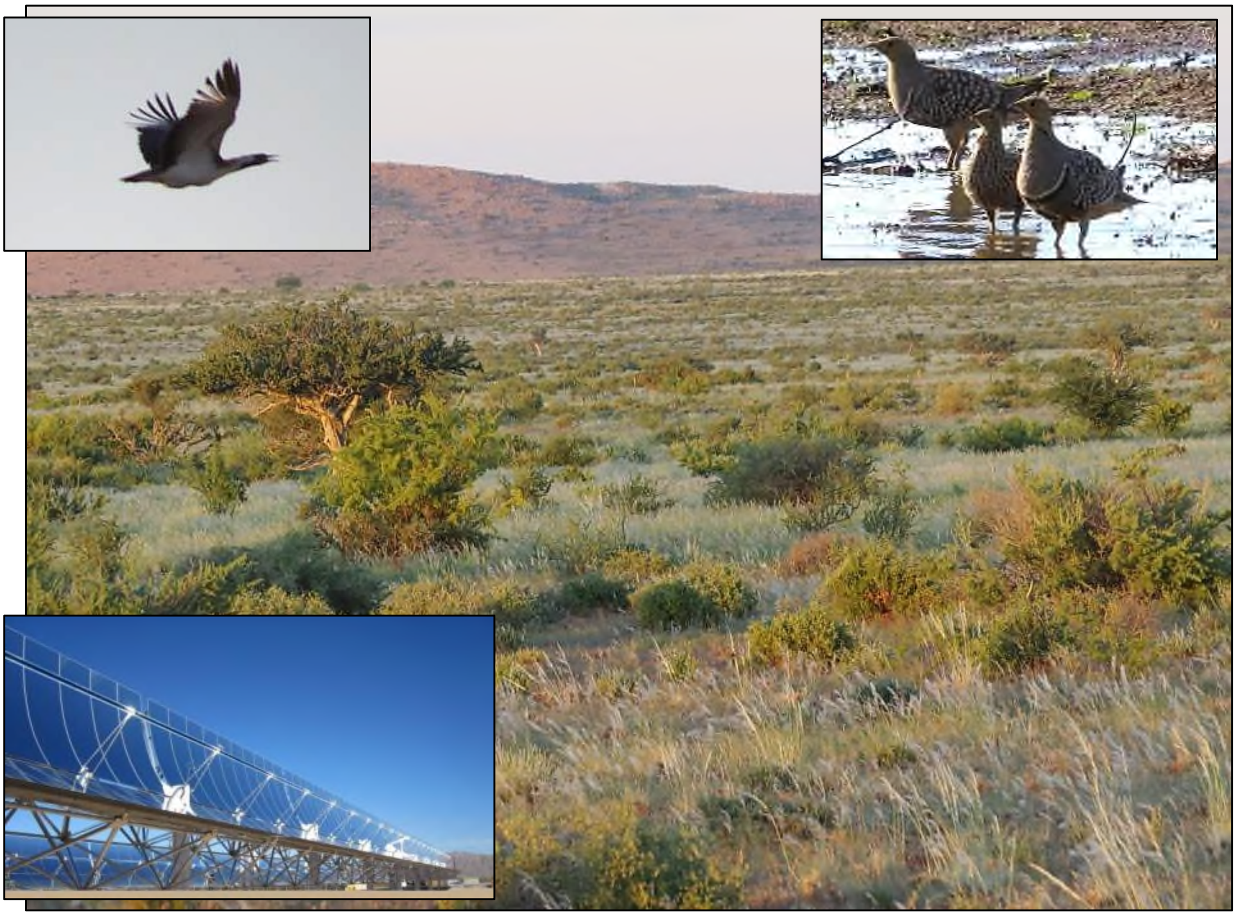
FINAL PRE-CONSTRUCTION AVIAN IMPACT ASSESSMENT OF THE ILANGA CSP 4, NEAR UPINGTON, NORTHERN CAPE



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On behalf of: EMVELO HOLDINGS (PTY) Ltd

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Contents

1 SUMMARY

This study reports on avian monitoring for the proposed Ilanga CSP solar project, proposed by Emvelo Holding (Pty) Ltd on various farms near "Karoshoek" east of Upington, Northern Cape. Our specific objective is to determine the numbers of collision-prone birds attracted to the proposed solar development before and after rains in November 2015 and March 2016 to understand and mitigate any possible impacts to sensitive and threatened species.

A brief review of recent literature on Concentrating Solar Plants (CSP) and their effects on avifauna reveals that CSP trough technology, which utilizes parabolic mirrors may attract birds to its reflective surfaces, and median levels of mortality and displacement may occur relative to other PV and CSP technology. Here we identify potential impacts associated with these facilities in the proposed Karoshoek Solar Valley Development area.

The possible impacts are: (i) displacement of nationally important species from their habitats by the presence of the parabolic mirrors, (ii) loss of habitats for such species due to direct habitat destruction under the CSP trough sites, (iii) disturbance during construction of the array, and (iv) collision with the parabolic troughs by birds that mistake them for water bodies (the so-called "lake effect"). Indirect and cumulative impacts include water abstraction from the Orange River which may reduce flow rate in low-flow seasons and force avifauna to seek alternative habitats.

The impact zone of the CSP 4 (trough) facility lies within the interface of Nama Karoo and Kalahari Shrubland. Up-to-date (SABAP2) bird atlas data combined with our data indicates that habitat in the Karoshoek Solar Valley Development footprint supports up to 114 bird species, including 13 species ranked in the top 100 collision-prone species. Six of these species are also red-listed: Black Harrier *Circus maurus*, Lanner Falcon *Falco biarmicus,* Kori Bustard *Ardeotis kori,* Ludwig's Bustard *Neotis ludwigi*, Verreaux's Eagle *Aquila verreauxi* and Secretarybird *Saggitarius serpentarius.* Given that harriers, eagle and bustards are highly collision-prone species they may interact negatively with the CSP 4 facility infrastructure. Similarly, the proximity to the Orange River may attract wetland species seeking other wetland areas, and cause mortality as birds attempt to land on the CSP mirrors. In addition larks and sandgrouse will lose habitat totaling ~680 ha.

Since the degree and significance of bird impacts will depend largely on the abundance and movements of key species, we measured bird densities in the site footprint and the passage rate of collision-prone birds through and over the site. Our 1 km surveys revealed a higher species richness of smaller birds in the wet season (15.5 v 9.0 species km^{-1}). The **Passage rate** of larger collision-prone birds was low at 0.43 birds per hour of observation and it did not differ between the seasons. Other species that may be attracted to the troughs, such as wetland birds, were not recorded but large numbers of sandgrouse were recorded commuting to water points in the wet season. Sociable Weaver are also present in large numbers and those displaced from their nests in *Acacia* and *Boscia* trees may attempt to re-nest on the CSP infrastructure.

The volume of water required for the generation of steam to drive the turbines at one CSP is estimated at 80 000 m^3 per year. Thus, steam generation required for the 8 CSPs planned for the solar park development may require over 600 000 m^3 annually from the Orange River. The cumulative impacts of many other solar farms proposed along the Orange River's borders may reduce flow at low flow, forcing wetland species to seek other water sources.

We quantified the impacts and found median low levels of significance for the collision-prone (bustard and korhaan) species on CSP 4 that require some mitigation. However, overhead power lines pose a significant threat, particularly to the bustards. This is assessed within a separate Basic Assessment process.

To mitigate the possible problems of impacts with the CSP troughs, we recommend that: (i) bird scaring techniques are used, including rotating prisms and experimental use of Torri lines (ribbons used on trawlers to deter albatrosses from taking baited hooks and drowning), if birds are found to impact the CSP troughs; (ii) the CSP troughs are constructed as far as possible from water points that could attract any wetland species; (iii) all power lines – *present and future* – must be marked with bird diverters to reduce the possible impact of the raptorial species. (A separate Basic Assessment is underway for this aspect of the possible impact). Systematic monitoring of the CSP facility, during and post-construction, is required for at least 12 months by trained ornithologists to determine the full impact of the facility on South Africa's red data birds.

1.1 CONSULTANT'S DECLARATION OF INDEPENDENCE

Birds & Bats Unlimited are independent consultants to Savannah Environmental. They have no business, financial, personal or other interest in the activity, application or appeal in respect of which they were appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of this specialist performing such work.

1.2 QUALIFICATIONS OF SPECIALIST CONSULTANT

Birds & Bats Unlimited Environmental Consultants (http://www.birds-and-bats-unlimited.com/), were approached to undertake the specialist avifaunal assessment for the pre-construction phase of the CSP solar parks proposed by Emvelo Holding (Pty) Ltd, east of Upington, Northern Cape. Dr Rob Simmons is an experienced ornithologist, with 30 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and 2 books, (see www.fitzpatrick.uct.ac.za/docs/robert.html for details). More than forty avian impact assessments have been undertaken throughout Namibia and South Africa. He also undertakes long-term research on threatened species (raptors, flamingos and terns) and their predators (cats) at the FitzPatrick Institute, UCT.

Marlei Martins, co-director of Birds & Bats Unlimited, has over 5 years' consultancy experience in avian wind farm impacts as well as environmental issues, and has been employed by several other consultancy companies all over South Africa because of her expertise in this field. She has published papers on her observations including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

2 TERMS OF REFERENCE

- To provide a desktop and field assessment of all potential impacts to avifauna by the CSP Parabolic trough technology at CSP 4 within the Karoshoek Solar Valley Development, near Upington;
- The final avian impact assessment should include all revised areas proposed after the initial visit in November 2015;
- To provide a summary of expected impacts for all threatened or collision-prone species found in the area;

- To quantify the expected impacts with and without mitigation measures;
- To provide possible mitigation measures to reduce impacts wherever they occur; and
- Provide recommendations for an environmental management plan to systematically monitor the site, during and post-construction, to determine impacts to the avifauna.

We start with a review of the solar technology to be employed to contextualize it, relative to possible and known avian impacts elsewhere in the world.

3 BACKGROUND

3.1 CSP SOLAR POWER

Renewable energy is generally provided either by water, wind or solar power and has the potential to supply the human population with unlimited non-polluting power. As a major greenhouse gas emitter South Africa is signatory of the Kyoto Protocol and is committed to turning to green energy sources that emit no greenhouse gases or other pollution. Southern Africa's Kalahari region is one of the Earth's hot spots for solar radiation because deserts provide some of the longest periods of continuous sunlight in the world http://www.iir-sa.gr/files/news/CSP.pdf. This makes it the ideal hub for solar projects that capture the sun's energy to provide an energy-hungry South Africa with the power it requires.

Three options are generally employed to capture solar energy: (i) Concentrated Solar Plants (CSPs) using heliostats that focus the sun's energy onto a central tower that heats a salt or oil liquid that in turn converts water to steam and drives a turbine (CSP tower); (ii) a CSP using trough technology with smaller parabolic mirrors that capture and focus the sun's energy onto a central pipe that also employs a heat-transfer liquid in turn converting water to steam to drive a turbine.; or (iii) Photo-voltaic panels that capture and convert sunlight directly into electrical power using conventional PV technology. There are fewer direct risks associated with the PV and CSP trough technology than CSP towers from an avian perspective (see below). However, all forms of solar technology appear to draw in birds - research suggests birds perceive the shiny mirrored-surfaces as open water (the so-called "Lake Effect" – Kagan et al. 2014). This CSP trough technology is the preferred option by the developer for the Ilanga CSP4 development and is therefore, the only one assessed in this report.

3.2 POTENTIAL AVIAN IMPACTS WITH CSP FACILITIES

The main avian impacts according to a position paper on the subject by Birdlife SA (http://www.birdlife.org.za/images/stories/conservation/birds_and_wind_energy/solar_power.pdf) are:

(i) displacement of nationally important species from their habitats;
(ii) loss of habitats for such species;
(iii) disturbance during construction and operation of the facility;
(iv) collision with the CSP mirrors (mistaking them for water bodies); or
(v) collision with associated infra-structure.

The nature and magnitude of impacts to birds from solar facilities is related to three factors: (a) location, (b) size of the facility, and (c) the technology involved (i.e. Photo-voltaic *vs* CSP trough *vs* CSP tower). Thus, the location in relation to avian flyways, wetlands, roost sites and the habitat removed in the footprint may have an important effect on the impact to birds of the solar site. The size of the footprint will be directly related to the negative impact on smaller birds, thus habitat of range-restricted or collision-prone species around the site must be determined with accuracy.

An area up to 680 ha is required in the operation of the overall 150MW CSP 4 facility (comprising the 480ha authorized 100MW facility and the 200ha proposed 50MW facility), and this will reduce habitat availability for birds where construction takes place. It is a simple exercise to calculate the numbers potentially lost from our estimates of birds per unit area. On this basis, these are likely to be minimal considerations given that smaller birds generally occur at higher densities than larger birds, breed faster, and are less likely to suffer high population reduction. However, avoidance of some habitats will reduce the impact.

Avian fatalities at CSP sites have been summarised from those investigated in the USA by two recent reports (Kagan et al. 2014, Walston et al. 2015). Of the three types of solar energy capture (PV, CSP trough and CSP tower) the CSP trough sites recorded median levels of avian fatalities relative to the PV and CSP tower sites in one review (Kagan et al. 2014).

Given that impact trauma was the most common cause of mortality at two of the three solar sites investigated, minimising the reasons for the cause of that trauma are paramount. Biologists believe that birds mistake the troughs in the solar arrays for a body of water (the Lake effect – Kagan et al. 2014) and suffer physical trauma when they attempt to land on it. Birds, particularly wetland species, are the main victims of this sort of impact.

In a review of all bird fatalities at large scale operational solar plants across the world (mainly the USA but one in Israel) Walston et al. (2015) found that few solar plants had undertaken systematic monitoring of bird fatalities (Table 1).

Table 1. Summary of all avian fatality data from large-scale solar facilities from the USA (after Walston et al. 2015). The results for CSP trough technology are given in **bold**.

Project Name	Avian Fatality Data – systematic or incidental?	Survey Period	Incidental Fatalities	Systematic Fatalities (Unadjusted)**
Mohave Solar (CSP trough)	Yes – Incidental	Aug. 2013–March 2014	14	None collected
Genesis (CSP trough)	Yes – Incidental	Jan. 2012–May 2014	183	None collected
California Valley Solar Ranch (PV)	Yes – Systematic	Aug. 2012–Aug. 2013	Not Available	368
Desert Sunlight (PV)	Yes – Incidental	Sept. 2011–March 2014	154	None collected
Topaz Solar Farm (PV)	Yes – Incidental and Systematic	Jan. 2013 –Jan. 2014	19	41
California Solar One (CSP tower)	Yes – Systematic	May 1982–May 1983 (40visits)	Not Available	70 (114 birds)
Crescent Dunes (CSP tower)	Yes - systematic	Under construction	Not available	Not available
Ivanpah (CSP Tower)	Yes – Systematic	Oct. 2013–March 2014	159	376 (includes 7 injured birds)

*Causes of death include: solar flux, impact trauma, predation, electrocution and emaciation

** Unadjusted refers to the fact that numbers are not adjusted for biases resulting from predator removal or human observer bias

In summarising the avian species found, Walston et al. (2015) noted that:

- most birds were small passerines (40%-63% at 7 solar farms);
- Kagan et al. (2014) also found 20 of the 30 birds identified at the Genesis CSP trough site in California were smaller passerine birds or swallows;
- they also recovered waterbirds such as grebes, herons and gulls suggesting these species may be attracted by the *perceived* availability of water or the lake effect (Kagan et al. 2014);
- overall, waterbirds were found to average 11% of the fatalities at solar farms, but reached 46% of all fatalities at one solar PV facility (Desert Sunlight) in California;
- there were too few fatalities at different types of facilities to test the lake effect of Kagan et al. (2014); and
- there was a clear trend at all solar facilities for resident species to dominate the

fatalities. At the Genesis CSP trough facility 64% of the fatalities were resident species, meaning that 36% were migrants (Walston et al. 2015), the highest among those reviewed.

Tabulating fatalities of birds at solar sites is not enough to determine the impact to birds of conservation significance. They must be collected systematically and account for human error in (not) finding carcasses, and the rate of carcass removal by scavengers.

In an arid environment where sensitive species may not occur at all if rains do not fall (Dean 2004, Dean et al. 2009) even a full year's monitoring is unlikely to be sufficient. Thus, visits must be timed to coincide with the most productive time of year – i.e. the rain season.

Therefore, the present CSP 4 trough facility site was closely and *systematically* monitored by Birds & Bats Unlimited, over a dry and wet season, to determine movements and rates of passage of all collision-prone species (as defined by BARESG 2014).

As a relatively new field, and with the burgeoning solar farm industry in South Africa focussed on the Kalahari Desert, we need to be pro-active in our research and innovative designs to reduce mortality.

3.2.1 Habitat loss – Destruction, Disturbance and Displacement

The construction and maintenance of CSP technology causes mainly permanent habitat destruction under the parabolic mirrors. Maintenance activities are likely to cause some disturbance to birds in the general surrounds, and especially the shy or ground-nesting species resident in the area. Mitigation of such effects requires that best-practice principles be rigorously applied – i.e. sites are selected to avoid the destruction of key habitats for red data species, and the disturbance and construction and the final footprint size, for key species, should all be kept to a minimum. Construction time for each facility is expected to take 2-3 years.

From the habitat removal point of view, it is a simple exercise to calculate the numbers of birds potentially lost from our density estimates of important species/birds per unit area of habitat. On this basis, these are likely to be minimal considerations given that smaller birds are generally more common than larger birds, breed faster, and are less likely to suffer high population reduction. However, where range-restricted species occur on sites ear-marked for development this can have a larger impact.

Because only two CSP facilities are operational in South Africa (and no post-construction avian reports are available), and there are relatively few published studies of avian mortalities at such sites in other parts of the world (Table 1), this section is necessarily brief and is in need of further study, transparency and data sharing in southern Africa.

3.2.2 Collision – with reticulation lines and CSP troughs

Several South African bird species are well known to collide with overhead power lines, fences, towers and other aerial objects (Jenkins et al. 2010). These have been tabulated and the reasons for their propensity for collision investigated (Martin and Shaw 2010). The extenuating factors were then extrapolated to all South African species based on wing loading, aerial flights, nocturnal activity, red-data status (Taylor et al. 2015) and several other contributing factors (BARESG 2014).

We have used Birdlife South Africa's list and taken the top 100 species as the most likely to collide with power lines. The most collision-prone species are generally the larger species such as bustards, but also raptors. It is somewhat surprising that birds also collide with ground-based structures and, as shown above (Table 1), these include passerines, and wetland birds in collision with CSP troughs in the USA. While we do not know which species will be similarly prone in South Africa, they are likely to be a similar suite of birds (i.e. wetland and aerial species), and those known to collide with aerial structures (bustards and raptors). It is these we focused on during our surveys.

4 STUDY METHODS

4.1 Aims and methods

The primary aims of the avian pre-construction monitoring at the CSP 4 site proposed by Emvelo Holding (Pty) Ltd are to:

- Determine the densities of birds regularly present, or resident, within the impact area of the CSP before the construction phase;
- Document the patterns and movements of birds in the vicinity of the proposed CSP before their construction;
- Monitor the patterns and rates of movements of birds in the CSP areas in relation

to time of day, and over one dry and one wet season when bird numbers and species richness may change;

- ➢ Establish a pre-construction baseline for all Red data and collision-prone bird species including all breeding birds within the study area;
- ➢ Quantify the impacts before and after mitigation; and
- ➢ Inform final design, construction and management strategy of development with a view to mitigating potential impacts.

We consulted several published sources of bird data including:

- Information on the biology (Hockey et al 2005), distribution (Harrison et al. 1997) and conservation status (Taylor et al. 2015) of South African birds;
- The Important Bird Areas Programme (IBA) of Birdlife South Africa (Barnes 1998);
- Contemporary South-Africa-wide atlas data were extracted from the Southern African Bird Atlas Project (SABAP), which were obtained from the Animal Demography Unit website (http://sabap2.adu.org.za/index.php) for the relevant "pentads" of 5' x 5' (of 9 km x 8km) surrounding the planned development areas. From these data we compiled a list of the avifauna likely to occur within the impact zone of the proposed power lines. Because of the remoteness of the area there were limited SABAP2 data available at http://sabap2.adu.org.za/index.php for this region;
- These data were combined with our two visits to the area in November 2015 and March 2016 to record bird densities and passage rates of sensitive species.

This report combines the data gleaned from all sources to give an assessment of the birds present and moving through the site and, thus, the potential impacts they face arising from the solar development.

4.2 LIMITATIONS AND ASSUMPTIONS

Inaccuracies in the above sources of information can limit or bias this study in the following ways

- The SABAP1 data for this area is over 20 years old (Harrison *et al.* 1997), so we have used only the new SABAP 2 data set. This has a higher spatial resolution specific to the power lines and is up to date (2007 to 2015). However, there were only 9 cards in the pentads that cover the solar park itself and *none* were full protocol - this limits the overall species totals;

- Use of the older SABAP 1 data set may not only include (Orange River) species that are very unlikely to be found in this arid area, but also artificially inflate the species totals given. For example, Todd (2012) reported 190 bird species from atlas data including Black Storks *Ciconia nigra*, many of which are unlikely to occur on site because they are wetland species;
- Our own additional data derived from one dry-season and one wet-season site visit is still insufficient to cover all areas of the farm in any depth. We may miss certain rare species or nocturnal species that a longer visit timed for the dry and wet seasons would uncover;
- We operate in a near complete vacuum of data on the effects of solar farms on Southern African avifauna. This arises mainly through the recent advent of solar farms in South Africa (two are in operation in 2016 and neither have released data on what species are being killed or displaced).

While no data set can be a perfect representation of what is present and at risk on a site, our familiarity with arid systems and wide-scale surveys of the avifauna in wet and dry periods elsewhere (Seymour et al. 2015) means we are unlikely to have missed many important species in the surveys reported below.

4.3 Study area

The Ilanga CSP 4 facility to be developed by Emvelo Holding (Pty) Ltd is located approximately 30 km east of Upington within the Khara Hais Local Municipality, which falls under the Siyanda District Municipality in the Northern Cape. The facility is proposed on Portion 2 of Matjiesrivier farm and falls within the broader Karoshoek Solar Valley Development which includes a number of authorised CSP facilities. The site is geographically centred on S28°32'59.86" E21°30'12.38" on red Kalahari Sand.

4.3.1 Vegetation of the study area

The study area occurs on the interface between the Nama Karoo biome to the south and Kalahari Savannah biome to the north (Mucina and Rutherford 2006, p44). A large swathe of Bushmanland Arid Grassland runs north-south through the area (Mucina and Rutherford p335), and elements of five other vegetation types are found and described by Todd (2012). The area experiences summer rainfall up to 510 mm near Upington. High day-time temperatures occur in summer (mean 37°C) and relatively cool temperatures occur in winter (4-23°C). The site was dry and all but the larger trees were dormant in November 2015, our first site visit. Substantial rains (~250 mm in February and March 2016), had fallen by our second site visit in March 2016 and a new grass cover was evident and the *Rhigozum* bushes and *Acacia* and *Boscia* trees were in flower and full leaf.

4.3.2 Avian microhabitats

Bird habitat in the region consists of two basic vegetation types: Nama Karoo scrub and Kalahari Savannah with a very sparse cover of *Boscia* and *Acacia* trees along dry water courses. The main avian micro-habitats were provided by the grasses, (exploited by bustards, larks and finches) and the trees (exploited by flycatchers, sociable weavers and perching raptors). Artificial habitats are provided by the farmers - windmills, and power poles. Some pans occur outside the immediate study area and will attract many arid-adapted birds including sandgrouse, and raptors.

Photo 1: Typical dry-season habitat (top) in the western half of the Karoshoek Solar Valley Development showing *Rhigozum* shrubs (foreground), dead grasses (mid-ground), and mature *Boscia albitrunca* in the background. By contrast the wet-season transformation (bottom) sees the *Rhigozum* bushes, grasses and *Boscia* in full leaf.

5 ON SITE METHODS

Two site visits were undertaken to the CSP 4 site to coincide with different environmental conditions:

- a dry season visit from 31 October - 7 November 2015;
- a wet-season visit following substantial and on-going rains from 29 February – 9 March 2016;
- in each visit we surveyed birds in 1-km transects in areas proposed for the CSP solar arrays. These transects covered all main habitat types present; and
- we also undertook Vantage Point observations covering 12 h as suggested by draft BARESG guidelines (Jenkins et al. 2015).

All **1-km bird transects** took place in the morning (bird-active) hours. Each transect was walked slowly over 35 to 60 minute duration, depending on terrain and number of birds present. All species were identified where possible using Swarovski 8.5 x 42 binoculars, and the number of individual birds and the perpendicular distance to them, recorded. In denser habitat, or with some cryptic birds (e.g. larks), species were identified by call and the distance to them estimated. This allows an estimate of the density (birds per unit area and per km, expressed as bird km^{-1}) and the species richness in each area. We simultaneously recorded all large birds (mainly bustards and raptors) and noted and recorded the position of any nests found. Over 900 (dry season) and 1300 (wet season) individual birds were recorded in the CSP areas in these transects alone.

The most important aspect of this monitoring is **Vantage Point (VP) surveys,** that determine the number of flights **of collision-prone species** per hour through the possible area of impact. This gives an indication of the collision-risk to larger species that may impact the infrastructure in the solar facility. As suggested by the draft BARESG guidelines (Jenkins et al. 2015), 12 hours per VP is the minimum recommended observation time for each VP. Each VP should have a view-shed (area of observation) not exceeding 2 km. Because of the large size and flat nature of the terrain we walked some areas not well covered by the VP points and observed from the rooftop of our vehicle at other sites.

6 RESULTS

6.1 PRESENCE AND MOVEMENTS OF SENSITIVE SPECIES

Large sensitive species, observed from our walking transects or VPs, are defined as those species that are known, or expected, to be at risk from the CSP infrastructure, or attracted by the reflective surfaces of the CSP troughs. These species are typically large and threatened red data species that occur in the study areas (e.g. bustards and raptors), but could include wetland species attracted by the mirrored surfaces.

No recent (SABAP2) data were available from the Southern African Bird Atlas Projects website (http://sabap2.adu.org.za/index.php) for the Karoshoek Solar Valley Development footprint itself. Therefore, we took information from a slightly wider net that included the Ilanga powerline (Birds Unlimited 2014). To these we added our own dry (November 2015) and wet-season (March 2016) data for those species found directly on site.

6.2 AVIAN SPECIES RICHNESS AND RED DATA SPECIES

The CSP 4 site is shown in Figure 1. A total of 114 bird species were recorded on the 17 bird atlas cards from the Karoshoek Solar Valley Development area and similar areas to the west (following the authorized Ilanga power line) submitted to the Animal Demography Unit from 2007 to 2019 (Appendix 1). Of these, 8 were collision-prone as ranked by the BARESG (2014), and only 2 were red-listed (Kori Bustard *Ardeotis kori* and Lanner Falcon *Falco biarmicus*).

However, we noted four additional red data species in our two site visits: a Black Harrier *Circus maurus*, breeding Verreaux's Eagle *Aquila verreauxii*, a Secretarybird *Sagittarius serpentarius*, and numerous Ludwig's Bustards *Neotis ludwigi*. Thus, 6 red-data species occur on site (Table 2)**.** A further 7 collision-prone species (Table 2) were recorded on the Ilanga CSP 4 development site, giving 13 collision prone/red data species in total.

Because the SABAP data were completely missing for pentads away from the Orange River we tallied every species recorded in our transects, VPs and incidental observations to determine overall species richness in the dry and wet seasons over the development area alone. A total of 72 species were recorded which will be added to the SABAP2 data base.

In summary, a total of **13 collision-prone species** occur within the Ilanga CSP 4 solar development site, **of which six are red-listed.**

Table 2. Threatened (**in red**) and collision-prone bird species (**in bold**) likely to occur over the proposed CSP 4 trough development area drawn from SABAP2 atlas cards for 4 pentads. These are based on 17 cards, submitted to the SABAP2 project from 2007 to 2015. Those shaded were recorded in our site visits in November 2015 and March 2016, but not previously recorded.

					Susceptible to:
Common name	**Scientific name**	**Threat status**	**Reporting Rate***	**Collision Rank****	**Disturbance**
Verreaux's Eagle	*Aquila verreauxii*	**Vulnerable**		**2**	Moderate
Black Harrier	*Circus maurus*	**Endangered**		**6**	High
Ludwig's Bustard	*Neotis ludwigii*	**Endangered**		**10**	Moderate
Secretarybird	*Saggitarius serpentarius*	**Vulnerable**		**12**	Moderate
Lanner Falcon	*Falco biarmicus*	**Near-threatened**	**6%**	**22**	
African Fish Eagle	*Haliaetus vocifer*	-	35%	**27**	
Kori Bustard	*Ardeotis kori*	**Near Threatened**	6%	**37**	Moderate
Karoo Korhaan	*Eupodotis vigorii*		6%	**49**	
Booted Eagle	*Aquila pennatus*	-		**55**	
Pale Chanting Goshawk	*Melierax canorus*	-	6%	**73**	Moderate
N Black Korhaan	*Afrotis afroides*		12%	**91**	
Black-shouldered Kite	*Elanus caeruleus*	-	**24%**	**96**	
Spotted Eagle Owl	*Bubo africanus*	-	6%	**100**	

*Reporting rate is a measure of the likelihood of occurrence, as recorded in the atlas period.

** Collision rank derived from the BAWESG 2014 guidelines. Smaller numbers denote more collision-prone.

Seasonal differences in the composition of the bird community are expected to be large in an arid environment (Dean 2004). This arises for several reasons for different groups of birds: wetland species (e.g. geese, stilts and crakes) are attracted by the sudden appearance of wetlands that were not available prior to pans flooding. They follow rain fronts to find such ephemeral wetlands (Simmons et al. 1999). Other birds including sandgrouse will use pans that fill with water. For other nomadic species (e.g. bustards, larks) they are attracted to high rainfall areas because of the flush of insects that follow rains (Allan and Osborne 2005). Thus, an arid area such as the Kalahari Desert is very much a "boom or bust" landscape and one dry season visit can give a biased impression relative to the explosion in biodiversity that can follow high rainfall events (Lloyd 1999). These differences were apparent after good rains that fell in February 2016 and continued into March at the time of our second visit. Thus, the species richness values will be close to their maximum.

6.2.1 Density of birds recorded within the proposed CSP sites

In our 1-km surveys we recorded an average of 9.0 species km^{-1} in the dry season and 15.5 species km^{-1} in the wet season (Table 3). The higher species richness in the wet season was also reflected in the density of birds per kilometre (Table 3). These species comprised typical Kalahari birds such as korhaans, scrub-robins, larks, chats, prinias, finches, sandgrouse and weavers (Appendix 1).

Table 3: Comparison of Dry vs Wet season bird species richness recorded over 1 km at Ilanga CSP 4 site in November 2015 and March 2016.

Summary	Species km^{-1}	Birds km^{-1}	Collision-prone species
CSP 4 dry season	9.0	49.5	N Black Korhaan, Spotted Eagle Owl
CSP 4 wet season	15.5	55.0	N Black Korhaan
Means	**12.3**	**47.6 birds h^{-1}**	**2 species**

6.2.1 Passage rates of collision-prone species within CSP 4

Two collision prone species in the top 100 (BARESG 2014) were present in the CSP 4 area of investigation (Table 4), one of which was a red data species. The rate at which they flew through the site was measured from our Vantage Points over two 12 h periods (once in the dry season once in the wet season). A relatively low Passage rate of 0.42 birds h^{-1} was recorded in both the dry and wet seasons (Table 4).

Other aerial species that may be influenced by the mirrored surfaces included Namaqua Sandgrouse that were infrequent in the dry season but averaged 4.0 birds h^{-1} in the wet season (Appendix 1).

Table 4: Comparison of Passage Rates of Collision-prone species from VP observation at Ilanga CSP site, November 2015 and March 2016

Summary	Birds	Hours	Passage Rate	Collision-prone species
Passage Rate (dry season)	5	12	0.42 birds h^{-1}	N Black Korhaan, Spotted Eagle Owl
Passage Rate (wet season)	5	12	0.42 birds h^{-1}	N Black Korhaan, Ludwig's Bustard
Means	**5**	**12**	**0.42 birds h^{-1}**	**3 species**

No wetland birds were ever recorded within the CSP 4 site suggesting that future collisions by these species with the CSP troughs is unlikely. Three species were recorded elsewhere in the development footprint and, therefore, the potential for collision still exists.

The only other species of note that may create some issues for the developers is the Sociable Weaver *Philetairus soceus* that occurs on site. They typically target mature trees to build their massive nests (photo 2) but frequently use man-made structures, and are able to build even on apparently smooth metal surfaces.

They may, therefore, attempt to nest on the structures supporting the CSP troughs and nests would have to be cleared on a regular basis.

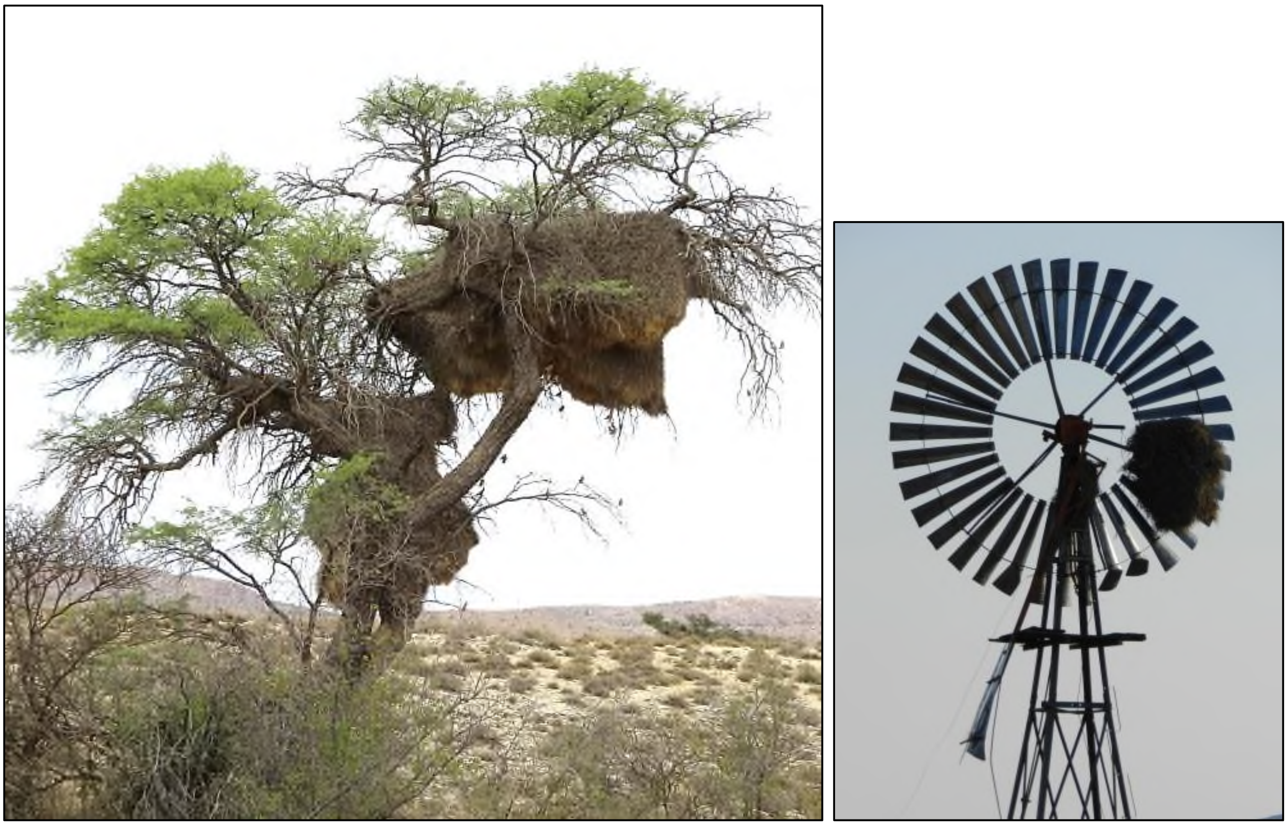

Photo 3: Sociable Weavers were common within the Karoshoek Solar Valley Development area and naturally choose large trees such as this *Acacia* to build their massive nests. They also turn to man-made structures (such as this wind pump on the Ilanga power line route) and any active colonies close to the proposed site can be expected to try to build on nearby structures themselves.

6.2.2 Flights paths of collision-prone species within CSP 4 development site

The flight paths of the collision-prone species through the proposed CSP 4 area are shown in Figure 2. The most frequently recorded species was the Northern Black Korhaan *Afrotis afroides* that undertakes aerial territorial display flights year round. The only red-listed species recorded in flight was the Ludwig's Bustard that flew south

(Figure 2). A nest of a Secretarybird (photo 4) was found in the centre of the site (S28°33'57.80", E21°29'15.90"). The nest appeared inactive and no Secretarybirds were recorded on site. Thus, this may not be an issue for the CSP 4 Facility.

Other non-collision-prone species that are attracted to water were recorded on site in large numbers, and these included Namaqua Sandgrouse (48 birds in 12 h) and swifts and swallows (Figure 3). Their interactions with mirrored surfaces are however yet to be determined in a southern African setting.

In summary, 72 species, 13 collision-prone species and 6 threatened red-data species have been recorded over the total Karoshoek Solar Valley Development site. Species richness was much lower on the CSP 4 site with the density of smaller species being higher in the wet season than in the dry season. Namaqua Sandgrouse were particularly numerous in the wet season. Only three collision-prone species were recorded on the CSP 4 site of which one was a red-data species (Ludwig's Bustard). The Passage Rate of these birds was relatively low at 0.42 birds h^{-1}.

The following section quantifies the potential impacts of the collision-prone species by the CSP trough at CSP 4.

Photo 4: A Secretarybird nest in an Acacia tree in the centre of CSP 4 at S28°33'57.80", E21°29'15.90". The nest appeared to be inactive and no birds were seen on the CSP 4 site. However, a Secretarybird was recorded in March 2016, 8 km north-east of this nest.

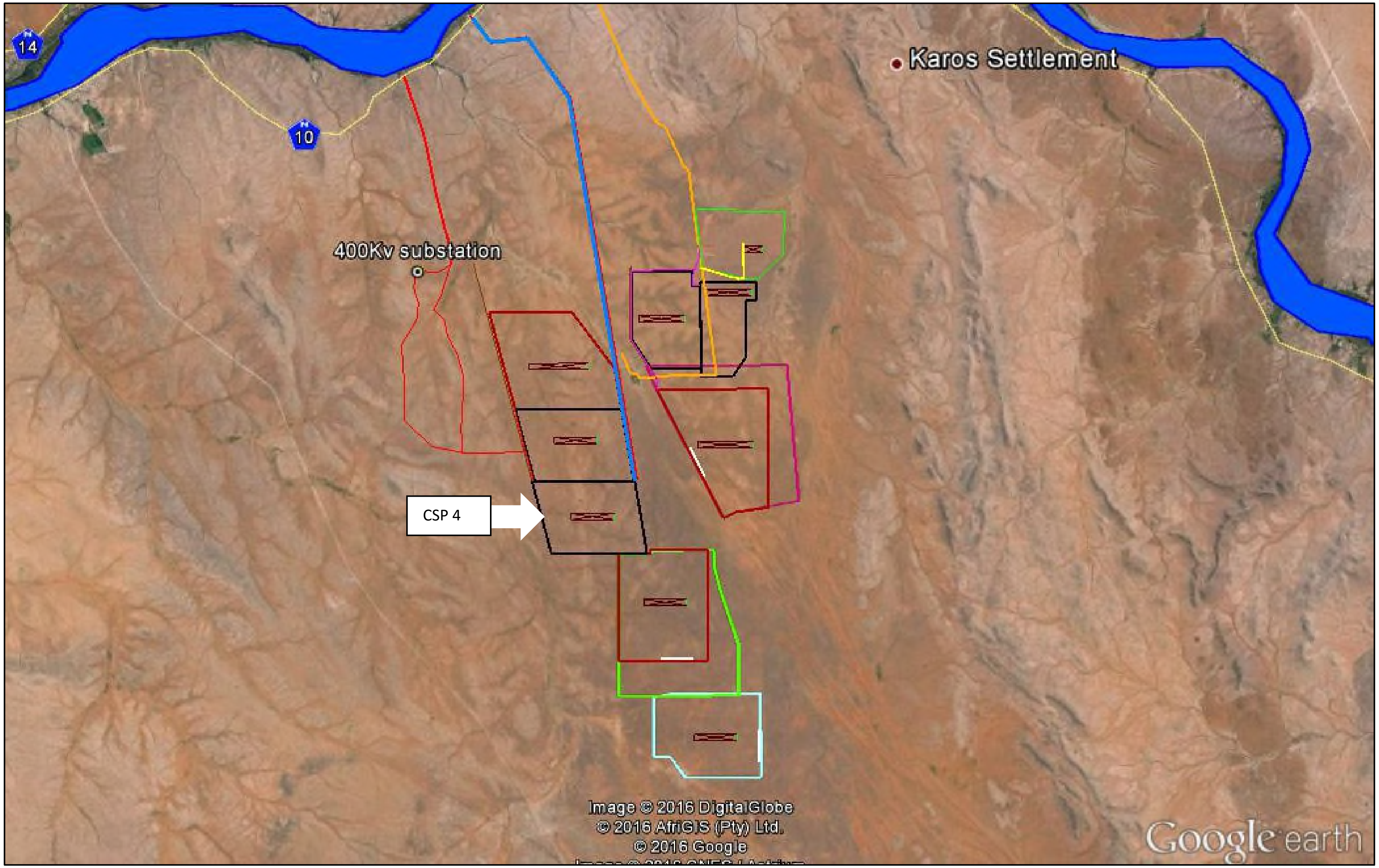

Figure 1: Layout of the **Karoshoek Solar Valley Development** showing Ilanga CSP 4 as well as all other authorised and proposed CSP sites. The proposed new roads are shown in red and the water pipeline in blue, in relation to the Orange River. The increased areas are shown adjacent to the coloured rhomboids.

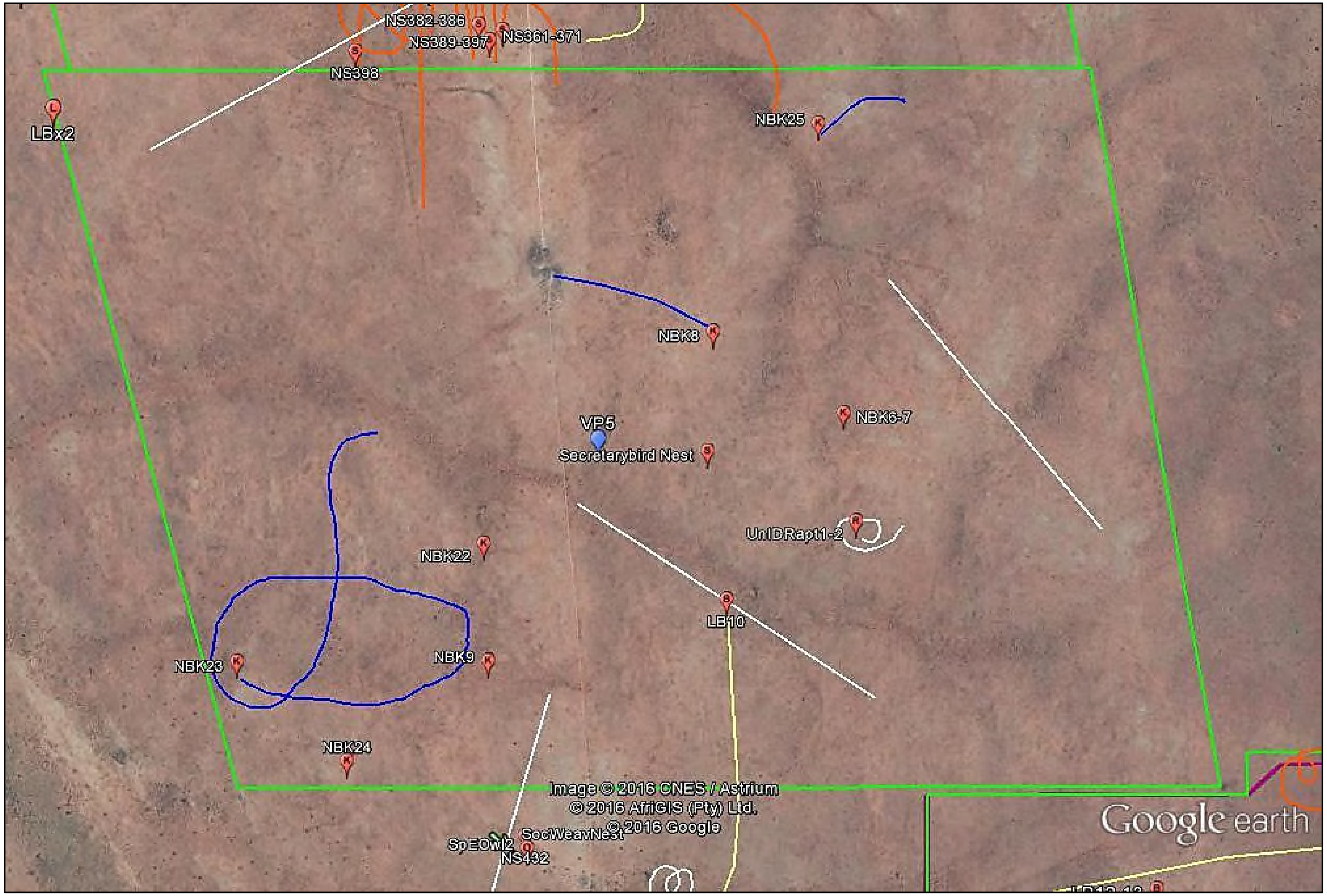

Figure 3: Collision-prone bird movements and perch sites in the Ilanga CSP 4 solar site on Portion 2 of Matjiesrivier farm near Upington, from November 2015 and March 2016. Two species of collision-prone birds were recorded in flights in the site, LB = Ludwig's Bustard and NBK = Northern Black Korhaan. The scale is given by the 1 km transect lines (white lines). An inactive Secretarybird nest was apparent in the centre of the site (photo 4), but no birds have been seen on this site.

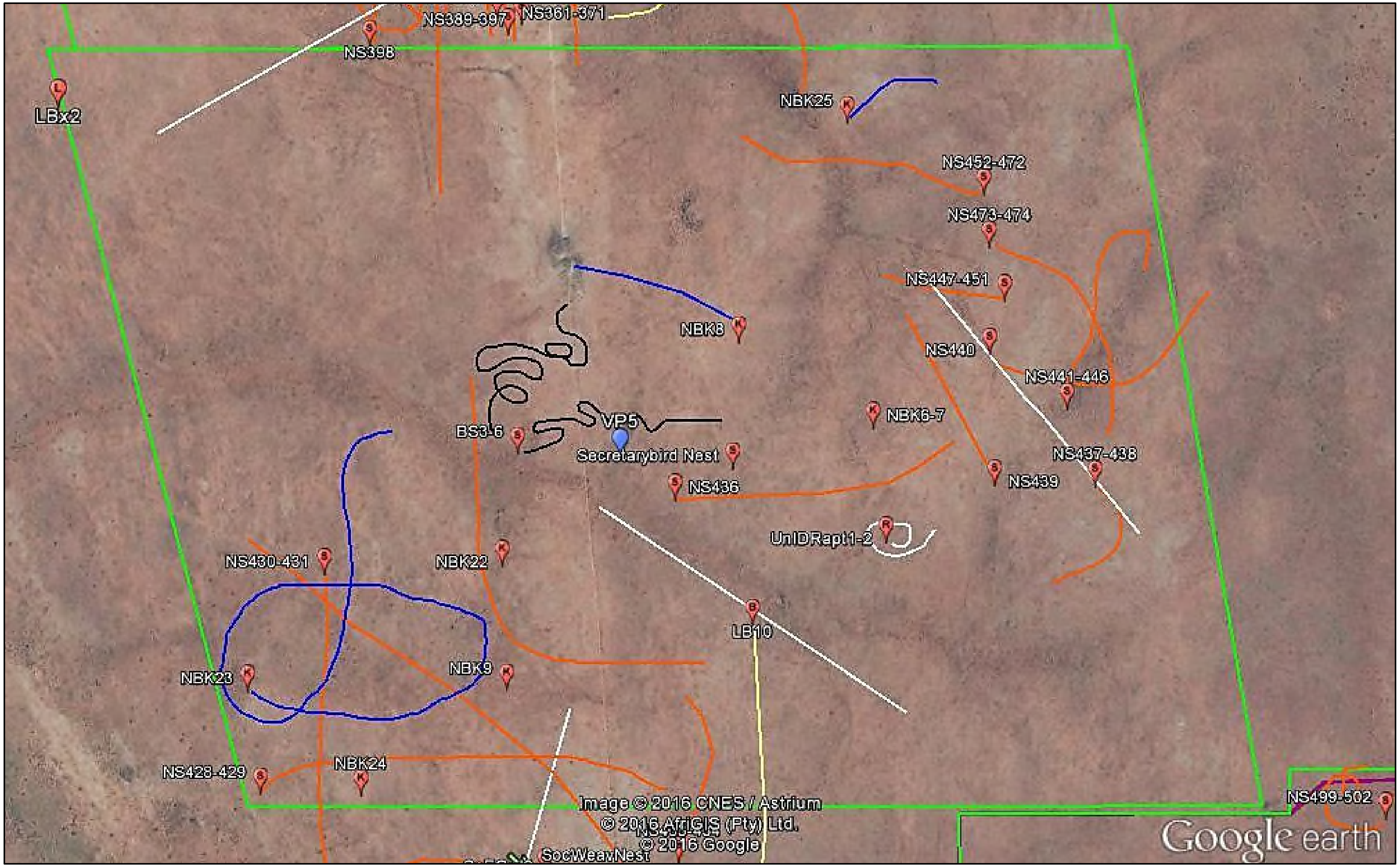

Figure 4: All aerial bird movements and perch sites in the Ilanga CSP 4 solar plant on Portion 2 of Matjiesrivier farm near Upington, November 2015 and March 2016. Two main species of non-collision-prone birds were recorded in flights in the site, BS = Barn Swallow (black lines) and NS = Namaqua Sandgrouse (orange lines). Flights of 48 sandgrouse were recorded in 12 h of observation in the wet season indicating high use of the area by this species. The scale is given by the 1 km transect lines (white lines).

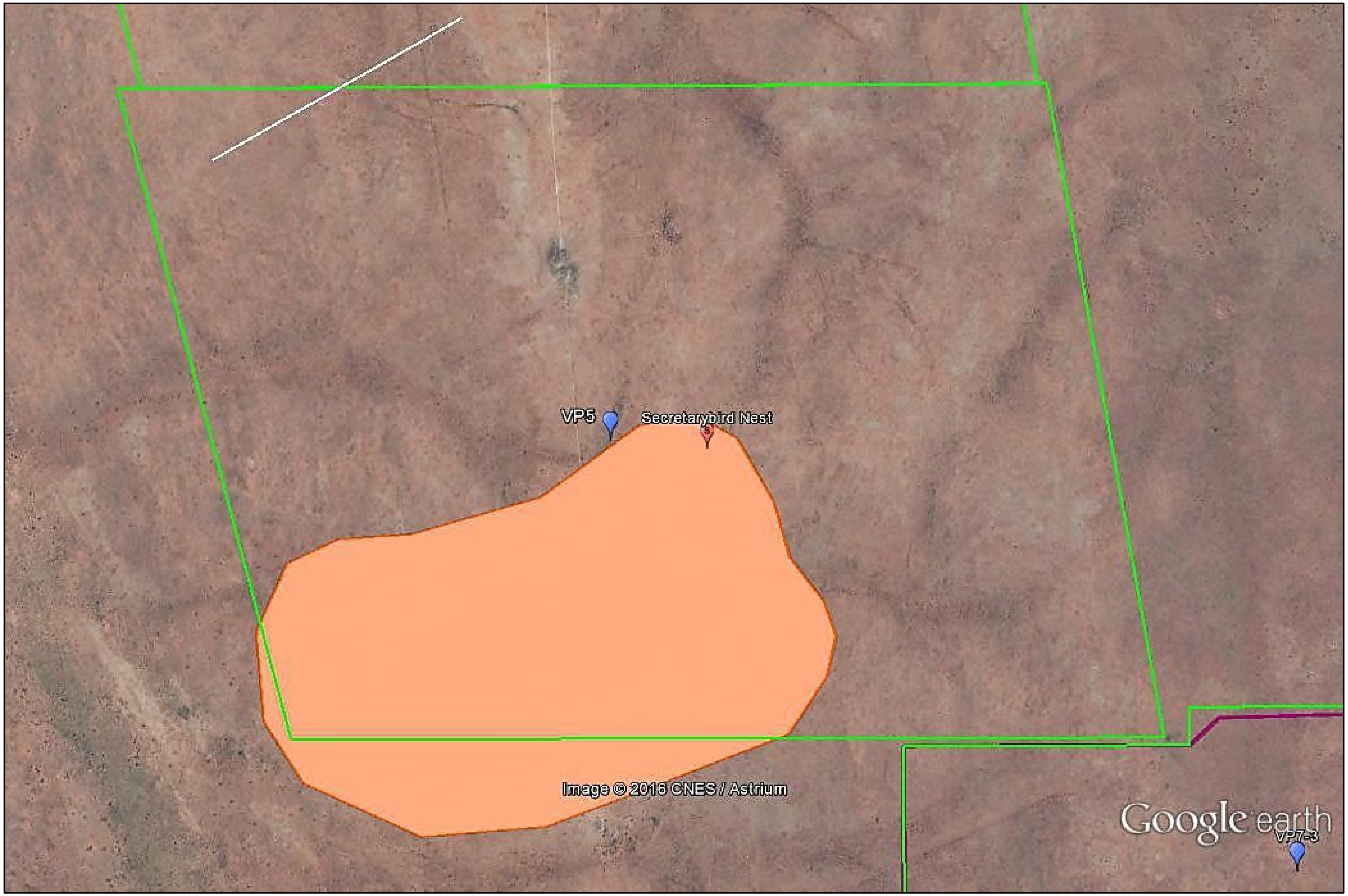

Figure 5: Avian sensitivity map of CSP 4, indicating the main area of collision-prone bird activity in the south-west corner. The inactive Secretarybird nest is the main reason this medium sensitivity area extends towards the centre of the CSP. If it remains inactive then the area will contract in size.

7 QUANTIFYING THE IMPACTS

The Significance (**S**) of the impacts can be semi-quantified by independently assessing the extent (**E**) of the impact in length or area, the duration (**D**) in months or years, the expected Magnitude (**M**) in terms of its impact (minor to major) on the species likely to be affected, and the probability (**P**) that the impact will occur. The significance can then be calculated as **S = (E+D+M)P** , as follows (Table 4).

Nature: The impact of the proposed CSP trough areas will generally be negative given the certainty that: (i) ~680 ha will be transformed and the associated bird habitat destroyed; (ii) birds may collide with the CSP mirrors if they mistakenly perceive them as open water; and (iii) collision-prone species living around the periphery may collide with any overhead power lines linking the solar development to the substation. The latter impact will be addressed in an independent Basic Assessment of all power lines.

The Extent (**E,** from 1-5) of the impact will occur within the chosen CSP area (of 680 ha) = **(1)**

The Duration (**D**, from 1-5) will be long-term **(4)** for the lifetime of the CSP area.

The Magnitude (**M,** from 0-10) of the impact of the CSP areas is expected to have a medium impact **(5)** for the wetland birds and medium-low impact **(4)** bustards and raptors and lower for the Korhaans **(2).**

For any wetland birds, some **(1)** may be killed by collision with the troughs (Kagen et al. 2014). Three Ludwig's Bustards, and many smaller birds will be displaced by habitat destruction of 680 ha but no Sociable Weaver nests will be lost during construction in the CSP area.

The Probability of occurrence (**P,** from 1-5) of the korhaans and raptors having a negative interaction with the CSP troughs is ranked medium low **(2)** but for the bustards as red data species it is ranked high **(6)** because of their decline in Southern Africa. For the wetland birds, the probability of occurrence is very low **(1)** because they were not recorded on site during our visit.

The Significance S, [calculated as **S = (E+D+M)P**], is as follows (Table 4) for the species identified as at risk in the (i) CSP site.

The scale varies from 0 (no significance) to 100 (highly significant and unacceptable). A score above 50 is considered high and mitigation is required.

Displacement and Avoidance are treated together because they are expected to have equal impacts on the species considered sensitive.

Table 4. A summary of the quantified impacts to the collision-prone bustards, raptors and wetland bird species likely to be impacted by the proposed CSP plant.

(i) Within the CSP site itself – DISPLACEMENT AND AVOIDANCE **Nature:** Mostly negative due to avoidance of area due to destruction of suitable habitat in, or displacement from area by human activity during construction around the **CSP 4 site** for the Red-listed bird groups identified as at risk above. (**Bust** = Bustards, **Rapt** = Raptors, **Korh** = Korhaans, **WetB** = Wetland birds):		
	Without mitigation	**With mitigation**
Extent	**1**	**1**
Duration	**4**	**4**
Magnitude	**5 (Bust)** medium **3 (Rapt)** medium-low **2 (WetB)** low **2 (Korh)** low	**4 (Bust)** **2 (Rapt)** **2 (WetB)** **1 (Korh)**
Probability	**6 (Bust)** medium **4 (Rapt)** low **2 (WetB)** low **2 (Korh)** low	**5 (Bust)** **3 (Rapt)** **1 (WetB)** **1 (Korh)**
Significance (E+D+M)P	**60 (Bust)** high **32 (Rapt) medium-low** **16 (WetB),** low **14 (Korh)** low	**45 (Bust) medium** **21 (Rapt)** low **7 (WetB)** low **6 (Korh)** low
Status (+ve or –ve)	Negative	Negative
Reversibility	Medium	(medium)

Irreplaceable loss of species?	For any red data species on site (bustards and if the threatened Secretarybird's nest becomes active) these species' foraging and breeding area will be lost.
Can impacts be mitigated?	Avoid the highest sensitivity areas of the bustards.

Mitigation for impacts for the CSP troughs

There is only one class of mitigation for the CSP troughs to reduce displacement or avoidance: (i) avoid highly sensitive bird area (especially pans, or feeding nesting or roosting areas) for the red data species.

The highest sensitivity areas are shown in Figure 5.

Cumulative impacts:

For the CSP itself the mortality and displacement impact on birds is poorly known, but many solar farms are now being constructed in the Kalahari/Karoo region and more will occur in the future: thus more research and monitoring of the combined impacts is required.

Residual impacts:

None. An environmental management programme will assess whether the bustards return to areas around the CSP trough site 4.

(ii) Within the CSP site itself – COLLISIONS (post construction)

Nature: Mostly negative due to direct impact mortality from impacting the mirrored surfaces in the **CSP 4** for the Red-listed bird groups identified as at risk above. We don't expect any collisions to occur pre-construction.
(**Bust** = Bustards, **Rapt** = Raptors, **Korh** = Korhaans, **WetB** = Wetland birds):

	Without mitigation	**With mitigation**
Extent	**1**	**1**
Duration	**4**	**4**
Magnitude	**3 (Bust)** low **3 (Rapt)** low **5 (WetB)** medium **2 (Korh)** low	**2 (Bust)** **2 (Rapt)** **3 (WetB)** **1 (Korh)**

Probability	**2 (Bust)** low **2 (Rapt)** low **5 (WetB)** medium **2 (Korh)** low	**1 (Bust)** **1 (Rapt)** **3 (WetB)** **1 (Korh)**
Significance (E+D+M)P	**16 (Bust)** low **16 (Rapt)** low **50 (WetB),** medium **14 (Korh)** low	**7 (Bust)** low **7 (Rapt)** low **24 (WetB)** low **6 (Korh)** low
Status (+ve or –ve)	Negative	Neutral
Reversibility	Medium	(mitigations untested)
Irreplaceable loss of species?	No, few red data species occur on site. It depends entirely whether wetland species (or other African species) are attracted to and collide with the mirrors.	
Can impacts be mitigated?	Probably yes: the use of bird scaring strategies on the site will probably deter species from interacting negatively.	

Mitigation for impacts for the CSP troughs

There are two classes of mitigation for the CSP troughs: (i) move them away from highly sensitive bird area (especially pans or other nests or roosts), or (ii) employ bird-diverters to deter birds mistaking the troughs for open water.

We recommend that Emvelo install video cameras above some troughs for post-construction monitoring of any mortality of birds in the vicinity, through direct observation and carcass searches in a systematic and regular fashion.

Cumulative impacts:

For the CSP itself the collision-mortality of birds is poorly known, but many solar farms are now being constructed in the Kalahari/Karoo region and more will occur in the future: thus more research and monitoring of the combined impacts is required.

Residual impacts:

After mitigation, direct mortality through collision by the species identified above may still occur. An environmental management programme will assess the efficacy of the mitigations to reduce direct impacts or any problems with sandgrouse, or the aerial swallows/swifts impacting panels. Further research and mitigation can then be suggested and tested as the need arises.

7.1 CUMULATIVE IMPACTS

Cumulative impacts are defined as “Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project” (Hyder, 1999, in Masden et al. 2010).

Thus, in this context, cumulative impacts are those that will impact the general avian communities in and around the Karoshoek solar development, mainly by other solar farms and associated infrastructure. This will happen via the same factors identified here viz: collision, avoidance and displacement. Therefore, we need to know as a starting point the number of solar farms around the region within 50 km, and secondly, to know their impact on avifauna.

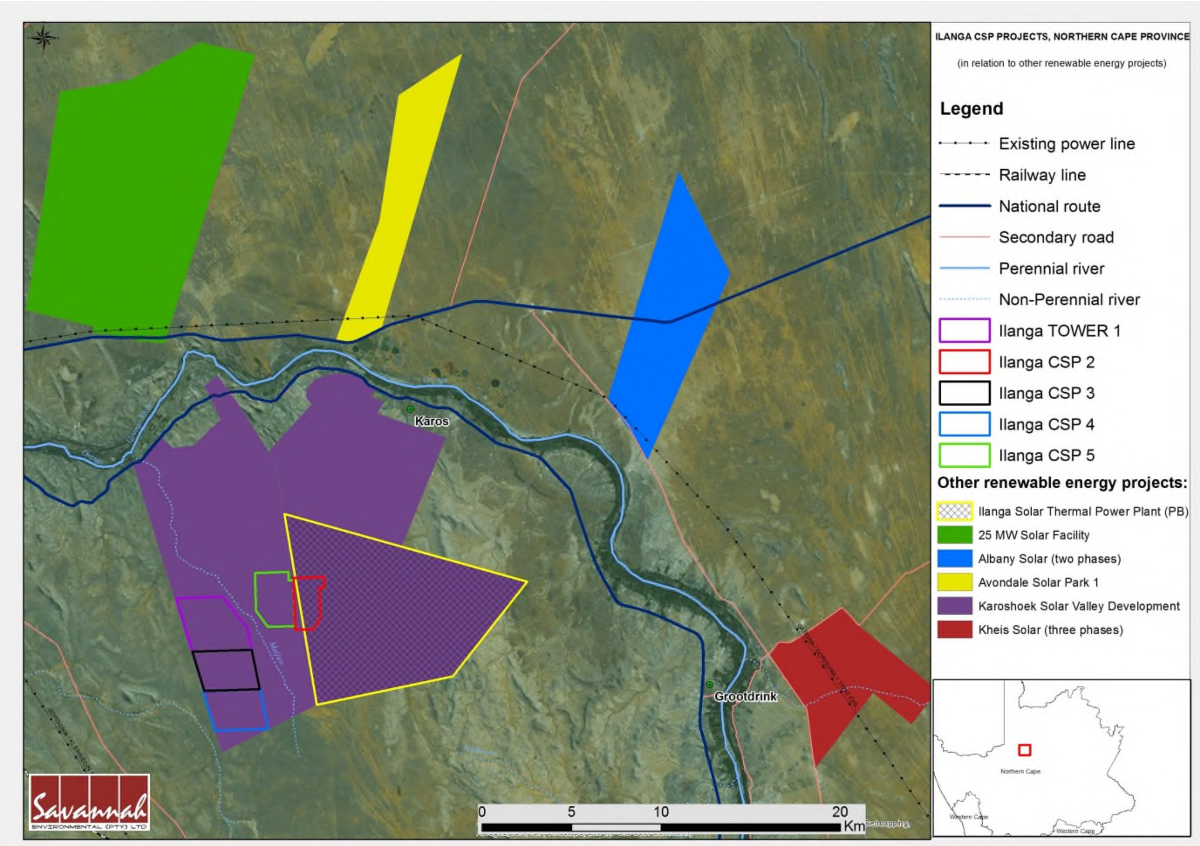

Figure 5: The location and extent of all other solar farm developments in the Karos/Upington area (as supplied by Savannah Environmental) in 2016.

There are four proposed or approved solar farms of various sizes within 50 km of Karoshoek (Figure 5).

Given the general assumption that footprint size and bird impacts are linearly related for CSP solar farms, a starting point in determining cumulative impacts is to determine:

- the number of bird displaced per unit area, by habitat destruction, or disturbed or displaced by human activity;
- the numbers of bird killed by collision with the structures on site;
- the number of birds killed by collision with infrastructure leading away from the site;
- the number of birds killed by flying through the solar flux of the CSP tower sites.

Because there are no post-construction mortality data or displacement data for any of these aspects in South Africa, it is a futile exercise to attempt to put any figures to the Cumulative Impacts for birds in and around the Orange River's solar farms. Once the data is collected and published (or released to other specialists) we can provide figures for this aspect.

Orange River water off–take rates are considerations already under investigation by hydrologists. However, the influence on the Orange River's wetland birds, which use the river as a linear oasis (Simmons & Allan 2002), needs to be assessed. This arises because the Orange River flow is reduced at certain times of year to very low rates, and no less than 20% of the flow is required as an ecological reserve to maintain ecological functioning of the river (http://orangesenqurak.com/challenge/water+demand/environmental+flows.aspx). Further off-take amounting to a possible 640 000 m^3, (8 CSP sites x 80 000 m^2) particularly at low flow (November-December) may force some wetland species to seek other water sources. This becomes an issue for the CSPs and the bank of mirrored surfaces that will be in the environment surrounding the river environs. If the Lake Effect of Kagen et al. (2014) attracts such water-seeking wetland birds then the large off-take of water from the Orange River may exacerbate this effect. We would predict:

- a seasonal influx of wetland birds to the CSPs in the dry season and an increase in mortality;
- greater mortality with time as more and more solar developments take more and more water away at such times.

A simple calculation of the Cumulative Impact of this would be related to:

- the rate of avian mortality per surface area of the mirrored surfaces of the CSPs per year;

- the surface area of the mirrored surfaces of each CSP;
- the reduction in flow of the Orange River causing more birds to seek other water sources; and
- the number of solar farms within 50 km of the Karoshoek site.

In 2016 we cannot yet quantify all of these variables, so a prediction of Cumulative Impact is not possible. Data gathering and sharing over even just one 12-month period, of one or more solar farms, will allow us to determine impacts on Orange River avifauna.

8 ENVIRONMENTAL MANAGEMENT PLAN

Given the size and number of the CSP plants proposed for the total Karoshoek Solar Valley Development, the overall impact on the avifauna species requires systematic monitoring at both the construction and post-construction phases. This is a recommendation of the draft solar guidelines (Jenkins et al. 2015).

The guidelines suggest an adaptive and well-planned systematic monitoring of bird displacement (comparing avian densities before and after construction, particularly collision-prone and red data species) and all fatalities. The latter must take account of biases introduced by scavengers removing carcasses and human observers not detecting bird remains.

The monitoring should include the following (after Jenkins et al. 2015):

- Post-construction monitoring should be started as the facility becomes operational, bearing in mind that the effects of the CSP facility may change over time;

- Post-construction monitoring can be divided into three categories: a) habitat classification, b) quantifying bird numbers and movements (replicating baseline data collection), and c) estimating bird mortalities;

- Estimating bird fatality rates includes: a) estimation of searcher efficiency and scavenger removal rates, b) carcass searches, and c) data analysis incorporating systematically collected data from a and b above;

- A minimum of 20-30% of the CSP solar footprint should be methodically searched for fatalities, with a search interval informed by scavenger removal trials and objective monitoring. Any evidence of mortalities or injuries within the remaining area should be recorded and included in reports as incidental finds;

- The search area should be defined and consistently applied throughout monitoring;
- Observed mortality rates must be adjusted to account for searcher efficiency (which is likely to change seasonally depending on vegetative condition of the site), scavenger removal and the proportion of the facility covered by the monitoring effort. Some of these factors may change seasonally due to the breeding season of scavengers and whether visibility of the survey area changes through the year;
- The duration and scope of post-construction monitoring should be informed by the outcomes of the previous year's monitoring, and reviewed annually;
- Post-construction monitoring of bird abundance and movements and fatality surveys should span 2-3 years to take inter-annual variation into account; and
- If significant problems are found or suspected, the post-construction monitoring should continue as needed in conjunction with adaptive management and mitigations, taking into account the risks related to the particular site and species involved.

A comprehensive assessment, guided by the principles above, is required not only to enact and experiment with different mitigation measures where significant mortality is found, but to allow data to be collected that will benefit the welfare of avifauna at other solar farms. This may be important for a study of cumulative avian impacts for the large number of solar farms planned for the Northern Cape of South Africa.

Management interventions: Where avian fatalities are found to occur (i) to red-data species or (ii) at unacceptably high levels, to these or other species, then mitigation measures should be brought into play. Thus, experiments with bird deterrent techniques such as Torri Lines, successfully used to prevent albatrosses and petrels descending onto baited hooks behind trawlers at sea, can be tried and tested.

Bird-scaring prisms are also an option that can be tested. Where natural or artificial pans occur and attract wetland species that are then killed by the CSP mirrors, action to close down the pan or dam will then be required. (Avoiding construction around natural pans beforehand is recommended to avoid such action).

This also explains why systematic rather than *ad hoc* sampling post-construction is recommended (above) in order to identify where and why some areas of the site may be killing more birds than others.

Management interventions may also be required where red data birds are known to be displaced outside the footprint due to disturbance inside the footprint. Other management interventions will also be required if Sociable Weavers displaced from natural nest sites attempt to build on the CSP structures themselves. Removal of nests or the provision of higher structures ("sypadpale") that Sociable Weavers may naturally transfer their nest too is also a management option.

Such interventions should be discussed with ornithologists familiar with the species concerned.

9 CONCLUSIONS AND RECOMMENDATIONS

The proposed Ilanga CSP 4 Facility near Upington is one of many such renewable energy initiatives that are being planned for this high-flux solar radiation region of South Africa.

The avifauna of the area may be affected by the infrastructure of the Solar Power (CSP) plant and our analysis of the number of collision-prone birds on CSP 4 suggests that some bustards and korhaans may be impacted. However, the significance will be medium to low since few bustards occurred and the korhaans are less collision-prone despite being more aerial. The Secretarybird nest found was inactive and the presence of only one bird in the entire solar development suggests it is unlikely to be re-used. Both may change as a complete vacuum of information exists in southern Africa

No Sociable Weaver nests occurred on the site and therefore the probability of this species transferring its massive nest from natural sites to the CSP infrastructure is expected to be low. We do not know how the sandgrouse, which were numerous on site, will react to mirrored surfaces. However, a well-structured and systematic construction and post-construction assessment, as laid out in the Environmental Management Programme in conjunction with Management interventions (above) will determine this and can provide appropriate mitigations.

Precious little research in South Africa is presently available to determine the impact of CSP trough and tower technology on the South African avian community, so a full 12months of post-construction monitoring at this site by trained ornithologists (able to distinguish Ludwig's from Kori Bustards) is strongly recommended.

We also recommend that all available precautions are taken to avoid threatened species and wetland birds being attracted to the troughs. If species are attracted and collide with the CSP troughs by mistaking them for open water then we recommend that innovative bird deterrent techniques are used, such as the Torri lines mentioned in the avian Scoping Report (Simmons and Martins 2015).

If these recommendations can be followed and prove effective, we believe that the Ilanga CSP 4 development can be allowed to proceed with the least impact to the avifauna of the area.

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11 April 2016

Revised 15 April 2016

11 APPENDICES

Appendix 1 All bird species recorded around the Karoshoek Solar development

All bird species and their likelihood of occurrence from the bird atlas pentads that run along the Ilanga power line to the CSP site. These pentads are: 2825_2115, 2825_2120, 2825_2125, 2825_2130 from the period 2007 to 2013. Extracted from the Animal Demography Unit, University of Cape Town website http://sabap2.adu.org.za and based on 17 cards. **Red data species are given in red, collision-prone species in bold.** Blue shading indicates wetland species that may be attracted to the parabolic mirrors via the "lake effect" and collide with them.

Note: this list includes pentads that overlap the Orange River inflating the number of species that will occur in the drier footprint of the Ilanga solar development. We have added our species records in the last column.

Species	Pentads/4	Records	Total cards	Reporting Rate %	Recorded in our site visits in Ilanga solar park
Ostrich, Common	1	1	17	5.9	√
Grebe, Little	1	2	17	11.8	
Cormorant, White-breasted	2	6	17	35.3	
Cormorant, Reed	3	6	17	35.3	
Darter, African	2	7	17	41.2	
Heron, Grey	1	4	17	23.5	
Heron, Black-headed	1	1	17	5.9	
Heron, Goliath	1	1	17	5.9	√
Egret, Little	1	4	17	23.5	
Egret, Cattle	3	10	17	58.8	
Bittern, Little	1	1	17	5.9	
Hamerkop	2	8	17	47.1	
Stork, Abdim's	1	1	17	5.9	
Ibis, African Sacred	3	5	17	29.4	√
Ibis, Hadeda	3	16	17	94.1	
Goose, Egyptian	2	11	17	64.7	√
Shelduck, South African	2	2	17	11.8	
Duck, African Black	1	1	17	5.9	
Duck, Yellow-billed	1	1	17	5.9	
Teal, Cape	1	1	17	5.9	
Red-billed Teal					√
Harrier, Black					√
Eagle, Verreaux's					√
Eagle, Booted					√
Falcon, Lanner	**1**	**1**	**17**	**5.9**	√
Kestrel, Rock					√
Falcon, Pygmy	1	1	17	5.9	√

Kite, Black-shouldered	2	4	17	23.5	
Fish-Eagle, African	**2**	**6**	**17**	**35.3**	
Pale-chanting Goshawk	**1**	**1**	**17**	**5.9**	√
Guineafowl, Helmeted	2	8	17	47.1	
Common Quail					√
Crake, Black	1	1	17	5.9	
Moorhen, Common	1	1	17	5.9	
Bustard, Kori	**1**	**1**	**17**	**5.9**	√
Bustard, Ludwig's					√
Korhaan, Karoo	**1**	**1**	**17**	**5.9**	√
Northern Black Korhaan	**1**	**2**	**17**	**11.8**	√
Plover, Three-banded	2	4	17	23.5	
Lapwing, Crowned	1	5	17	29.4	
Lapwing, Blacksmith	3	9	17	52.9	√
Sandgrouse, Namaqua	2	2	17	11.8	√
Double-banded Courser					√
Pigeon, Speckled	3	16	17	94.1	
Dove, Red-eyed	3	13	17	76.5	
Turtle-Dove, Cape	3	14	17	82.4	√
Dove, Laughing	3	15	17	88.2	√
Dove, Namaqua	1	3	17	17.6	√
Cuckoo, Diderick	1	3	17	17.6	
Owl, Barn	1	3	17	17.6	
Owlet, Pearl-spotted	1	1	17	5.9	
Eagle-Owl, Spotted	1	1	17	5.9	√
Common Swift					√
Swift, White-rumped	2	3	17	17.6	
Swift, Little	3	12	17	70.6	√
Palm-Swift, African	2	12	17	70.6	
Mousebird, White-backed	3	14	17	82.4	√
Mousebird, Red-faced	1	8	17	47.1	√
Kingfisher, Pied	2	5	17	29.4	
Kingfisher, Giant	2	4	17	23.5	
Kingfisher, Malachite	2	3	17	17.6	
Kingfisher, Striped	1	1	17	5.9	
Bee-eater, European	1	2	17	11.8	
Bee-eater, Swallow-tailed	3	4	17	23.5	
Hoopoe, African	2	10	17	58.8	
Barbet, Black-collared	1	1	17	5.9	
Barbet, Acacia Pied	3	4	17	23.5	√
Barbet, Crested	3	9	17	52.9	
Honeyguide, Lesser	1	2	17	11.8	
Shrike, Lesser Grey					√
Woodpecker, Golden-tailed	1	3	17	17.6	

Lark, Fawn-coloured	1	2	17	11.8	√
Lark, Sabota	3	4	17	23.5	√
Lark, Spike-heeled	2	2	17	11.8	√
Stark's Lark					√
Swallow, Barn	2	4	17	23.5	√
Swallow, White-throated	1	6	17	35.3	
Swallow, Greater Striped	2	10	17	58.8	√
Martin, Rock	3	6	17	35.3	√
Martin, Brown-throated	3	8	17	47.1	
Tit, Ashy	1	1	17	5.9	
Crow, Pied	1	4	17	23.5	√
Bulbul, African Red-eyed	3	16	17	94.1	
Rock-Thrush, Short-toed	1	1	17	5.9	
Wheatear, Capped	1	1	17	5.9	√
Chat, Ant-eating					√
Chat, Karoo					√
Chat, Familiar	3	3	17	17.6	
Robin-Chat, Cape	3	12	17	70.6	
Scrub-Robin, Karoo	3	5	17	29.4	√
Kalahari Scrub Robin					√
Swamp-Warbler, Lesser	2	5	17	29.4	
Reed-Warbler, African	2	3	17	17.6	
Eremomela, Yellow-bellied					√
Warbler, Rufous-eared	1	4	17	23.5	√
Cisticola, Zitting	3	6	17	35.3	
Cisticola, Levaillant's	3	4	17	23.5	
Cisticola, Desert					√
Prinia, Black-chested	3	8	17	47.1	√
Warbler, Namaqua	1	1	17	5.9	√
Tit-Babbler, Chestnut-vented	2	2	17	11.8	√
Tit-babbler, Layard's					√
Flycatcher, Chat					√
Flycatcher, Fiscal	3	3	17	17.6	
Batis, Pririt	3	4	17	23.5	
Wagtail, African Pied	1	1	17	5.9	
Wagtail, Cape	2	13	17	76.5	√
Pipit, African	2	3	17	17.6	
Fiscal, Common	2	11	17	64.7	√
Bokmakierie,	2	4	17	23.5	√
Brubru	1	3	17	17.6	
Starling, Wattled	2	9	17	52.9	
Starling, Cape Glossy	3	4	17	23.5	
Sunbird, Dusky	3	5	17	29.4	√
Sparrow-Lark, Grey-backed					√

Sparrow-Lark, Black-eared					√
Sparrow-Weaver, White-browed	2	9	17	52.9	√
Weaver, Sociable	3	5	17	29.4	√
Sparrow, House	3	13	17	76.5	
Sparrow, Cape	3	13	17	76.5	√
Masked-Weaver, Southern	3	15	17	88.2	√
Quelea, Red-billed	3	6	17	35.3	√
Bishop, Southern Red	2	9	17	52.9	
Firefinch, Red-billed	2	4	17	23.5	
Finch, Scaly-feathered					√
Waxbill, Common	2	2	17	11.8	
Whydah, Pin-tailed	1	4	17	23.5	
Canary, Black-headed					√
Canary, Black-throated	2	6	17	35.3	
Canary, Yellow	2	3	17	17.6	√
White-throated Canary					√
Dove, Rock	3	8	17	47.1	
Thrush, Karoo	1	13	17	76.5	
White-eye, Orange River	3	15	17	88.2	
Lark, Eastern Clapper	1	1	17	5.9	√
Coucal, Burchell's	1	3	17	17.6	
Sparrow, Southern Grey-headed	2	3	17	17.6	
Bunting, Lark-like					√

APPENDIX 2: BIRD DENSITIES BY HABITAT

Species recorded on site in 1-km transects on the Karoshoek Solar Valley Development in November 2015 and March 2016.

Species	Number	PerpDist	Date	Transect	Habitat	Time: Start	Time: Fin
Cape turtle dove	1	100	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Stark's lark	1	50	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Northern black korhaan	1	150	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Bokmakierie	2	100	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Northern black korhaan	2	70	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Ant-eating chat	1	25	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Barn swallow	1	10(1)	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Rufous-eared warbler	2	25	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
Rock martin	1	5(1)	06/11/2015	KT5-1	Stunted dry shrubs, overgrazed	06h15	06h48
8 species	**12**	**birds**	**In this trans: Red Data species = 0, Collision-prone species = 1**				
						Time: Start	**Time: Fin**
Sabota lark	1	15	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Namaqua sandgrouse	3	50(5)	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Ostrich	4	200	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Namaqua sandgrouse	1	15	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Bokmakierie	1	70	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Namaqua sandgrouse	21	50(20)	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Spotted eagle-owl	1	50	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Ant-eating chat	1	15	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Sociable weaver	10	30	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Stark's lark	40	25	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Namaqua sandgrouse	1	0(40)	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Spike-heeled lark	1	5	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
Fawn-coloured lark	2	25	07/11/2015	KT5-2	Dry river bed, rhygozium	08h08	08h50
10 species	**87**	**birds**	**In this trans: Red Data species = 0, Collision-prone species = 1**				
Total Birds	**99**						
Total Species	**15**						
Total Collision-prone sp	**2**	Spotted Eagle Owl; Northern Black Korhaan					
Total Red-data Species	**0**						
Summary (DRY)	**Species**	**Birds**	**Habitat**				
KT5-1	8	12	Stunted dry shrubs, overgrazed				
KT5-2	10	87	Dry river bed, rhigozum				
Means	**9.00**	**49.50**					

Species	Number	PerpDist	Date	Transect	Habitat	Time: Start	Time: Fin
Sociable weaver	4	30	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Cape turtle dove	1	100	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Rufous-eared warbler	1	50	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Namaqua sandgrouse	2	100(30)	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Cape clapper lark	1	70	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Northern black korhaan	2	75	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Larklike bunting	1	20	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Northern black korhaan	1	200	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Larklike bunting	1	50	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Grey-backed sparrowlark	3	25	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Sociable weaver	20	200	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Rufous-eared warbler	1	10	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Sociable weaver	1	60	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Acacia pied barbet	1	100	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Namaqua sandgrouse	2	100(30)	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Sabota lark	1	70	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Grey-backed sparrowlark	1	20	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Black-chested prinia	1	52	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Ant-eating chat	1	30	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Grey-backed sparrowlark	14	15	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Black-chested prinia	2	10	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Common fiscal	1	65	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Namaqua sandgrouse	1	110	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Sabota lark	1	55	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Sociable weaver	10	5	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Namaqua dove	1	20	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Black-chested prinia	1	5	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Black-eared finch lark	2	25	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
Bokmakierie	2	50	07/03/2016	KT5-2	Dry river bed, Rhigozum	06h50	07h27
16 species	**81**	**birds**	**In this trans: Red Data species = 0, Collision-prone species = 1**				
						Time: Start	**Time: Fin**
Namaqua sandgrouse	2	10	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Rufous-eared warbler	1	60	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua dove	1	5	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Common quail	1	80	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua sandgrouse	1	150	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Bokmakierie	1	170	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Northern black korhaan	1	200	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Ant-eating chat	1	80	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Northern black korhaan	1	180	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua sandgrouse	1	200	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Sabota lark	1	10	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Rufous-eared warbler	1	30	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Larklike bunting	1	50	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Spike-heeled lark	2	5	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Yellow canary	2	50	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Rufous-eared warbler	1	60	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Scaly-feathered finch	1	35	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Grey-backed sparrowlark	1	30	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua sandgrouse	1	180	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Cape clapper lark	1	60	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua dove	1	0	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50

Ostrich	1	200	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Scaly-feathered finch	2	25	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Cape clapper lark	1	50	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
Namaqua dove	1	20	09/03/2016	KT5-4	Rhigozum, very few trees	07h15	07h50
15 species	**29**	**birds**	**In this trans: Red Data species = 0, Collision-prone species = 1**				
Total Birds	**110**						
Total Species	**21**						
Total Collision-prone species	**1**	Northern Black Korhaan					
Total Red-data Species	**0**						
Summary (WET)	**Species**	**Birds**	**Habitat**				
KT5-2	16	81	Dry river bed, Rhigozum				
KT5-4	15	29	Rhigozum, very few trees				
Means	**15.50**	**55.00**					

APPENDIX 3: PASSAGE RATES OF COLLISION-PRONE SPECIES

Date	Time	Obsv period	Hrs	Vantage Point	No.	Species	GPS pos on map	Height	Flight duration (seconds)
06/11/2015	8h58	06h15-12h15	6	**VP5-1**	1	Namaqua sandgrouse	NS74	0m	0
07/11/2015	07h00	06h30-12h30	6	**VP5-2**	**2**	**Northern black korhaan**	NBK6-7	0m	0
	07h04				**1**	**Northern black korhaan**	NBK8	2m-3m-5m-3m	60s
	07h18				2	Namaqua sandgrouse	NS72-73	0m	0
	08h52				**1**	**Spotted eagle-owl**	SEOwl2	0m	-
	11h15				**1**	**Northern black korhaan**	NBK9	0m	-
			12	**TOTALS**	**5**	**collision-prone Birds**	**3**	**Species**	
					8	**all birds**			
Passage rate:		**5 birds in**		**12**	**hr**	**0.42**	**birds/hr**	**Northern black korhaan**	**Spotted eagle-owl**

Date	Time	Obsv period	Hrs	Vantage Point	No.	Species	GPS pos on map	Height	Flight duration (seconds)
07/03/2016	8h07	07h30-13h30	6	**VP5-1**	2	Namaqua sandgrouse	NS428-429	40-40-40m	30
	8h14				2	Namaqua sandgrouse	NS430-431	50-50-50m	30
	8h40				1	Namaqua sandgrouse	NS432	40-40-40m	30
	9h17				2	Namaqua sandgrouse	NS433-434	50-30-10m	45
	9h31				**1**	**Ludwig's bustard**	LB10	60-60-60-60-60-60-60m	95
	9h40				1	Namaqua sandgrouse	NS435	50-50-50m	40
	10h22				1	Namaqua sandgrouse	NS436	Heard only	
	11h08				**1**	**Northern black korhaan**	NBK22	Heard only	
	11h21				1	Namaqua sandgrouse	NS437	50-50m	20

	12h25				**1**	**Northern black korhaan**	NBK23	20-20-20-20-30-30-40-40-50-50-40-25-2m	180
	12h30				**1**	**Northern black korhaan**	NBK24	Heard only	
09/03/2016	7h10	07h05-13h05	6	**VP5-2**	2	Namaqua sandgrouse	NS437-438	1-5-10m	30
	7h20				1	Namaqua sandgrouse	NS439	70-80-80-80-80m	60
	7h43				1	Namaqua sandgrouse	NS440	50-50-50-50-50m	60
	7h49				6	Namaqua sandgrouse	NS441-446	20-20-20-20-20-10-10m	80
	8h15				5	Namaqua sandgrouse	NS447-451	30-25-25m	30
	8h30				**1**	**Northern black korhaan**	NBK25	15-15m	20
	8h47				21	Namaqua sandgrouse	NS452-472	30-30-30-35-35-35-35m	95
	9h31				2	Namaqua sandgrouse	NS473-474	20-20-20-20m	50
	10h00				2	UnID Raptor	UnIDRapt1-2	40-40-40-20-2-2-2m	90
			12	**TOTALS**	**5**	**Collision-prone birds**	**3**	**Species**	
					48				
Passage rate:		**5 birds in**		**12**	**hr**	**0.42**	**birds/hr**	**Ludwig's bustard**	**Northern black korhaan**
		48				4	birds/hr	Namaqua Sandgrouse	