

**BASELINE STUDY:
VERTEBRATE FAUNA AND FLORA ASSOCIATED
WITH THE TWIN HILLS MINING PROJECT:
AMENDMENTS TO INFRASTRUCTURE LAYOUT
2023 – KARIBIB AREA**

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CONTENTS

Vertebrate fauna and flora associated with the Twin Hills Mining Project: Amendments to infrastructure layout 2023 – Karibib area

1	Introduction	1
2	Methods	7
2.1	Literature review	7
3	Results	7
3.1	Reptile Diversity	7
3.2	Amphibian Diversity	14
3.3	Mammal Diversity	17
3.4	Avian Diversity	25
3.5	Tree and Shrub Diversity	37
3.6	Grass Diversity	44
3.7	Other Species	50
3.8	Important Species	52
3.9	Important Areas	55
3.10	Ecosystem services	58
4	Conclusion	62
5	References	63

1 Introduction

A desktop study (i.e., literature review) was conducted between 24 and 26 July 2023 on the vertebrate fauna (e.g., reptiles, amphibians, mammals, and birds) and flora (larger trees and shrubs and grasses) expected to occur in the general Karibib area. The focus was on species and areas potentially affected by amendments to infrastructure layout – See Figure 1. A previous study was conducted by Cunningham (2021a) on the vertebrate fauna and flora associated with the general area and original infrastructure layout and included rapid site assessments during February and May 2021 (i.e., summer and winter observations). This was followed by an alternative infrastructure layout report (Cunningham 2021b). The aim of this current study is to determine the vertebrate fauna and flora potentially affected by the latest amendments to the infrastructure layout (i.e., 2023 final layout) as presented in Figures 1-10.

This literature review was to determine the actual as well as potential vertebrate fauna and flora associated with the general Karibib area and commonly referred to as the Semi-desert Savannah and Transition Zone [Escarpment area] (Giess 1971, Van der Merwe 1983) or the areas referred to by Mendelsohn *et al.* (2002) as the Western Highlands. This semi-desert and savannah transition zone as referred to by Giess (1971) is typified by shrubs (“fodder bushes”) such as *Blepharis pruinosa*, *Leucosphaera bainesii* and *Monechma genistifolia*. Larger woody species such as *Acacia erioloba* are confined to the drainage lines. The Karibib area is characterised by *A. senegal* shrubs while *Cyphostemma currorii* and *C. bainesii* also occur in this region. The trees common in the area are *Commiphora glaucescens*, *C. virgata* and *C. dinteri* as well as *Boscia albitrunca* and *B. foetida*. The grass cover is sparse and consists of the climax grasses *Stipagrostis obtusa* and *S. uniplumis* (Giess 1971).

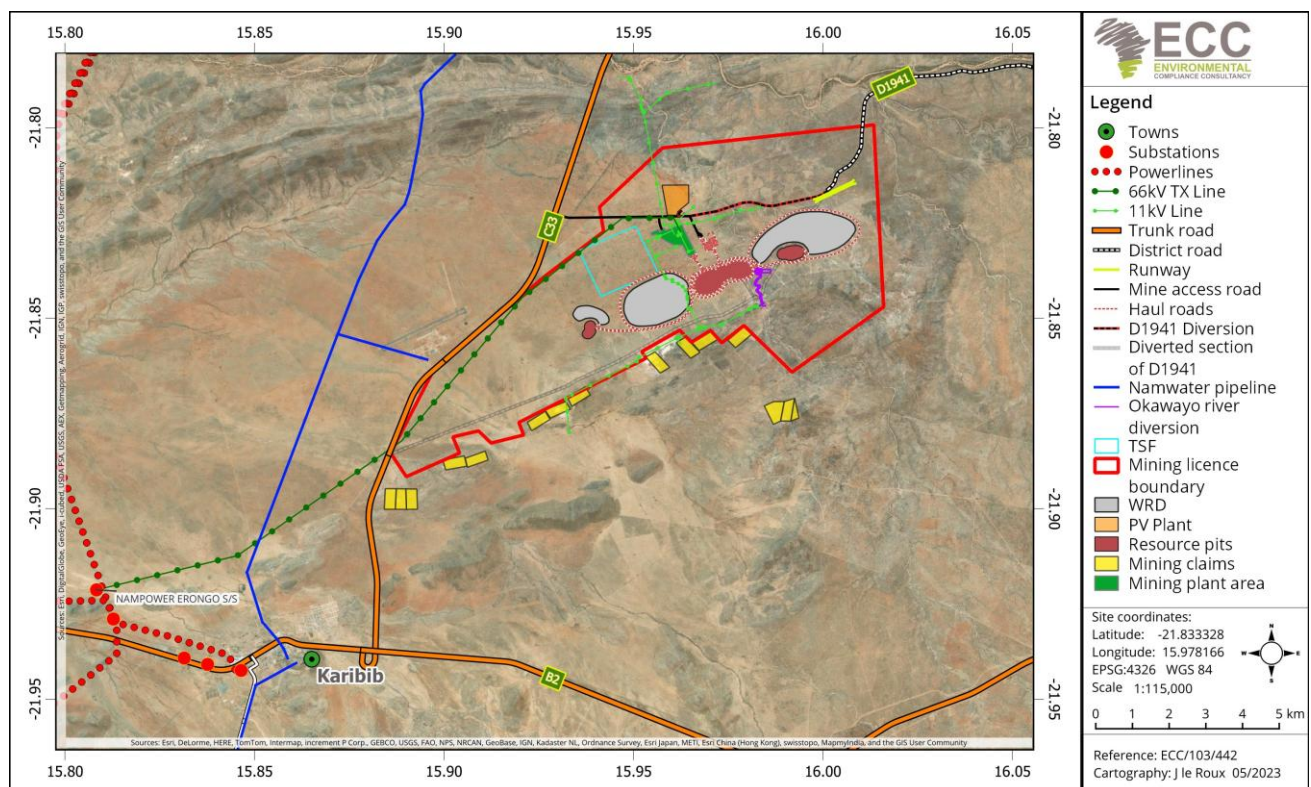


Figure 1. The Twin Hills Project area northeast of Karibib, including the latest amendments to infrastructure layout (WRD; TSF; Solar PV Plant; 66 & 11kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion), in the Erongo Region.



Figure 2. Waste Rock Dump (WRD) sites. White arrow indicates tributary to be avoided.



Figure 3. TSF site.



Figure 4. Solar PV Plant site.



Figure 5. Various 11 kV overhead transmission lines.



Figure 6. Mine access route.



Figure 7. Various mine pits.



Figure 8. Location of runway.



Figure 9. Okawayo River diversion and embankment dam site.



Figure 10. D1941 diversion route.

The Namib Desert biome is well protected with parks in this biome making up 69% of the network compared to only 7% of the Savannah biome, being formally protected and the Mountain Savannah area being wholly under protected (Barnard 1998). Escarpments, mountains, and inselbergs are generally considered as sites of special ecological importance with granite domes (Karibib and Omaruru districts) high in biotic richness and endemism (Curtis and Barnard 1998).

The Karibib area in general is regarded as “moderate” in overall (all terrestrial species) diversity while the overall terrestrial endemism in the area on the other hand is “high” (Mendelsohn *et al.* 2002). The overall diversity and abundance of large herbivorous mammals (big game) is viewed as “moderate” with 3-4 species expected – e.g., gemsbok, kudu, mountain zebra and springbok – while overall diversity and density of large carnivorous mammals (large predators) is viewed as “moderate” with 4 species expected – e.g., leopard, cheetah, spotted and brown hyena (Mendelsohn *et al.* 2002).

The generally Karibib area is viewed as an area of importance for local endemic plant species, especially the Erongo Mountains with between 26-35 endemic species (Mendelsohn *et al.* 2002). The overall plant diversity (all species) in the general Karibib area is estimated at between 150-299 species and the Erongo Mountain area between 400-499 species (Mendelsohn *et al.* 2002). These estimates are limited to “higher” plants as information regarding “lower” plants is sparse. The greatest variants affecting the diversity of plants are habitat and climate, with the highest plant diversity generally associated with high rainfall areas. Pockets of high diversity are found throughout Namibia in “unique” habitats – often transition zones – e.g., mountains, inselbergs, etc. Plant endemism, other than the Erongo Mountains, is viewed as “medium to high” – with between 6-15 endemics expected from the general area (Mendelsohn *et al.* 2002). Furthermore, Mendelsohn *et al.* (2002) views the overall plant production as medium to low in the general Karibib area and high in the Erongo Mountains, the availability of hardwoods as medium and the grazing and browse as average in the general area. Bush thickening (encroachment) is viewed as problematic between Karibib and Omaruru with *Acacia reficiens* (red-bark Acacia) the dominant problem species (Bester 1996, Cunningham 1998, Mendelsohn *et al.* 2002).

The carrying capacity for the general area is 10-20kg/ha (Mendelsohn *et al.* 2002) or 12-15LAU/ha (van der Merwe 1983) and the risk of farming is viewed as relatively high. Sheep farming is the dominant farming activity in the Karibib area, with between 70-80% of stock farmed with being sheep and 20-30% goats and cattle, respectively (van der Merwe 1983). The stock density is estimated at <3sheep/km² (1.5% of total sheep in Namibia) and <1cattle/km² (1.3% of total cattle in Namibia) (van der Merwe 1983). There are numerous existing tourism ventures in the area with the tourism potential viewed as relatively high (Mendelsohn *et al.* 2002).

The area does not fall within a Communal Conservancy with the closest being #Gaingu located in the Spitskoppe area to the west of Karibib, neither within a Freehold (i.e., commercial) Conservancy with Okawi being the closest, east of Karibib (Mendelsohn *et al.* 2002, MEFT/NACSO 2021, See: www.nacso.org.na).

It is estimated that at least 75 species of reptile, 7 amphibian, 88 mammal, 217 birds, 74-101 larger trees and shrubs and up to 80 grass species occur in the general/immediate Karibib area of which a high proportion are endemics (e.g., reptiles – 45.3%).

2 Methods

2.1 Literature review

A comprehensive and intensive literature review (i.e., desktop study) regarding the reptiles, amphibians, mammals, birds, larger trees, and shrubs (>1m in height) and grasses that could potentially occur in the general Karibib area (including the proposed alternative infrastructure layout areas) was conducted using as many references as manageable.

Previous studies conducted by by Cunningham (2021a, b), including fieldwork and the original and alternative infrastructure layout, as well as Google Earth, was used to assess the proposed amendments to the infrastructure layout.

A list of the references consulted can be viewed in the Reference section (Page 60).

3 Results

3.1 Reptile Diversity

Reptile diversity known and/or expected to occur in the Karibib area, including species confirmed from the general area (See Cunningham 2011, 2013, 2017), as well as during the recent fieldwork conducted by Cunningham (2021), is presented in Table 1.

Approximately 261 species of reptiles are known or expected to occur in Namibia, thus supporting approximately 30% of the continent's species diversity (Griffin 1998a). At least 22% or 55 species of Namibian lizards are classified as endemic. The occurrence of reptiles of "conservation concern" includes about 67% of Namibian reptiles (Griffin 1998a). Emergency grazing and large-scale mineral extraction in critical habitats are some of the biggest problems facing reptiles in Namibia (Griffin 1998a). The overall reptile diversity and endemism in the general Karibib area is estimated at between 41-70 species and 21-28 species, respectively (Mendelsohn *et al.* 2002) or between 61-70 and 13-16 species, respectively (Jarvis *et al.* 2022). Griffin (1998a) presents figures of between 21-30 and 7-8 for endemic lizards and snakes, respectively, from the general area, while the closest protected areas, the Skeleton Coast and Namib-Naukluft National Parks, have an estimated 77 and 100 species, respectively. There is currently no data for the !Dorob National Park.

Table 1. Reptile diversity expected (literature study) and confirmed by Cunningham (2021) ($\sqrt{s}$ = summer 2021 and $\sqrt{w}$ = winter 2021) including author's confirmed records (and farm manager sightings - $\sqrt{\#}$) from other studies conducted from the general area (See: Cunningham 2011, 2013, 2017).

Species: Scientific name	Species: Common name	Cunningham (2021)	Navachab Gold (2011)	Helikon Lithium (2013)	Helikon/ Rubicon Lithium (2017)	Namibian conservation and legal status	International status		
							SARDB	IUCN	CITES
TORTOISES AND TERRAPINS									
<i>Stigmochelys pardalis</i>	Leopard Tortoise	√#				Vulnerable; Peripheral; Protected Game		LC	C2
<i>Psammobates oculiferus</i>	Kalahari Tent Tortoise					Vulnerable; Protected Game			C2
<i>Pelomedusa subrufa</i>	Marsh/Helmeted Terrapin	√s		√		Secure			C3
SNAKES									
Blind Snakes									
<i>Rhinotyphlops lalandei</i>	Delalande's Beaked Blind Snake					Insufficiently known; Rare?			
Thread Snakes									
<i>Namibiana (Leptotyphlops) occidentalis</i>	Western Thread Snake					Endemic; Secure	P	LC	
<i>Namibiana (Leptotyphlops) labialis</i>	Damara Thread Snake					Endemic; Secure		LC	
Pythons									
<i>Python anchietae</i>	Dwarf Python					Endemic; Insufficiently known; Protected game		LC	C2
<i>Python natalensis</i>	Southern African Python	√#			√	Vulnerable; Peripheral; Protected Game	V		C2
Burrowing Snakes									
<i>Atractaspis bibronii</i>	Bibron's Burrowing Asp					Secure			
<i>Xenocalamus bicolour bicolor</i>	Bicoloured Quill-snouted Snake					Secure			
Typical Snakes									
<i>Boaedon (Lamprophis) fuliginosus</i>	Brown House Snake								
<i>Lycophidion capense</i>	Cape Wolf Snake								
<i>Lycophidion namibianum</i>	Namibian Wolf Snake					Endemic; Secure		LC	
<i>Mehelya capensis</i>	Cape File Snake					Secure			
<i>Limaformosa (Mehelya) vernayi</i>	Angola File Snake					Insufficiently known; Rare?		LC	
<i>Pseudaspis cana</i>	Mole Snake	√w				Secure			

Vertebrate Fauna & Flora - Cunningham

<i>Pythonodipsas carinata</i>	Western Keeled Snake					Endemic; Secure		LC
<i>Prosymna frontalis</i>	South-western Shovel-snout					Endemic; Secure	P	LC
<i>Hemirhagerrhis viperinus</i>	Viperine Bark Snake					Endemic; Secure		
<i>Dipsina multimaculata</i>	Dwarf Beaked Snake					Endemic; Secure		
<i>Psammophis trigrammus</i>	Western Sand Snake					Endemic; Secure		LC
<i>Psammophis notostictus</i>	Karoo Sand Snake					Secure		
<i>Psammophis leightoni namibensis</i>	Namib Sand Snake					Secure		LC
<i>Psammophis brevirostris leopardinus</i>	Leopard Grass Snake					Endemic; Secure		
<i>Philothamnus semivariegatus</i>	Spotted Bush Snake					Secure		
<i>Dasypeltis scabra</i>	Common/Rhombic Egg Eater					Secure		LC
<i>Telescopus semiannulatus polystriatus</i>	Eastern Tiger Snake					Secure		
<i>Aspidelaps lubricus infuscatus</i>	Coral Snake					Secure		
<i>Aspidelaps scutatus scutatus</i>	Shield-nose Snake					Secure		
<i>Naja nivea</i>	Cape Cobra					Secure		
<i>Naja nigricincta</i>	Black-necked Spitting Cobra	√#				Endemic; Secure		
<i>Bitis arietans</i>	Puff Adder	√#				Secure		
<i>Bitis caudalis</i>	Horned Adder	√#				Secure		
WORM LIZARDS								
<i>Zygaspis quadrifrons</i>	Kalahari Round-headed Worm Lizard					Secure		
LIZARDS								
Skinks								
<i>Typhlosaurus braini</i>	Brain's Blind Legless Skink					Endemic; Secure		LC
<i>Typhlacontias brevipes</i>	FitzSimon's Burrowing Skink					Endemic; Secure		LC
<i>Trachylepis acutilabris</i>	Wedge-snouted Skink	√S,W	√		√	Secure		LC
<i>Trachylepis capensis</i>	Cape Skink					Secure		
<i>Trachylepis hoeschi</i>	Hoesch's Skink					Endemic; Secure		LC
<i>Trachylepis occidentalis</i>	Western Three-striped Skink					Secure		
<i>Trachylepis spilogaster</i>	Kalahari Tree Skink	√S,W				Endemic; Secure		
<i>Trachylepis striata wahlbergi</i>	Striped Skink	√S				Secure		
<i>Trachylepis sulcata</i>	Western Rock Skink		√		√	Secure		
<i>Trachylepis variegata variegata</i>	Variegated Skink	√S,W	√			Secure		
Old World Lizards								
<i>Heliobolus lugubris</i>	Bushveld Lizard	√W				Secure		
<i>Meroles suborbitalis</i>	Spotted Desert Lizard		√			Secure		LC
<i>Pedioplanis breviceps</i>	Short-headed Sand Lizard					Endemic; Secure		LC
<i>Pedioplanis namaquensis</i>	Namaqua Sand Lizard	√S,W	√		√	Secure		

Vertebrate Fauna & Flora - Cunningham

<i>Pedioplanis undata</i>	Western Sand Lizard	√ ^{S,W}	√		√	Endemic; Secure	LC	
<i>Pedioplanis inornata</i>	Plain Sand Lizard	√ ^{S,W}		√		Endemic; Secure	LC	
Plated Lizards								
<i>Cordylosaurus subtessellatus</i>	Dwarf Plated Lizard					Endemic; Secure	LC	
<i>Matabosaurus maltzahani</i> (<i>Gerrhosaurus validus</i>)	Giant Plated Lizard		√			Secure	LC	
Girdled Lizards								
<i>Karusasaurus (Cordylus) jordani</i>	Jordan's Girdled Lizard					Endemic; Secure	LC	C2
Monitors								
<i>Varanus albigularis</i>	Rock or White-throated Monitor	√#	√			Vulnerable; Peripheral; Protected Game	S to V	C2
Agamas								
<i>Agama achuleata</i>	Ground Agama	√ ^W	√	√		Secure		
<i>Agama anchietae</i>	Anchietae's Agama	√ ^S		√		Secure	LC	
<i>Agama planiceps</i>	Namibian Rock Agama	√ ^S	√	√	√	Endemic; Secure	LC	
Chameleons								
<i>Chamaeleo namaquensis</i>	Namaqua Chameleon	√#				Secure	LC	C2
Geckos								
<i>Afroedura africana</i>	African Flat Gecko					Endemic; Insufficiently known; Rare	LC	
<i>Chondrodactylus angulifer</i>	Giant Ground Gecko					Endemic; Secure	LC	
<i>Lygodactylus bradfieldi</i>	Bradfield's Dwarf Gecko	√ ^{S,W}				Endemic; Secure		
<i>Narudasia festiva</i>	Festive Gecko					Endemic; Secure	LC	
<i>Pachydactylus bicolour</i>	Velvety Thick-toed Gecko					Endemic; Secure		
<i>Pachydactylus capensis</i>	Cape Thick-toed Gecko					Endemic; Secure		
<i>Pachydactylus fasciatus</i>	Banded Thick-toed Gecko		√			Endemic; Secure	LC	
<i>Pachydactylus kochii</i>	Koch's Thick-toed Gecko					Endemic; Secure	LC	
<i>Pachydactylus turneri</i>	Turner's Thick-toed Gecko		√			Secure		
<i>Pachydactylus punctatus</i>	Speckled Thick-toed Gecko	√ ^S				Secure		
<i>Pachydactylus rugosus</i>	Rough Thick-toed Gecko					Endemic; Secure	LC	
<i>Pachydactylus scherzi</i>	Namib Variable Gecko					Endemic; Secure	LC	
<i>Pachydactylus weberi</i>	Weber's Thick-toed Gecko					Secure	LC	
<i>Ptenopus garrulus</i>	Common Barking Gecko					Secure	LC	
<i>Rhoptropus afer</i>	Common Namib Day Gecko					Endemic; Secure	LC	
<i>Rhoptropus boultoni</i>	Boulton's Namib Day Gecko		√		√	Endemic; Secure	LC	
<i>Rhoptropus bradfieldi</i>	Bradfield's Namib Day Gecko					Endemic; Secure	LC	

Namibian conservation and legal status according to the Nature Conservation Ordinance No 4 of 1975

Endemic – includes Southern African Status (Branch 1998)

SARDB (2004): S to V – Safe to Vulnerable; V – Vulnerable; P – Peripheral

IUCN (2022): LC – Least Concern [All other species not yet assessed]

CITES: CITES Appendix 2/3 species

Source for literature review: Alexander and Marais (2007), Bonin *et al.* (2006), Branch (1998), Branch (2008), Boycott and Bourquin (2000), Broadley (1983), Buys and Buys (1983), Cunningham (2006), Cunningham (2011), Cunningham (2013), Cunningham (2017), Cunningham (2021), Griffin (2003), Hebbard (n.d.), IUCN (2022), Marais (1992), SARDB (2004), Tolley and Burger (2007)

Reptile species observed and/or confirmed from the Navachab Gold Mine area (approximately 40km southwest of the study area) included 1 tortoise, 1 terrapin, 5 snakes, 9 lizards, 1 monitor lizard, 2 agamas and 8 geckos (i.e., 27 species) (Cunningham 2011), while reptiles confirmed from the Helikon/Rubicon Lithium Mine (approximately 30km south of the study area) include 2 skinks, 1 Old World lizard and 2 agamas (i.e., 5 species) (Cunningham 2013) and 1 python, 1 skink, 2 Old World lizards, 1 agama and 1 gecko (i.e., 6 species) (Cunningham (2017).

At least 75 species of reptiles are expected to occur in the Karibib area with 34 species being endemic – i.e., 45.3% endemic. These consist of at least 30 snakes (1 blind snake, 2 thread snake, 2 python, 2 burrowing snakes and 23 typical snakes), 11 of which are endemic (33.3%) to Namibia, 2 tortoises, 1 terrapin, 42 lizards (1 worm lizard, 10 skinks, 6 Old World lizards, 2 plated lizards, 1 girdled lizard, 1 monitor lizard, 3 agamas, 1 chameleon and 17 geckos), 23 (54.8%) of which are endemic to Namibia. Skink's (10 species), Old World lizards (6 species) and gecko's (17 species) are the most numerous lizards expected from the general area. Namibia with approximately 129 species of lizards (Lacertilia) has one of the continents richest lizard fauna (Griffin 1998a). Geckos have the highest occurrence of endemics in the general area, with 13 of the 17 species (76.5%) expected and/or known to occur in the area, being endemic to Namibia.

According to the Namibian legislation 3 species are viewed as rare (*Rhinotyphlops lalandei*, *Limaformosa (Mehelya) vernayi*, *Afroedura africana*), 4 species as vulnerable (*Stigmochelys pardalis*, *Psammobates oculiferus*, *Python natalensis*, *Varanus albigularis*), 5 species as protected game, 4 species insufficiently known and 3 species as peripheral. The IUCN (2022) classifies 37 species as least concern although, not all the reptiles have yet been assessed by the IUCN Red List. The SARDB (2004) classifies 1 species as vulnerable, 1 species as safe to vulnerable and 2 species as peripheral, while CITES lists 7 species under Appendix 2 and 1 species under Appendix 3. Since reptiles are an understudied group of animals, especially in Namibia, it is expected that more species may be in the general area than presented above.

Cunningham (2021) confirmed 20 species during summer and winter observations from the area, while a total of at least 28 species are confirmed from the general area if one includes species identified by Cunningham (2011, 2013 and 2017) – See Table 1.

The most important species expected to occur in the general area (See Table 1) are viewed as the tortoises *Stigmochelys pardalis* and *Psammobates oculiferus*; pythons – *P. anchietae* and *P. natalensis*; Namibian wolf snake (*Lycophidion namibianum*); monitor (*Varanus albigularis*) and some of the endemic and little-known gecko species – e.g., *Pachydactylus* species. Tortoises, snakes, and monitor lizards are routinely killed for food or as perceived threats. Other important species are those viewed as “rare” – i.e., *Rhinotyphlops lalandei*, *Mehelya vernayi* and *Afroedura africana* – although very little is known about these species.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction and operation, are expected to be detrimental to reptiles associated with the various affected areas/habitats.

WRD sites

The impact of the WRD sites is not expected to be detrimental to reptiles – i.e., would not impede their movement, etc. However, the artificial habitat is expected to attract certain reptiles to the area (e.g., certain gecko species, snakes, agamas, etc.). Furthermore, the northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is not expected to be detrimental to reptiles – i.e., would not impede their movement, etc. However, the artificial habitat is expected to attract certain reptiles to the area (e.g., certain snakes, etc.) (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction by the proposed Solar PV Plant, the impact of plant infrastructure is not expected to be detrimental to any of the unique reptiles – i.e., small footprint, not a pristine area, would not impede their movement, etc. (See Figure 4).

Transmission lines (11 kV)

The impact of heavy machinery during construction, and especially the excavation of holes to plant poles for the proposed transmission line are expected to be detrimental to reptiles associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

However, open holes could act as pitfall traps and should not be left open overnight and/or covered.

The impact of aboveground transmission line infrastructure is not expected to be detrimental to reptiles – i.e., would not impede their movement, etc. (See Figure 5).

Access route

The impact of an access route is not expected to be detrimental to most reptiles as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g. 40km/h), no off-road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure for important slow moving, especially nocturnal reptiles.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route. However, a tarmac access route would attract certain reptiles (e.g., nocturnal species) to it for basking due to its retention and slow release of heat, resulting in potentially more mortalities. This could be negated by limiting nocturnal vehicle activity along this route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to reptiles associated with the affected area/habitat and/or could act as pitfall traps. However, most reptiles known/expected to occur in the area are small lacertid and gecko species which would probably use the pit(s) as part of their habitat and/or rather be attracted to the rocky waste dumps as more suitable habitat.

The impacts of the mining activities are expected to be detrimental to reptiles associated with the affected area/habitat, especially slow moving and/or sedentary species. All vehicle activities (including long hauling) should abide by the speed limits to avoid road mortalities. However, the overall low densities of all reptile species in the mining area would negate the problem (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to reptiles associated with the affected area/habitat. This would affect a relatively small area over a short/limited period (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to reptiles associated with the affected area/habitat.

Species using the riparian vegetation habitat and/or the river system as a thoroughfare would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently reptiles associated with this habitat (e.g., snakes, dwarf gecko, etc.) (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to reptiles associated with the affected area/habitat. This would affect a relatively small area over a short/limited period (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities and none of the unique reptiles are expected to be exclusively associated with this area.

3.2 Amphibian Diversity

Amphibian diversity known and/or expected to occur in the Karibib area, including species confirmed from the general area (See Cunningham 2011, 2013, 2017) as well as during the recent fieldwork conducted by Cunningham (2021), is presented in Table 2.

Amphibians are declining throughout the world due to various factors of which much has been ascribed to habitat destruction. Basic species lists for various habitats are not always available with Namibia being no exception in this regard while the basic ecology of most species is also unknown. Approximately 4,000 species of amphibians are known worldwide with just over 200 species known from southern Africa and at least 57 species expected to occur in Namibia. Griffin (1998b) puts this figure at 50 recorded species and a final species richness of approximately 65 species, 6 of which are endemic to Namibia. This “low” number of amphibians from Namibia is not only because of the generally marginal desert habitat, but also due to Namibia being under studied and under collected. Most amphibians require water to breed and are therefore associated with the permanent water bodies, mainly in northeast Namibia.

According to Mendelsohn *et al.* (2002), the overall frog diversity in the general Karibib area is estimated at between 4-7 species or 5-8 species, of which 3 species are endemic (Jarvis *et al.* 2022). Griffin (1998b) puts the species richness in the general area at 10 species, while the closest protected areas, the Skeleton Coast and Namib-Naukluft National Parks, have an estimated 10 and 9 species, respectively. There is currently no data for the !Dorob National Park.

Amphibian species observed and/or confirmed from the Navachab Gold Mine area (approximately 40km southwest of the study area) included 1 toad and 1 rubber frog (Cunningham 2011), while no amphibians were confirmed from the Helikon/Rubicon Lithium Mine (approximately 30km south of the study area) area (Cunningham 2013, 2017).

At least 7 species of amphibians are expected to occur in suitable habitat in the Karibib area. The area is under represented, with 2 toads, and 1 species each for rubber, puddle, bullfrog, sand, and platanna known and/or expected (i.e., potentially could be found in the area) to occur in the area. Of these, 2 species are endemic (*Poyntonophrynus (Bufo) hoeschi* and *Phrynomantis annectens*) (Griffin 1998b) and 1 species is classified as “near threatened” (*Pyxicephalus adspersus*) (Du Preez and Carruthers 2009) – i.e., high level (42.9%) of amphibians of conservation value from the general area.

Table 2. Amphibian diversity expected (literature study) and confirmed by Cunningham (2021) ($\sqrt{s}$ = summer 2021) including author's confirmed records from other studies conducted from the general area (See: Cunningham 2011, 2013, 2017).

Species: Scientific name	Species: Common name	Cunningham (2021)	Navachab Gold (2011)	Helikon Lithium (2013)	Helikon/Rubicon Lithium (2017)	Namibian conservation and legal status	International Status: IUCN
Toads							
<i>Amietophrynus poweri</i>	Western Olive Toad						LC
<i>Poyntonophrynus hoeschi</i>	Hoesch's Pygmy Toad		√			Endemic	LC
Rubber Frog							
<i>Phrynomantis annectens</i>	Marbled Rubber Frog	$\sqrt{s}$	√			Endemic	LC
Puddle Frog							
<i>Phrynobatrachus mababiensis</i>	Dwarf Puddle Frog						LC
Bullfrogs							
<i>Pyxicephalus adspersus</i>	Giant Bullfrog					Near threatened	LC
Sand Frogs							
<i>Tomopterna tandyi</i>	Tandy's Sand Frog						LC
Platannas							
<i>Xenopus laevis</i>	Common Platanna						LC

Endemic – (Griffin 1998b)

Near threatened – (Du Preez and Carruthers 2009)

IUCN (2022): LC – Least Concern

Source for literature review: Carruthers (2001), Channing (2001), Channing and Griffin (1993), Cunningham (2011), Cunningham (2013), Cunningham (2017), Cunningham (2021), Du Preez and Carruthers (2009), IUCN (2022), Passmore and Carruthers (1995), SARDB (2004)

Two species – *Poyntonophrynus hoeschi* and *Phrynomantis annectens* – were confirmed from the Navachab Gold Mine area (Cunningham 2011), while no amphibians were confirmed from the Helikon and Rubicon Mining areas south of Karibib (Cunningham 2013, 2017).

Cunningham (2021) confirmed 1 species – *Phrynomantis annectens* (Marbled Rubber Frog) – from the area.

Important species include the 2 endemics – *Poyntonophrynus hoeschi* and *Phrynomantis annectens* and *Pyxicephalus adspersus*, which are classified as “near threatened” in southern Africa (Du Preez and Carruthers 2009). The latter species numbers are decreasing throughout its range in Namibia mainly due to being targeted as food (Griffin pers. com). Although *Phrynomantis annectens* tadpoles observed, confirmed their presence in the area, they occur widespread throughout Namibia and are not exclusively associated with the Twin Hills project area.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction and operation, are expected to be detrimental to amphibians associated with the various affected areas/habitats.

WRD sites

The impact of the WRD sites is not expected to be detrimental to amphibians – i.e., would not affect their habitat or impede their movement, etc. The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is not expected to be detrimental to amphibians – i.e., would not affect their habitat or impede their movement, etc. (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction by the proposed Solar PV Plant, the impact of plant infrastructure is not expected to be detrimental to any of the unique amphibians – i.e., small footprint, not a pristine area, would not impede their habitat and movement, etc. (See Figure 4).

Transmission lines (11 kV)

The impact of aboveground transmission line infrastructure is not expected to be detrimental to amphibians – i.e., would not affect habitat and impede their movement, etc. (See Figure 5).

Access route

The impact of an access route is not expected to be detrimental to most amphibians as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure for important slow moving, especially nocturnal, amphibians.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route. However, a tarmac access route with culverts and drainage pipes could retain water and serve as artificial

habitat luring amphibians to the road with potentially more mortalities. This could be negated by limiting nocturnal vehicle activity along this route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to amphibians associated with the affected area/habitat and/or could act as pitfall traps. However, most amphibians known/expected to occur in the area would probably use the pit(s) as part of their habitat, especially if water would collect/seep into these areas.

The impacts of the mining activities are expected to be detrimental to amphibians associated with the affected area/habitat, especially slow moving and/or sedentary species. All vehicle activities (including long hauling) should abide by the speed limits to avoid road mortalities. However, the overall low densities of all amphibian species in the mining area would negate the problem (See Figure 7).

Runway

The impact of heavy machinery during construction, are not expected to be detrimental to amphibians associated with the area as suitable habitat is limited in this area. This would affect a relatively small area over a short/limited period (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to amphibians associated with the affected area/habitat.

Species using the riparian vegetation habitat and/or the river system as a thoroughfare would be negatively affected, although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently amphibians associated with this habitat (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to amphibians associated with the affected area/habitat. This would affect a relatively small area over a short/limited period (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities and none of the unique amphibians are expected to be exclusively associated with this area.

3.3 Mammal Diversity

Mammal diversity known and/or expected to occur in the Karibib area, including species confirmed from the general area (See Cunningham 2011, 2013, 2017), as well as during the recent fieldwork conducted by Cunningham (2021), is presented in Table 3.

Namibia is well endowed with mammal diversity with at least 250 species occurring in the country. These include the well known big and hairy as well as a legion of smaller and lesser-known species. Currently 14 mammal species are considered endemic to Namibia, of which 11 species are rodents and small carnivores, of which very little is known. Most endemic mammals are associated with the Namib and escarpment, with 60% of these rock-dwelling (Griffin 1998c). According to Griffin (1998c) the endemic mammal fauna is best characterized by the endemic rodent family *Petromuridae* (Dassie rat) and the rodent genera *Gerbillurus* and *Petromyscus*.

Table 3. Mammal diversity expected (literature study) and confirmed by Cunningham (2021) ($\sqrt{s}$ = summer 2021 and $\sqrt{w}$ = winter 2021) including author's confirmed records (and farm manager sightings - $\sqrt{\#}$) from other studies conducted from the general area (See: Cunningham 2011, 2013, 2017).

Species: Scientific name	Species: Common name	Cunningham (2021)	Navachab Gold (2011)	Helikon Lithium (2013)	Helikon/ Rubicon Lithium (2013)	Namibia Carnivore Red List	Namibian conservation and legal status	International status			
								SARDB	IUCN	CITES	
Elephant Shrews											
<i>Macroscelides proboscideus</i>	Round-eared Elephant-shrew						Endemic; Secure				
<i>Elephantulus rupestris</i>	Western Rock Elephant-shrew						Secure				
<i>Elephantulus intufi</i>	Bushveld Elephant-shrew	√ ^{s,w}	√	√	√		Secure	DD			
Aardvark											
<i>Orycteropus afer</i>	Aardvark	√ ^w	√		√		Secure; Protected Game				
Shrews											
<i>Crocidura fuscomurina</i>	Tiny Musk Shrew						Secure	DD			
<i>Crocidura cyanea</i>	Reddish-grey Musk Shrew						Secure	DD			
Hyrax											
<i>Procavia capensis</i>	Rock Hyrax	√ ^s	√	√	√		Secure; Problem animal				
Bats											
<i>Eidolon helvum</i>	African Straw-coloured Fruit Bat						Secure (Migrant)	NT	NT		
<i>Mops midas</i>	Midas Free-tailed Bat						Secure				
<i>Miniopterus natalensis</i>	Natal Long-fingered Bat						Secure	NT			
<i>Mimetillus thomasi</i>	Thomas's Flat-headed Bat						Not listed				
<i>Sauromys petrophilus</i>	Flat-headed Free-tailed Bat						Secure				
<i>Tadarida aegyptiaca</i>	Egyptian Free-tailed Bat						Secure				
<i>Neoromicia capensis</i>	Cape Serotine Bat						Secure				
<i>Neoromicia zuluensis</i>	Zulu Serotine Bat						Secure				
<i>Nycticeinops schlieffeni</i>	Schlieffen's Twilight Bat						Secure				

Vertebrate Fauna & Flora - Cunningham

<i>Pipistrellus rueppellii</i>	Rüppell's Pipistrelle					Insufficiently known; Peripheral		
<i>Pipistrellus rusticus</i>	Rusty Pipistrelle					Not listed		
<i>Cistugo seabrai</i>	Namibian Wing-gland Bat					Endemic; Rare	V	
<i>Eptesicus hottentotus</i>	Long-tailed Serotine Bat					Secure		
<i>Scotophilus dinganii</i>	African Yellow Bat					Secure		
<i>Nycteris thebaica</i>	Egyptian Slit-faced Bat					Secure		
<i>Rhinolophus fumigatus</i>	Rüppell's Horseshoe Bat					Secure	NT	
<i>Rhinolophus clivosus</i>	Geoffroy's Horseshoe Bat					Secure	NT	
<i>Rhinolophus darlingi</i>	Darling's Horseshoe Bat					Secure	NT	
<i>Rhinolophus denti</i>	Dent's Horseshoe Bat					Secure	NT	
<i>Rhinolophus hildebrandtii</i>	Hildebrandt's Horseshoe Bat					Not listed		
<i>Macronycteris</i> (<i>Hipposideros</i>) <i>commersoni</i>	Commerson's Roundleaf Bat					Secure		NT
<i>Hipposideros caffer</i>	Sundevall's Roundleaf Bat					Secure	DD	
<i>Macronycteris</i> (<i>Hipposideros</i>) <i>gigas</i> *	Giant Leaf-nosed Bat					Not listed		
<i>Macronycteris</i> (<i>Hipposideros</i>) <i>vittatus</i>	Striped Leaf-nosed Bat					Not listed		NT
Hares and Rabbits								
<i>Lepus capensis</i>	Cape Hare	√ ^S	√	√		Secure		
<i>Lepus saxatilis</i>	Scrub Hare					Secure		
<i>Pronolagus randensis</i>	Jameson's Red Rock Rabbit					Secure		
Rodents								
Porcupine								
<i>Hystrix africaeaustralis</i>	Cape Porcupine	√ [#]	√	√	√	Secure		
Rats and Mice								
<i>Petromys typicus</i>	Dassie Rat	√ ^{S,W}	√	√		Endemic; Secure	NT	
<i>Pedetes capensis</i>	Springhare					Secure		
<i>Xerus inauris</i>	South African Ground Squirrel	√ ^W	√			Secure		
<i>Xerus princeps</i>	Damara Ground Squirrel					Endemic	NT	
<i>Graphiurus rupicola/platyops</i>	Western Rock Dormouse					Endemic; Secure	DD	

Vertebrate Fauna & Flora - Cunningham

<i>Graphiurus murinus</i>	Woodland Dormouse						Secure			
<i>Rhodomys pumilio</i>	Four-striped Grass Mouse		√				Secure			
<i>Mus indutus</i>	Desert Pygmy Mouse		√				Secure			
<i>Mastomys natalensis</i>	Natal Multimammate Mouse						Secure			
<i>Mastomys coucha</i>	Southern Multimammate Mouse						Secure			
<i>Thallomys paedulus</i>	Acacia Rat						Secure			
<i>Thallomys nigricauda</i>	Black-tailed Tree Rat						Secure			
<i>Aethomys chrysophilus</i>	Red Veld Rat						Secure			
<i>Micaelamys namaquensis</i>	Namaqua Rock Mouse	√s,w	√				Secure			
<i>Desmodillus auricularis</i>	Cape Short-tailed Gerbil						Secure			
<i>Gerbillurus paeba</i>	Hairy-footed Gerbil						Secure			
<i>Gerbillurus setzeri</i>	Setzer's Hairy-footed Gerbil						Endemic			
<i>Tatera leucogaster</i>	Bushveld Gerbil	√s,w	√			√	Secure	DD		
<i>Saccostomus campestris</i>	Pouched Mouse					√	Secure			
<i>Malacothrix typica</i>	Gerbil Mouse						Secure			
<i>Petromyscus collinus</i>	Pygmy Rock Mouse						Endemic; Secure			
<i>Mus musculus</i>	House Mouse						Invasive alien			
Primates										
<i>Galago moholi</i>	South African Galago						Vulnerable; Protected Game			C2
<i>Papio ursinus</i>	Chacma Baboon	√s,w	√		√		Secure; Problem animal			C2
Hedgehog										
<i>Atelerix frontalis angolae</i>	Southern African Hedgehog		√				Insufficiently Known; Rare; Protected Game	NT; R		
Carnivores										
<i>Proteles cristatus</i>	Aardwolf	√#					Insufficiently known; (Vulnerable?) Peripheral			
<i>Parahyaena (Hyaena) brunnea</i>	Brown Hyena	√#				NT	Insufficiently known; (Vulnerable?) Peripheral	NT	NT	
<i>Crocota crocuta</i>	Spotted Hyena					V	Secure?; Peripheral	NT		
<i>Acinonyx jubatus</i>	Cheetah		√		√	E	Vulnerable; Protected Game	V	V	C1
<i>Panthera pardus</i>	Leopard	√s				V	Secure?; Peripheral; Protected Game		V	C1

Vertebrate Fauna & Flora - Cunningham

<i>Caracal caracal</i>	Caracal					Secure; Problem Animal				C2
<i>Felis silvestris</i>	African Wild Cat	√ ^S	√	√		Vulnerable				C2
<i>Genetta genetta</i>	Small Spotted Genet	√ [#]				Secure				
<i>Suricata suricatta marjoriae</i>	Suricate					Endemic; Secure				
<i>Cynictis penicillata</i>	Yellow Mongoose	√ ^{S,W}	√		√	Secure				
<i>Galerella sanguinea</i>	Slender Mongoose	√ ^S				Secure				
<i>Galerella flavescens</i> (<i>nigrata</i>)	Kaokoland/Black Slender Mongoose					Endemic; Secure				
<i>Otocyon megalotis</i>	Bat-eared Fox	√ [#]				Vulnerable?; Peripheral				
<i>Vulpes chama</i>	Cape Fox					Vulnerable?				
<i>Canis mesomelas</i>	Black-backed Jackal	√ ^{S,W}	√		√	Secure; Problem animal				
<i>Mellivora capensis</i>	Honey Badger/Ratel		√			Secure; Protected Game	NT			
<i>Ictonyx striatus</i>	Striped Polecat					Secure				
Equidae										
<i>Equus zebra hartmannae</i>	Hartmann's Mountain Zebra		√	√		Endemic; Secure; Specially Protected Game	E	V		C2
Suidae										
<i>Phacochoerus africanus</i>	Common Warthog	√ ^{S,W}	√			Secure; Huntable Game				
Antelopes										
<i>Giraffa camelopardalis</i>	Giraffe	√ ^S	√			Vulnerable; Peripheral; Specially Protected Game			V	
<i>Tragelaphus strepsiceros</i>	Greater Kudu	√ ^W ;√ [#]	√	√	√	Secure; Huntable Game				
<i>Oryx gazella</i>	Gemsbok	√ ^S	√			Secure; Huntable game				
<i>Sylvicapra grimmia</i>	Common Duiker	√ ^S	√			Secure				
<i>Antidorcas marsupialis</i>	Springbok	√ ^{S,W}	√			Secure; Huntable game				
<i>Madoqua damarensis</i>	Damara Dik-dik					Insufficiently Known; Protected Game				
<i>Raphicerus campestris</i>	Steenbok	√ ^{S,W}	√	√	√	Secure; Protected Game				
<i>Oreotragus oreotragus</i>	Klipspringer		√	√	√	Secure; Specially Protected Game				

SARDB (2004): R – Rare, E – Endangered, V – Vulnerable, NT – Near Threatened, DD – Data Deficient

IUCN (2022): V – Vulnerable, NT – Near Threatened. All other species not listed are viewed as “Least Concern” by IUCN (2022)

CITES: CITES Appendix 1/2 species

*Monadjem *et al.* (2010)

Namibia Carnivore Red List (NCE, LCMAN, MEFT 2022): E – Endangered; V – Vulnerable; NT – Near Threatened. All other species not listed are viewed as “Least Concern”

Source for literature review: Cunningham (2011), Cunningham (2013), Cunningham (2017), Cunningham (2021), De Graaff (1981), Griffin and Coetzee (2005), Estes (1995), IUCN (2022), Joubert and Mostert (1975), Monadjem *et al.* (2010), NCE, LCMAN, MEFT (2022), SARDB (2004), Skinner and Smithers (1990), Skinner and Chimimba (2005), Stander and Hanssen (2003) and Taylor (2000)

Overall terrestrial diversity and endemism – all species – is classified as “average” and “high” respectively in the general Karibib area (Mendelsohn *et al.* 2002). The overall diversity (5-6 species) and abundance of large herbivorous mammals is “high” in the general area with kudu, mountain zebra and oryx having the highest densities of the larger species (Mendelsohn *et al.* 2002). The overall abundance and diversity of large carnivorous mammals is “average” (4 species) in the general area, with leopard and cheetah having the highest densities of the larger species (Mendelsohn *et al.* 2002). The overall mammal diversity in the general Karibib area is estimated at between 61-75 species, with 5-6 species being endemic to the area (Mendelsohn *et al.* 2002) or 3-4 endemics (Jarvis *et al.* 2022). Griffin (1998c) puts the species richness distribution of endemic mammals between 7-8 species in the general area, while the closest protected areas, the Skeleton Coast and Namib-Naukluft National Parks, at 87 and 80 species, respectively. There is currently no data for the !Dorob National Park.

According to the literature, at least 87 species of mammals are known and/or expected to occur in the general Karibib area, of which 10 species (11.5%) are classified as endemic. The Namibian legislation classifies 2 species as “rare”, 5 species as “vulnerable”, 3 species as “specially protected game”, 9 species as “protected game”, 5 species as “insufficiently known”, 4 species as “hunnable game” and 4 species as “problem animals”. Five species of bat are not listed – i.e., according to Monadjem *et al.* (2010) these bats potentially could occur in the general Karibib area according to a habitat modelling programme, although not yet actually confirmed.

At least 31% (27 species) of the mammalian fauna that occur or are expected to occur in the general Karibib area are represented by rodents, of which 5 species (18.5%) are endemic.

This is followed by bats 27.6% (24 species), of which 1 species is classified as “rare”. Twenty-nine species (33.3%) have IUCN, CITES and SARDB international conservation status (some species have more than one conservation status). The IUCN (2022) classifies 4 species each as vulnerable (cheetah, leopard, Hartmann’s mountain zebra, giraffe) and near threatened (African straw-coloured fruit bat, Commerson’s roundleaf bat, striped leaf-nosed bat, brown hyena). The SARDB (2004) classifies 1 species as rare, 1 species as endangered, 2 species as vulnerable, 12 species as near threatened and 6 species as data deficient, while CITES lists 2 species as Appendix 1 and 5 species as Appendix 2. The Namibia Carnivore Red List classifies 1 species as endangered, 2 species as vulnerable and 1 species as near threatened (NCE, LCMAN, MEFT 2022). The House Mouse (*Mus musculus*) is viewed as an invasive alien species to the area. *Mus musculus* are generally known as casual pests and not viewed as problematic, although they are known carriers of “plague” and can cause economic losses.

Of the 87 species of mammals known and/or expected to occur in the general Karibib area, 9 species (10.3%) are classified as endemic. Rodents (of which 5 species – 18.5% – are endemic) and bats (of which 1 species is classified as rare) are the groups least studied. Species of greatest concern in the general area are those viewed as rare in Namibia (i.e., Namibian wing-gland bat and Southern African hedgehog) and endangered (cheetah), vulnerable (spotted hyena, leopard) and near threatened (brown hyena) by the Namibian Carnivore Red List and species classified as vulnerable (cheetah, leopard, Hartmann’s mountain zebra, giraffe) and near threatened (African straw-coloured fruit bat, Commerson’s roundleaf bat, striped leaf-nosed bat, brown hyena) by the IUCN (2022). Another important and unique species, although not observed, but known to occur in the general area, is the endemic Kaokoland slender or black mongoose (See: Cowley and Cunningham 2004, Warren *et al.* 2009).

Cunningham (2021) confirmed 26 species during summer and winter observations from the area, while a total of at least 34 species are confirmed from the general area if one includes species identified by Cunningham (2011, 2013 and 2017) – See Table 3. Furthermore, small

mammal trapping resulted in 3 species – *Elephantulus intufi*, *Tatera leucogaster* and *Micaelamys namaquensis* – during summer and winter, although the capture success rates varied between 17.8% and 27.8%, respectively (Cunningham 2021). The increased rate of capture from summer to winter is probably due to the small mammals showing a “population explosion” associated with the good rains and abundant grass cover – a common phenomenon.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction and operation, are expected to be detrimental to mammals associated with the various affected areas/habitats.

WRD sites

The impact of the WRD is not expected to be detrimental to mammals – i.e., would not impede their movement, etc. However, the artificial habitat is expected to attract certain mammals to the area (e.g., certain small carnivores and rodents, etc.). The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is not expected to be detrimental to mammals – i.e., would not affect their habitat impede their movement, etc. However, the artificial habitat is expected to attract certain mammals to the area (e.g., certain carnivores, ungulates, etc.) (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction by the proposed Solar PV Plant, the impact of plant infrastructure is not expected to be detrimental to any of the unique mammals – i.e., small footprint, not a pristine area, would not impede their habitat and movement, etc. (See Figure 4).

Transmission lines (11 kV)

The impact of heavy machinery during construction, and especially the excavation of holes to plant poles for the proposed transmission line are expected to be detrimental to mammals associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

However, open holes could act as pitfall traps and should not be left open overnight and/or covered.

The impact of aboveground transmission line infrastructure is not expected to be detrimental to mammals – i.e., would not impede their movement, etc. However, some mammals – e.g., small-spotted genet, mongoose – are attracted to the substations and on-pole-mounted switching gear, probably for foraging and heat, and may cause problems at these structures. This could be mitigated by electrostatic animal and/or squirrel guards on the bushings (Van Rooyen 2003). Other mammals that could be affected by the electrical infrastructure are baboons which often get electrocuted by various types of infrastructure and giraffe. Pole mounted transformers and bushings can be insulated and/or substations could be equipped with electric fencing to prevent baboons entering such areas, while giraffe require a minimum clearance of 5,700mm for 11kV transmission lines (Van Rooyen 2003) (See Figure 5).

Access route

The impact of an access route is not expected to be detrimental to most mammals as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-

road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure for important slow moving, especially nocturnal, mammals.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route. However, a tarmac access route would attract certain mammals (e.g., nocturnal species) to it for basking due to its retention and slow release of heat and foraging (e.g., small carnivores) resulting in potentially more mortalities. This could be negated by limiting nocturnal vehicle activity along this route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to mammals associated with the affected area/habitat and/or could act as pitfall traps. However, most larger mammals known/expected to occur in the area would avoid the active mining areas and/or be deterred by the waste rock dump sites around the pits, while the smaller mammals would probably use the pit(s) as part of their habitat and/or rather be attracted to the rocky waste dumps as more suitable habitat. Filling up of the pits after mining and/or sloping the pits would negate the pitfall problem.

The impacts of the mining activities are expected to be detrimental to mammals associated with the affected area/habitat although larger mammals known/expected to occur in the area would avoid the active mining areas. All vehicle activities (including long hauling) should abide by the speed limits to avoid road mortalities. Furthermore, larger mammals are very adaptable to disturbances, range over vast areas, and are attracted to areas with grazing after localised rainfall events (i.e., mostly avoid disturbed areas) while the overall low densities of all mammal species in the mining area would negate the problem (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to mammals associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Grass, on the runway shoulders, should be maintained and kept short so as not to act as habitat and/or attract various herbivores (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to mammals associated with the affected area/habitat.

Species using the riparian vegetation habitat and/or the river system as a thoroughfare would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently mammals associated with this habitat as well as act as an artificial water body further attracting various species (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to mammals associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Ongoing mining activities adjacent the diversion is expected to limit the presence of most mammals and consequently limit mortalities (roadkill) along this new section of the D1941 (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities and none of the unique mammals are expected to be exclusively associated with this area.

3.4 Avian Diversity

Bird diversity known and/or expected to occur in the Karibib area, including species confirmed from the general area (See Cunningham 2011, 2013, 2017), as well as during the recent fieldwork conducted by Cunningham (2021), is presented in Table 5.

Although Namibia's avifauna is comparatively sparse compared to the high rainfall equatorial areas elsewhere in Africa, approximately 658 species have already been recorded, with a diverse and unique group of arid endemics (Brown *et al.* 1998, Maclean 1985). Fourteen species of birds are endemic or near endemic to Namibia, with most Namibian endemics occurring in the savannas (30%), of which ten species occur in a north-south belt of dry savannah in central Namibia (Brown *et al.* 1998).

Bird diversity and endemism is viewed as "high" in the general Karibib area with 171-200 species, of which 8 species being endemic (Mendelsohn *et al.* 2000) or 10-12 endemics (Jarvis *et al.* 2022). Simmons (1998a) suggests 7-9 endemic species and a "high" ranking for southern African endemics and "average" ranking for red data birds expected from the general area. Although the Karibib area is not classified as an Important Birding Area (IBA) in Namibia (Simmons 1998a), the closest such sites are located to the west at the coast – i.e., Walvis Bay, Sandwich, and Mile 4 Saltworks – while the closest inland IBA's are Brandberg and Naukluft.

According to the literature at least 217 bird species [mainly terrestrial "breeding residents"] occur and/or could occur in the general Karibib area at any time (Hockey *et al.* 2006, Maclean 1985, Tarboton 2001). Twelve of the 14 Namibian endemics are expected to occur in the general area (85.7% of all Namibian endemic species or 5.6% of all the species expected to occur in the area). Eight species are classified as endangered (violet wood-hoopoe, Ludwig's bustard, white-backed vulture, black harrier, tawny eagle, booted eagle, martial eagle, black stork), 2 species as vulnerable (lappet-faced vulture, secretarybird) and 5 species as near threatened (Rüppel's parrot, kori bustard, Verreaux's eagle, peregrine falcon, marabou stork) (Simmons *et al.* 2015). Fifty-seven species have a southern African conservation rating, with 8 species classified as endemic (14% of southern African endemics or 3.7% of all the birds expected) and 49 species classified as near endemic (86% of southern African endemics or 22.7% of all the birds expected) (Hockey *et al.* 2006). The IUCN (2022) classifies 1 species as critically endangered (white-backed vulture), 5 species as endangered (Ludwig's bustard, black harrier, lappet-faced vulture, martial eagle, secretarybird), 1 species as vulnerable (tawny eagle) and 1 species as near threatened (kori bustard).

Cunningham (2021) confirmed 75 species during summer and winter observations from the area, while a total of at least 115 species are confirmed from the general area if one includes species identified by Cunningham (2011, 2013 and 2017) – See Table 4. The most important species confirmed by Cunningham (2021) are Monteiro's hornbill (endemic), Damara hornbill (endemic), kori bustard (NT), white-backed vulture (CE), lappet-faced vulture (E) and secretarybird (V).

The most important bird species from the general area are those classified as endemic to Namibia of which the Damara hornbill and Herero chat are viewed as the most important due to the overall lack of knowledge of these species. Although also viewed as important, Rüppel's korhaan is migratory throughout its range, while the rockrunner inhabits inaccessible terrain and is widespread throughout mountainous areas in Namibia. Other species of concern are those classified as endangered (violet wood-hoopoe, Ludwig's bustard, black harrier, tawny eagle, booted eagle, martial eagle, black stork) and near threatened (Rüppel's parrot, Verreaux's eagle, peregrine falcon, marabou stork) (Simmons *et al.* 2015) and those species classified by the IUCN (2022) as critically endangered (white-backed vulture), endangered (Ludwig's bustard, black harrier, lappet-faced vulture, martial eagle,

secretarybird), vulnerable (tawny eagle) and near threatened (kori bustard). Although white-backed vulture, lappet-faced vulture and secretarybird are not known to breed in the area (Eddie Nederlof *pers.com.*), such nesting sites, should these be established and/or located in future, are viewed as extremely important and should be avoided at all costs.

Table 4. Avian diversity expected (literature study) and confirmed by Cunningham (2021) ($\sqrt{s}$ = summer 2021 and $\sqrt{w}$ = winter 2021) including author's confirmed records (and farm manager sightings - $\sqrt{\#}$) from other studies conducted from the general area (See: Cunningham 2011, 2013, 2017).

Species: Scientific name	Species: Common name	Cunningham (2021)	Navachab Gold (2011)	Helikon Lithium (2013)	Helikon/ Rubicon Lithium (2017)	Namibian conservation and legal status	International status	
							Southern African status	IUCN
<i>Struthio camelus</i>	Common Ostrich		$\sqrt{}$					
<i>Scleroptila levaillantoides</i>	Orange River Francolin							
<i>Pternistis hartlaubi</i>	Hartlaub's Spurfowl					Endemic	Near endemic	
<i>Pternistis adspersus</i>	Red-billed Spurfowl	$\sqrt{s}$	$\sqrt{}$				Near endemic	
<i>Pternistis swainsonii</i>	Swainson's Spurfowl						Near endemic	
<i>Coturnix coturnix</i>	Common Quail	$\sqrt{s,w}$						
<i>Coturnix delegorguei</i>	Harlequin Quail							
<i>Numida meleagris</i>	Helmeted Guineafowl	$\sqrt{s,w}$	$\sqrt{}$	$\sqrt{}$	$\sqrt{}$			
<i>Turnix sylvaticus</i>	Kurrichane Buttonquail							
<i>Indicator minor</i>	Lesser Honeyguide							
<i>Campethera abingoni</i>	Golden-tailed Woodpecker							
<i>Dendropicos fuscescens</i>	Cardinal Woodpecker							
<i>Dendropicos namaquus</i>	Bearded Woodpecker							
<i>Tricholaema leucomelas</i>	Acacia Pied Barbet		$\sqrt{}$		$\sqrt{}$		Near endemic	
<i>Tockus monteiri</i>	Monteiro's Hornbill	$\sqrt{s,w}$	$\sqrt{}$	$\sqrt{}$	$\sqrt{}$	Endemic		
<i>Tockus damarensis</i>	Damara Hornbill	$\sqrt{w}$				Endemic		
<i>Tockus leucomelas</i>	Southern yellow-billed Hornbill	$\sqrt{w}$	$\sqrt{}$		$\sqrt{}$		Near endemic	
<i>Tockus nasutus</i>	African Grey Hornbill	$\sqrt{w}$	$\sqrt{}$				Near endemic	
<i>Upupa africana</i>	African Hoopoe	$\sqrt{s}$	$\sqrt{}$		$\sqrt{}$			
<i>Phoeniculus purpureus</i>	Green Wood-Hoopoe							
<i>Phoeniculus damarensis</i>	Violet Wood-Hoopoe					E; Endemic		
<i>Rhinopomastus cyanomelas</i>	Common Scimitarbill	$\sqrt{s,w}$	$\sqrt{}$	$\sqrt{}$	$\sqrt{}$			
<i>Coracias caudatus</i>	Lilac-breasted Roller	$\sqrt{s}$	$\sqrt{}$					
<i>Coracias naevius</i>	Purple Roller	$\sqrt{s}$	$\sqrt{}$					
<i>Merops hirundineus</i>	Swallow-tailed Bee-eater	$\sqrt{s}$	$\sqrt{}$		$\sqrt{}$			

Vertebrate Fauna & Flora - Cunningham

<i>Merops apiaster</i>	European Bee-eater								
<i>Colius colius</i>	White-backed Mousebird	√ ^S						Endemic	
<i>Urocolius indicus</i>	Red-faced Mousebird		√						
<i>Clamator jacobinus</i>	Jacobin Cuckoo	√ ^S							
<i>Clamator glandarius</i>	Great Spotted Cuckoo								
<i>Cuculus clamosus</i>	Black Cuckoo								
<i>Cuculus gularis</i>	African Cuckoo								
<i>Chrysococcyx klaas</i>	Klaas's Cuckoo								
<i>Chrysococcyz caprius</i>	Diderick Cuckoo		√						
<i>Poicephalus rueppellii</i>	Rüppell's Parrot							NT; Endemic	Near endemic
<i>Agapornis roseicollis</i>	Rosy-faced Lovebird				√	√		Endemic	Near endemic
<i>Cypsiurus parvus</i>	African Palm Swift		√						
<i>Tachymarpis melba</i>	Alpine Swift	√ ^S	√						
<i>Apus bradfieldi</i>	Bradfield's Swift		√						Near endemic
<i>Apus affinis</i>	Little Swift		√						
<i>Apus caffer</i>	White-rumped Swift								
<i>Corythaixoides concolor</i>	Grey Go-away Bird	√ ^{S,W}	√						
<i>Tyto alba</i>	Barn Owl								
<i>Otus senegalensis</i>	African Scops Owl								
<i>Ptilopsis granti</i>	Southern White-faced Scops Owl								
<i>Bubo africanus</i>	Spotted Eagle Owl	√ ^S			√				
<i>Bubo lacteus</i>	Verreaux's Eagle-Owl								
<i>Glaucidium perlatum</i>	Pearl-spotted Owlet								
<i>Caprimulgus pectoralis</i>	Fiery-necked Nightjar								
<i>Caprimulgus tristigma</i>	Freckled Nightjar	√ ^S	√						
<i>Caprimulgus rufigena</i>	Rufous-cheeked Nightjar								
<i>Caprimulgus europaeus</i>	European Nightjar								
<i>Columba livia</i>	Rock Dove								
<i>Columba guinea</i>	Speckled Pigeon		√		√				
<i>Streptopelia capicola</i>	Cape Turtle Dove	√ ^S	√		√		√		
<i>Streptopelia senegalensis</i>	Laughing Dove	√ ^S	√						
<i>Oena capensis</i>	Namaqua Dove	√ ^{S,W}	√				√		
<i>Neotis ludwigii</i>	Ludwig's Bustard		√					E	Near endemic
<i>Ardeotis kori</i>	Kori Bustard	√ ^{S,W}	√					NT	E NT
<i>Lophotis ruficrista</i>	Red-crested Korhaan	√ ^{S,W}	√				√		Near endemic
<i>Afrotis afraoides</i>	Northern Black Korhaan	√ ^{S,W}							Endemic

Vertebrate Fauna & Flora - Cunningham

<i>Eupodotis rueppellii</i>	Rüppell's Korhaan		√			Endemic	Near endemic	
<i>Pterocles namaqua</i>	Namaqua Sandgrouse		√	√	√		Near endemic	
<i>Pterocles bicinctus</i>	Double-banded Sandgrouse	√ ^W			√		Near endemic	
<i>Burhinus capensis</i>	Spotted Thick-knee							
<i>Charadrius tricollaris</i>	Three-banded Plover		√					
<i>Vanellus armatus</i>	Blacksmith Lapwing	√ ^{S,W}						
<i>Vanellus coronatus</i>	Crowned Lapwing	√ ^{S,W}						
<i>Rhinoptilus africanus</i>	Double-banded Courser	√ ^W						
<i>Rhinoptilus chalcopterus</i>	Bronze-winged Courser							
<i>Cursorius rufus</i>	Burchell's Courser	√ ^S					Near endemic	
<i>Cursorius temminckii</i>	Temminck's Courser	√ ^S	√					
<i>Elanus caeruleus</i>	Black-shouldered Kite							
<i>Milvus migrans</i>	Black Kite	√ ^S	√					
<i>Gyps africanus</i>	White-backed Vulture	√ ^W , √ [#]	√			E		CE
<i>Aegypius tracheliotos</i>	Lappet-faced Vulture	√ ^W , √ [#]	√			V		E
<i>Circaetus pectoralis</i>	Black-chested Snake-Eagle	√ ^S	√		√			
<i>Circaetus cinereus</i>	Brown Snake-Eagle							
<i>Melierax canorus</i>	Southern Pale Chanting Goshawk	√ ^{S,W}			√		Near endemic	
<i>Melierax gabar</i>	Gabar Goshawk							
<i>Accipiter badius</i>	Shikra		√					
<i>Accipiter minullus</i>	Little Sparrowhawk							
<i>Accipiter ovampensis</i>	Owambo Sparrowhawk							
<i>Buteo vulpinus</i>	Steppe Buzzard		√					
<i>Buteo augur</i>	Augur Buzzard							
<i>Buteo rufofuscus</i>	Jackal Buzzard							
<i>Aquila nipalensis</i>	Steppe Eagle							
<i>Circus maurus</i>	Black Harrier					E		E
<i>Aquila rapax</i>	Tawny Eagle		√			E		V
<i>Aquila verreauxii</i>	Verreaux's Eagle		√		√	NT		
<i>Aquila spilogaster</i>	African Hawk-Eagle							
<i>Aquila pennatus</i>	Booted Eagle					E		
<i>Polemaetus bellicosus</i>	Martial Eagle					E		E
<i>Sagittarius serpentarius</i>	Secretarybird	√ [#]				V		E
<i>Polihierax semitorquatus</i>	Pygmy Falcon				√			
<i>Falco rupicolus</i>	Rock Kestrel		√	√	√			
<i>Falco rupicoloides</i>	Greater Kestrel							

Vertebrate Fauna & Flora - Cunningham

<i>Falco chicquera</i>	Red-necked Falcon					
<i>Falco biarmicus</i>	Lanner Falcon		√			
<i>Falco peregrinus</i>	Peregrine Falcon				NT	
<i>Egretta garzetta</i>	Little Egret	√ ^W				
<i>Egretta intermedia</i>	Yellow-billed Egret					
<i>Ardea cinerea</i>	Grey Heron					
<i>Ardea melanocephala</i>	Black-headed Heron					
<i>Bubulcus ibis</i>	Cattle Egret					
<i>Scopus umbretta</i>	Hamerkop					
<i>Ciconia nigra</i>	Black Stork				E	
<i>Ciconia abdimii</i>	Abdim's Stork					
<i>Leptoptilos crumeniferus</i>	Marabou Stork				NT	
<i>Dicrurus adsimilis</i>	Fork-tailed Drongo	√ ^{S,W}	√	√		
<i>Terpsiphone viridis</i>	African Paradise-Flycatcher					
<i>Nilaus afer</i>	Brubru					
<i>Dryoscopus cubla</i>	Black-backed Puffback					
<i>Tchagra australis</i>	Brown-crowned Tchagra					
<i>Laniarius atrococcineus</i>	Crimson-breasted Shrike	√ ^{S,W}		√		Near endemic
<i>Telophorus zeylonus</i>	Bokmakierie					Near endemic
<i>Prionops plumatus</i>	White-crested Helmet-Shrike					
<i>Lanioturdus torquatus</i>	White-tailed Shrike	√ ^{S,W}	√	√	Endemic	Near endemic
<i>Batis pririt</i>	Priirit Batis	√ ^W	√	√		Near endemic
<i>Corvus capensis</i>	Cape Crow					
<i>Corvus albus</i>	Pied Crow					
<i>Lanius collurio</i>	Red-backed Shrike		√			
<i>Lanius minor</i>	Lesser Grey Shrike	√ ^S	√			
<i>Lanius collaris</i>	Common Fiscal	√ ^{S,W}	√	√		
<i>Eurocephalus anguitimens</i>	Southern White-crowned Shrike					Near endemic
<i>Anthoscopus minutes</i>	Cape Penduline Tit					Near endemic
<i>Parus carpi</i>	Carp's Tit				Endemic	Near endemic
<i>Parus cinerascens</i>	Ashy Tit			√		Endemic
<i>Riparia paludicola</i>	Brown-throated Martin	√ ^S				
<i>Hirundo rustica</i>	Barn Swallow		√			
<i>Hirundo dimidiata</i>	Pearl-breasted Swallow					
<i>Hirundo cucullata</i>	Greater Striped Swallow					
<i>Hirundo spilodera</i>	South African Cliff-Swallow					

Vertebrate Fauna & Flora - Cunningham

<i>Hirundo fuligula</i>	Rock Martin	√ ^S	√	√	√		
<i>Delichon urbicum</i>	Common House Martin						
<i>Pycnonotus nigricans</i>	African Red-eyed Bulbul	√ ^{S,W}	√	√	√		Near endemic
<i>Achaetps pycnopygius</i>	Rockrunner		√			Endemic	Near endemic
<i>Sylvietta rufescens</i>	Long-billed Crombec	√ ^W	√				
<i>Eremomela icteropygialis</i>	Yellow-bellied Eremomela						
<i>Eremomela gregalis</i>	Karoo Eremomela						
<i>Eremomela usticollis</i>	Burnt-necked Eremomela						
<i>Acrocephalus baeticatus</i>	African Reed Warbler						
<i>Turdoides bicolor</i>	Southern Pied Babbler						Endemic
<i>Parisoma layardi</i>	Layard's Tit-Babbler						Endemic
<i>Parisoma subcaeruleum</i>	Chestnut-vented Tit-Babbler	√ ^{S,W}	√				Near endemic
<i>Zosterops pallidus</i>	Orange River White-eye						
<i>Cisticola subruficapilla</i>	Grey-backed Cisticola						Near endemic
<i>Cisticola jaridulus</i>	Desert Cisticola		√				
<i>Prinia flavicans</i>	Black-chested Prinia	√ ^{S,W}	√	√	√		
<i>Malcorus pectoralis</i>	Rufous-eared Warbler						
<i>Camaroptera brevicaudata</i>	Grey-backed Camaroptera						
<i>Calamonastes fasciolatus</i>	Barren Wren-Warbler						
<i>Mirafra passerina</i>	Monotonous Lark						
<i>Mirafra fasciolata</i>	Eastern Clapper Lark	√ ^S					Near endemic
<i>Mirafra sabota</i>	Sabota Lark	√ ^W	√	√			
<i>Calendulauda africanoides</i>	Fawn-coloured Lark	√ ^S					Near endemic
<i>Pinarocorys nigricans</i>	Dusky Lark						
<i>Ammomanopsis grayi</i>	Gray's Lark					Endemic	
<i>Chersomanes albofasciata</i>	Spike-heeled Lark				√		Near endemic
<i>Certhilauda subcoronata</i>	Karoo Long-billed Lark						Near endemic
<i>Eremopterix leucotis</i>	Chestnut-backed Sparrowlark						
<i>Eremopterix verticalis</i>	Grey-backed Sparrowlark				√		Near endemic
<i>Calandrella cinerea</i>	Red-capped Lark		√				
<i>Alauda starki</i>	Stark's Lark		√				Near endemic
<i>Monticola brevipes</i>	Short-toed Rock Thrush		√				
<i>Psophocichla litsitsirupa</i>	Groundscraper Thrush						
<i>Bradornis inuscatus</i>	Chat Flycatcher	√ ^{S,W}					Near endemic
<i>Melaenornis mariquensis</i>	Marico Flycatcher	√ ^{S,W}	√	√	√		Near endemic
<i>Muscicapa striata</i>	Spotted Flycatcher						

Vertebrate Fauna & Flora - Cunningham

<i>Cercotrichas leucophrys</i>	White-browed Scrub-Robin						
<i>Cercotrichas paena</i>	Kalahari Scrub-Robin	√ ^{S,W}	√		√		
<i>Namibornis herero</i>	Herero Chat					Endemic	Near endemic
<i>Oenanthe monticola</i>	Mountain Wheatear	√ ^W	√	√	√		Near endemic
<i>Oenanthe pileata</i>	Capped Wheatear	√ ^{S,W}	√		√		
<i>Cercomela schlegelii</i>	Karoo Chat						Near endemic
<i>Cercomela tracter</i>	Tracter Chat	√ ^S	√		√		Near endemic
<i>Cercomela familiaris</i>	Familiar Chat	√ ^W	√				
<i>Myrmecocichla formicivora</i>	Ant-eating Chat		√		√		Endemic
<i>Onychognathus nabouroup</i>	Pale-winged Starling	√ ^{S,W}	√	√	√		Near endemic
<i>Lamprotornis nitens</i>	Cape Glossy Starling	√ ^{S,W}	√		√		
<i>Lamprotornis australis</i>	Burchell's Starling						
<i>Cinnyricinclus leucogaster</i>	Violet-backed Starling		√				
<i>Creatophora cinerea</i>	Wattled Starling		√				
<i>Chalcomitra senegalensis</i>	Scarlet-chested Sunbird		√				
<i>Nectarinia fusca</i>	Dusky Sunbird	√ ^S	√	√	√		Near endemic
<i>Cinnyris mariquensis</i>	Marico Sunbird						
<i>Bualornis niger</i>	Red-billed Buffalo-Weaver		√		√		
<i>Sporopipes squamifrons</i>	Scaly-feathered Finch	√ ^W					Near endemic
<i>Plocepasser mahali</i>	White-browed Sparrow-Weaver	√ ^{S,W}	√	√	√		
<i>Philetairus socius</i>	Sociable Weaver	√ ^S					Endemic
<i>Ploceus intermedius</i>	Lesser Masked-Weaver	√ ^W					
<i>Ploceus velatus</i>	Southern Masked-Weaver	√ ^S	√	√	√		
<i>Ploceus rubiginosus</i>	Chestnut Weaver	√ ^{S,W}	√		√		
<i>Quelea quelea</i>	Red-billed Quelea	√ ^W					
<i>Amadina erythrocephala</i>	Red-headed Finch	√ ^W					Near endemic
<i>Estrilda erythronotos</i>	Black-faced Waxbill		√				
<i>Estrilda astrild</i>	Common Waxbill						
<i>Granatina granatina</i>	Violet-eared Waxbill	√ ^{S,W}	√				
<i>Pytilia melba</i>	Green-winged Pytilia						
<i>Vidua paradisaea</i>	Long-tailed Paradise-Whydah						
<i>Vidua regia</i>	Shaft-tailed Whydah		√		√		
<i>Passer domesticus</i>	House Sparrow		√				
<i>Passer motitensis</i>	Great Sparrow	√ ^S					Near endemic
<i>Passer melanurus</i>	Cape Sparrow						Near endemic
<i>Passer griseus</i>	Southern Grey-headed Sparrow						

<i>Motacilla capensis</i>	Cape Wagtail		√				
<i>Anthus cinnamomeus</i>	African Pipit						
<i>Anthus vaalensis</i>	Buffy Pipit						
<i>Anthus similes</i>	Long-billed Pipit						
<i>Serinus alario</i>	Black-headed Canary						Endemic
<i>Crithagra atrogularis</i>	Black-throated Canary						
<i>Serinus flaviventris</i>	Yellow Canary	√ ^{S,W}	√				Near endemic
<i>Serinus albogularis</i>	White-throated Canary	√ ^W	√	√			Near endemic
<i>Emberiza impetuanii</i>	Lark-like Bunting	√ ^{S,W}	√			√	Near endemic
<i>Emberiza tahapisi</i>	Cinnamon-breasted Bunting						
<i>Emberiza capensis</i>	Cape Bunting		√				Near endemic
<i>Emberiza flaviventris</i>	Golden-breasted Bunting						

This table excludes migratory birds (e.g., Petrel, Albatross, Skua, etc.), aquatic species (e.g., ducks, etc.) and species breeding extralimital (e.g., stints, sandpipers, etc.) and rather focuses on birds that are breeding residents or can be found in the area during any time of the year. This would imply that many more birds (e.g., Palearctic migrants) could occur in the area depending on “favourable” environmental conditions.

Namibian status: E – Endangered, V- Vulnerable, NT – Near Threatened (Simmons *et al.* 2015)

Southern African status: Hockey *et al.* (2006)

IUCN (2022): CE – Critically Endangered, E – Endangered, V- Vulnerable, NT – Near Threatened. All other species not listed are viewed as “Least Concern” by IUCN (2022)

Source for literature review: Brown *et al.* (1998), Cunningham (2011), Cunningham (2013), Cunningham (2017), Cunningham (2021), Hockey *et al.* (2006), IUCN (2022), Komen (n.d.), Little and Crowe (2011), Maclean (1985), Peacock (2015), Simmons *et al.* (2015), Tarboton (2001)

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction and operation, are expected to be detrimental to birds, especially species favouring large trees (e.g., various raptors); cavity nesting species (e.g., hornbills, barbets, etc. – also associated with large trees); and ground nesting species associated with the affected area/habitat.

WRD sites

The impact of the WRD is not expected to be detrimental to birds – i.e., would not impede their movement, etc. However, the artificial habitat is expected to attract certain birds to the area (e.g., chats, crows, owls, smaller raptors, etc.). The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is not expected to be detrimental to mammals – i.e., would not affect their habitat, impede their movement, etc. However, the artificial habitat is expected to attract certain birds to the area (e.g., crows, smaller raptors, various aquatic species, etc.) (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction by the proposed Solar PV Plant, the impact of plant infrastructure is not expected to be detrimental to any of the unique birds – i.e., small footprint, not a pristine area, would not impede their habitat and movement, etc.

Other problems such as “reflective surfaces” and “mirror collisions”, etc. are not applicable – i.e., does not pose the same avifaunal impact as CSP (Concentrated Solar Power) (Jenkins et al. 2017, Smit n.d.). However, the collision mortality impacts of birds with PV panels may be underestimated (Jenkins et al. 2017) and ongoing long-term monitoring is viewed as imperative to determine local bird mortalities and associated nesting implications (See Figure 4).

Transmission lines (11kV)

The impact of heavy machinery during the construction, and especially the excavation of holes to plant pole for the proposed transmission line are expected to be detrimental to birds, especially ground nesting species associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

However, open holes could act as pitfall traps for ostrich and should not be left open overnight and/or covered.

None of the unique/important species are exclusively associated with the proposed development area, although the effect of aboveground transmission line infrastructure is expected to be detrimental to certain birds – e.g. “pylon sensitive species”. Existing transmission line infrastructure, include 22kV (e.g., Karibib Air force Base) overhead lines in the general area as well as a proposed NamPower 66kV line from Karibib to support power supply to the mining operations.

Birds expected to be negatively affected (i.e., collision and/or electrocution) by the transmission line developments include:

- Birds flying at pylon height – e.g., bustards, swifts, sandgrouse, ravens, raptors, and aquatic and marine species.
- Birds with nocturnal transients – e.g., Palaearctic migrants and wetland birds (i.e., coastal area).

- *Birds following certain geological and/or landscape features (e.g., rivers; mountain ranges, etc.) whilst foraging and/or migrating – e.g., aquatic/marine species and raptors.*
- *Birds attracted to the area during rainfall events – e.g., bustards – and temporary water sources in ephemeral rivers/drainage lines – e.g., aquatic/marine species.*

Pylon sensitive species

Pylon sensitive bird species (See Scott and Scott n.d.) known/expected to occur in the general area include:

- *Black stork;*
- *Booted eagle;*
- *Kori bustard;*
- *Lappet-faced vulture;*
- *Ludwig's bustard;*
- *Marabou stork;*
- *Martial eagle;*
- *Peregrine falcon;*
- *Tawny eagle;*
- *Verreaux's eagle; and*
- *White-backed vulture.*

[Black-chested snake-eagle also known to be affected by transmission lines in the Husab Mine area (Baufeldt Pers. Com.)]

Other potential transmission line issues related to birds would be species that typically nest on such structures.

Nest induced faulting caused by birds (See Scott and Scott n.d.) includes:

- *Cape crow;*
- *Pied crow;*
- *Sociable weaver;*
- *Red-billed Buffalo-weaver;*
- *Eagles – large; and*
- *Vultures.*

[Dummy poles, placed adjacent to problem areas, could be used to attract nesting birds]

Factors influencing collision risk

The following factors influence the collision risk for birds (See: Van Rooyen 2003):

- *Voltage levels – i.e., correlation between physical size of bird and collision risk;*
- *Body size and flight behaviour – i.e., birds with a heavy body size and small wing surface are more prone to collisions;*
- *Flight height and habitat use – i.e., short distance, low altitude, frequency of overhead structures;*
- *Age (i.e., young birds more prone to collisions);*
- *Resident versus migratory birds (i.e., movement into unfamiliar terrain increases collisions);*
- *Weather (i.e., inclement weather increases collisions);*
- *Time of day (i.e., nocturnal movement increases collisions);*
- *Land use (i.e., cultivated areas attract birds); and*
- *Topography (i.e., mountains/rivers/shorelines act as corridors).*

As many of the “pylon sensitive” bird species occur in the general area, it is recommended that BFD's (Bird Flight Diverters – e.g., coils, flappers, etc.) are installed along the most important portions of the transmission line to minimise/prevent mortalities (See Figures 5 &

11). Covering conductors with LDPE (Low Density Polyethylene) pipe would further minimise risk to a variety of raptors on 11kV lines.



Figure 11. Various 11 kV overhead transmission lines and areas where flight diverters should be installed.

Access route

The impact of an access route is not expected to be detrimental to most birds as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure for important, especially nocturnal, birds.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route. However, a tarmac access route would attract certain birds (e.g., crows, smaller raptors, owls, etc.) to it for foraging purposes resulting in potentially more mortalities. This could be negated by limiting nocturnal vehicle activity along this route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to ostrich associated with the affected area/habitat and/or could act as pitfall traps. However, ostrich known/expected to occur in the area would avoid the active mining areas and/or be deterred by the waste rock dump sites around the pits while the smaller birds would probably use the pit(s) as part of their habitat and/or rather be attracted to the rocky waste dumps as more suitable habitat. Filling up of the pits after mining and/or sloping the pits would negate the pitfall problem.

The impacts of the mining activities are expected to be detrimental to birds associated with the affected area/habitat although larger birds known/expected to occur in the area would avoid the active mining areas. All vehicle activities (including long hauling) should abide by the speed limits to avoid road mortalities. Furthermore, most birds are very adaptable to disturbances, range over vast areas, and are attracted to areas with grazing after localised rainfall events (i.e., mostly avoid disturbed areas). However, raptor breeding trees (especially vulture species) should be avoided, especially during the breeding season, as they might abandon nests when regularly disturbed (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to birds associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Grass, on the runway shoulders, should be maintained and kept short so as not to act as habitat and/or attract various birds (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to avifauna associated with the affected area/habitat.

Species using the riparian vegetation habitat and/or the river system as a thoroughfare would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently birds associated with this habitat. Birds, especially aquatic species, would be attracted to the open surface water in the embankment dam (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to birds associated with the affected area/habitat. This would affect a relatively small area over a short/limited period (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining and farming activities (e.g., marble quarrying) and none of the unique birds are expected to be exclusively associated with this area.

3.5 Tree and Shrub Diversity

It is estimated that at least 74-101 species of larger trees and shrubs (>1m) (Coats Palgrave 1983 [85 spp.], Curtis and Mannheimer 2005 [101 spp.], Mannheimer and Curtis 2009 [91 spp.], Mannheimer and Curtis 2018 [101 spp.], Van Wyk and Van Wyk 1997 [62 spp. and 12 spp. endemic]) occur in the general Karibib area.

The trees and shrubs known, and/or expected to occur in the general area (derived from Mannheimer and Curtis 2018) is presented in Table 5 below. Species indicated are known from the quarter-degree square distribution principle used and don't necessarily occur throughout the entire area. Some species indicated to possibly occur in the area according to Coats Palgrave (1983) and Van Wyk and Van Wyk (1997) is excluded here.

Eight species of trees and shrubs (7.9%) expected to occur in the general Karibib area are classified as endemic, 4 species as near endemic (4%), 21 species (20.8%) are protected by the Forest Act No 12. of 2001, 5 species (5%) are protected under the Nature Conservation Ordinance No. 4 of 1975 while 6 species (5.9%) are classified as CITES Appendix 2 species. The IUCN (2022) classifies *Aloidendron (Aloe) dichotoma* (quiver tree) as vulnerable. All the trees with some kind of conservation and/or protected status are viewed as important in the general Karibib area. The most important species are viewed as *Aloidendron (Aloe)*

dichotoma, *Commiphora dinteri*, *Commiphora saxicola*, *Commiphora virgata*, *Cyphostemma bainesii*, *Cyphostemma currorii* and *Erythrina decora* (See Table 5).

Although between 74 and 101 larger species of trees and shrubs are known and/or expected to occur in the general area only 28, 36 and 25 species were identified in the following habitats – plains, hills and rivers – throughout the proposed development area, respectively (although not included in Table 5, 4 more species – i.e. *Kleinia longiflora*, *Leucosphaera bainesii*, *Monechma gentisifolium* and *Petalidium* spp. were observed in the plain areas and 3 more species – i.e. *Leucosphaera bainesii*, *Monechma gentisifolium* and *Petalidium* spp. were observed in the hill areas). A total of 58 species of larger trees and shrubs were identified throughout the area (See Table 5 including the above 4 mentioned shrub species) (Cunningham 2021).

A total of at least 62 species are confirmed from the general area if one includes species identified by Cunningham (2013, 2017) as well as the 4 shrub species indicated above – See Table 5.

The most important protected species (including endemic/near endemic, etc.) are viewed as:

Plains

- *Acacia erioloba*, *Albizia anthelmintica*, *Aloe litoralis*, *Boscia albitrunca*, *Cyphostemma currorii*, *Faidherbia albida* and *Ziziphus mucronata*

Hills

- *Acacia erioloba*, *Albizia anthelmintica*, *Boscia albitrunca*, *Commiphora glaucescens*, *Commiphora virgata*, *Cyphostemma currorii*, *Euphorbia guerichiana*, *Euphorbia avasmontana*, *Ficus cordata*, *Maerua schinzii*, *Moringa ovalifolia* and *Sterculia africana*

Rivers

- *Acacia erioloba*, *Albizia anthelmintica*, *Boscia albitrunca*, *Combretum imberbe*, *Euclea pseudebenus*, *Faidherbia albida* and *Ziziphus mucronata*

Table 5. Tree and shrub diversity expected (literature study) and confirmed (Cunningham 2021) including author's confirmed records from other studies conducted from the general area (See: Cunningham 2013, 2017). The trees and shrubs known, and/or expected to occur in the general area (derived from Mannheimer and Curtis 2018).

Species Expected: Scientific name	Cunningham (2021)			Helikon Lithium (2013)	Helikon/ Rubicon Lithium (2017)	Namibian conservation and legal status	Internation conservation status – IUCN	
	Plains	Hills	Rivers					
<i>Acacia erioloba</i>	√	√	√	√	√	Protected (F#)		
<i>Acacia erubescens</i>	√	√			√			
<i>Acacia hebeclada</i>				√	√			
<i>Acacia hereroensis</i>								
<i>Acacia karroo</i>					√			
<i>Acacia mellifera</i>	√	√	√	√	√			
<i>Acacia reficiens</i>	√	√	√	√	√			
<i>Acacia senegal</i>					√			
<i>Acacia tortilis</i>	√		√	√	√	End		
<i>Adenia pechuelii</i>								
<i>Adenolobus garipensis</i>		√			√			
<i>Adenolobus pechuelii</i>								
<i>Albizia anthelmintica</i>	√	√	√	√	√	Protected (F#)	V	
<i>Aloidendron (Aloe) dichotoma</i>						Protected (F#), NC, C2, N-end		
<i>Aloe litoralis</i>	√				√	NC, C2		
<i>Azima tetracantha</i>		√	√	√	√			
<i>Boscia albitrunca</i>	√	√	√		√	Protected (F#)		
<i>Boscia foetida</i>	√	√	√	√	√			
<i>Cadaba aphylla</i>								
<i>Caesalpinia rubra</i>								
<i>Catophractes alexandri</i>	√	√		√	√			
<i>Combretum apiculatum</i>		√			√			
<i>Combretum hereroense</i>			√					
<i>Combretum imberbe</i>								
<i>Commiphora africana</i>	√					Protected (F#)		
<i>Commiphora dinteri</i>						Protected (F#), End		
<i>Commiphora glandulosa</i>		√			√	N-end		
<i>Commiphora glaucescens</i>		√			√			

Vertebrate Fauna & Flora - Cunningham

<i>Commiphora pyracanthoides</i>						
<i>Commiphora saxicola</i>						Protected (F#), End
<i>Commiphora tenuipetiolata</i>		√			√	
<i>Commiphora virgata</i>		√				Protected (F#), End
<i>Cordia sinensis</i>						
<i>Croton gratissimus</i>		√				
<i>Cyphostemma bainesii</i>						Protected (F#), End, NC
<i>Cyphostemma currorii</i>	√	√				Protected (F#), NC
<i>Dichrostachys cinerea</i>	√	√	√	√	√	
<i>Diospyros lycioides</i>			√		√	
<i>Dombeya rotundifolia</i>		√			√	
<i>Ehretia alba</i>			√		√	
<i>Erythrina decora</i>						Protected (F#), End
<i>Elephantorrhiza suffruticosa</i>		√			√	
<i>Euclea pseudebenus</i>			√	√	√	Protected (F#)
<i>Euclea undulata</i>					√	
<i>Euphorbia avasmontana</i>		√				C2
<i>Euphorbia damarana</i>						End, C2
<i>Euphorbia guerichiana</i>		√			√	C2
<i>Euphorbia virosa</i>						C2
<i>Faidherbia albida</i>	√		√	√	√	Protected (F#)
<i>Flueggea virosa</i>		√				
<i>Ficus cordata</i>		√			√	Protected (F#)
<i>Ficus ilicina</i>						
<i>Ficus sycomorus</i>						Protected (F#)
<i>Gossypium anomalum</i>						
<i>Gossypium triphyllum</i>						
<i>Grewia avellana</i>						
<i>Grewia bicolor</i>	√				√	
<i>Grewia flava</i>	√	√	√	√	√	
<i>Grewia flavescens</i>		√	√		√	
<i>Grewia tenax</i>						
<i>Grewia villosa</i>		√	√			
<i>Gymnosporia senegalensis</i>		√	√			
<i>Ipomoea adenioides</i>	√					
<i>Laggera decurrens</i>	√					
<i>Lycium bosciifolium</i>	√	√	√		√	
<i>Lycium cinereum</i>						
<i>Lycium eenii</i>	√		√	√	√	

Vertebrate Fauna & Flora - Cunningham

<i>Maerua juncea</i>							
<i>Maerua parvifolia</i>							
<i>Maerua schinzii</i>		√			√		Protected (F#)
<i>Manuleopsis dinteri</i>							End
<i>Montinia caryophyllacea</i>	√				√		
<i>Moringa ovalifolia</i>		√					Protected (F#), NC, N-end
<i>Mundulea sericea</i>		√			√		
<i>Obetia carruthersiana</i>							N-end
<i>Olea europaea</i>							
<i>Ozoroa crassinervia</i>							
<i>Parkinsonia africana</i>	√			√	√		
<i>Pechuel-Loeschea leubnitziae</i>	√		√		√		
<i>Phaeoptilum spinosum</i>	√						
<i>Rothea myricoides</i>							
<i>Rhigozum trichotomum</i>	√				√		
<i>Salsola</i> spp.							
<i>Salvadora persica</i>			√				
<i>Searsia ciliata</i>							
<i>Searsia lancea</i>							Protected (F#)
<i>Searsia marlothii</i>		√	√		√		
<i>Searsia pyroides</i>							
<i>Steganotaenia araliacea</i>							
<i>Sterculia africana</i>		√			√		Protected (F#)
<i>Strophanthus amboensis</i>							
<i>Tamarix usneoides</i>							Protected (F#)
<i>Tarchonanthus camphoratus</i>							
<i>Tetradenia riparia</i>							
<i>Tinnea rhodesiana</i>							
<i>Terminalia prunioides</i>	√	√					
<i>Vangueria cyanescens</i>							
<i>Vangueria infausta</i>							
<i>Vernonia cinerascens</i>							
<i>Ximenia americana</i>	√	√	√	√	√		
<i>Ziziphus mucronata</i>	√		√	√	√		Protected (F#)

Endemic and Near-endemic – (Mannheimer and Curtis 2018)

F# – Forest Act No. 12 of 2001

NC – Nature Conservation Ordinance No. 4 of 1975

C2 – CITES Appendix 2 species

IUCN (2022): V – Vulnerable. All other species not listed are viewed as “Least Concern” or not yet been assessed by the IUCN Red List.

Source for literature review: Coats Palgrave (1983), Cunningham (2013), Cunningham (2017), Cunningham (2021), Curtis and Mannheimer (2005), IUCN (2022), Loots (2005), Mannheimer and Curtis (2009), Mannheimer and Curtis (2018), Rothmann (2004), Steyn (2003), Van Wyk and Van Wyk (1997)

According to Cunningham (2021) tree/shrub densities vary between 10.8 ± 0.69 (SE) and 16.2 ± 0.91 (SE), which can be converted to 1,080 and 1,620 trees/shrubs per hectare indicating that the area is relatively open, although there are patches of dense *Acacia erubescens* and *A. reficiens* in places, indicating the first signs of bush thickening, and should be monitored (Bester 1996, Cunningham 1998).

The protected and/or unique species identified by Cunningham (2021) throughout the proposed Twin Hills mining development areas occur widespread throughout Namibia and not limited to the Twin Hills project area. However, unique habitats such as ephemeral drainage lines have larger specimens which often serve as habitat for a variety of species – e.g., raptor breeding sites, bark, and cavity dwelling species (bats, birds, and reptiles), etc. – and stabilise river banks, while hills have a higher diversity of species, including unique species – e.g., *Commiphora* spp., *Ficus cordata*, *Moringa ovalifolia*, etc. However, many species (e.g., *A. litoralis*, *Cyphostemma currorii*, etc.) are relatively easily to transplant/relocate and could be relocated to other similar habitat should mining activities be necessary in the areas they occur in.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction, are expected to be detrimental to larger tree/shrub species associated with the various affected areas/habitats.

WRD sites

The impact of the waste rock dumps is expected to be detrimental to larger trees/shrubs as this would involve covering the areas with rock and other excavated material. The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is expected to be detrimental to larger trees/shrubs as this would involve clearing and then covering the areas with rock and other excavated material (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction, the impact of the Solar PV Plant infrastructure is not expected to be detrimental to any of the unique larger trees/shrubs, especially if unique habitats such as drainage lines, rocky outcrops, inselbergs, etc. are avoided. Some individual larger trees – e.g., *Acacia erioloba*, *Aloe litoralis*, *Boscia albitrunca*, etc. – may have to be removed (infrastructures) and/or pruned (transmission lines). A permit for the removal of these individual trees would have to be obtained from MEFT prior to development activities (See Figure 4).

Transmission lines (11 kV)

The impact of heavy machinery during construction, and especially the excavation of holes to plant poles for the proposed transmission lines are expected to be detrimental to larger trees/shrubs associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

The impact of aboveground transmission line infrastructure is not expected to be detrimental to larger trees/shrubs unless these grow beneath the transmission line and would have to be pruned and/or removed to gain access under the line and/or pose flashover problems (See Figure 5).

Access route

The impact of an access route is not expected to be detrimental to larger trees/shrubs as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure to minimise dust pollution and/or the destruction of flora during offroad driving.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to larger trees/shrubs as this would involve the excavation and removal of all flora on site.

The impacts of the mining activities are expected to be detrimental to larger trees/shrubs along various roads/tracks and other development areas – i.e., removal/destruction in/along certain areas and/or dust pollution and other contaminants. All vehicle activities (including long hauling) should abide by the speed limits to minimise dust pollution. However, larger trees/shrubs not in the immediate vicinity of proposed development areas will not be adversely affected (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to all flora associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Herbicides should not be used to control grass on runway verges as these could have long lasting and/or widespread implications affecting flora in adjacent areas (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to larger trees/shrubs associated with the affected area/habitat.

*The riparian vegetation habitat would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently large and protected tree species, especially *Acacia erioloba* and *Ziziphus mucronata*, associated with this habitat (See Figure 9).*

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to all flora associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Herbicides should not be used to control tree/shrub regrowth on road verges as these could have long lasting and/or widespread implications affecting flora in adjacent areas (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities and none of the unique larger trees/shrubs are expected to be exclusively associated with this area.

3.6 Grass Diversity

It is estimated that at least 52-72 grasses (Müller 2007 [72 spp.], Van Oudshoorn 2012 [52 spp.]) – approximate total of 80 species – occur in the general Karibib area. The grasses known and/or expected to occur in the general area (¹Müller 2007 and ²Van Oudtshoorn 2012) is presented in Table 6 below.

Of the approximately 80 grasses that are expected in the general area, 1 species is viewed as endemic (*Eragrostis omahekensis*) (Table 6).

Although between 52 and 72 grasses are known and/or expected to occur in the general area only 19, 16 and 12 species were identified in the following habitats – plains, hills, and rivers – throughout the proposed development area during summer and winter (combined), respectively. A total of 30 species of grasses were identified throughout the area (Cunningham 2021). A total of at least 32 species are confirmed from the general area if one includes species identified by Cunningham (2013, 2017) – See Table 6.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction, are expected to be detrimental to grass species associated with the various affected areas/habitats.

WRD sites

The impact of the waste rock dumps is expected to be detrimental to grasses as this would involve covering the areas with rock and other excavated material. The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is expected to be detrimental to grasses as this would involve clearing then covering the areas with rock and other excavated material (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction, the impact of the Solar PV Plant infrastructure is not expected to be detrimental to any of the unique grasses especially if unique habitats such as drainage lines, rocky outcrops, inselbergs, etc. are avoided (See Figure 4).

Transmission lines (11 kV)

The impact of heavy machinery during construction, and especially the excavation of holes to plant pylons for the proposed transmission line are expected to be detrimental to grasses associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

The impact of aboveground transmission line infrastructure is not expected to be detrimental to grasses (See Figure 5).

Access route

The impact of an access route is not expected to be detrimental to grasses as there are numerous existing tracks throughout the general area and the overall footprint is small. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-road driving, limited nocturnal driving, etc.), speed humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure to minimise dust pollution and/or the destruction of flora during offroad driving.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to grasses as this would involve the excavation and removal of all flora on site.

The impacts of the mining activities are expected to be detrimental to grasses along various roads/tracks and other development areas – i.e., removal/destruction in/along certain areas and/or dust pollution and other contaminants. All vehicle activities (including long hauling) should abide by the speed limits to minimise dust pollution. However, grasses not in the immediate vicinity of proposed development areas will not be adversely affected (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to all flora associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Herbicides should not be used to control grass on runway verges as these could have long lasting and/or widespread implications affecting flora in adjacent areas (See Figure 8).

Okawayo River diversion

The impact during construction, are expected to be detrimental to grasses associated with the affected area/habitat.

The riparian vegetation habitat would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently grasses, associated with this habitat (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to all flora associated with the affected area/habitat. This would affect a relatively small area over a short/limited period. Herbicides should not be used to control grass on road verges as these could have long lasting and/or widespread implications affecting flora in adjacent areas (See Figure 10).

The Twin Hills project area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities and none of the unique grasses are expected to be exclusively associated with this area.

Table 6. Grass diversity expected (literature study) and confirmed (Cunningham 2021) ($\sqrt{s}$ = summer 2021 and $\sqrt{w}$ = winter 2021) including author's confirmed records from other studies conducted from the general area (See: Cunningham 2013, 2017). The grasses known, and/or expected to occur in the general area (derived from ¹Müller 2007 and ²Van Oudtshoorn 1999).

Species: Scientific name	Cunningham (2021)			Helikon Lithium (2013)	Helikon/Rubicon Lithium (2013)	Ecological Status *	Grazing Value *
	Plains	Hills	Rivers				
^{1,2} <i>Andropogon chinensis</i>						Increaser 1	Average
² <i>Andropogon eucomus</i>						Increaser 2	Low
¹ <i>Anthephora argentea</i>						Decreaser	High
^{1,2} <i>Anthephora pubescens</i>		$\sqrt{s,w}$			$\sqrt{}$	Decreaser	High
¹ <i>Anthephora schinzii</i>	$\sqrt{s}$	$\sqrt{s}$			$\sqrt{}$	Increaser 2	Low
^{1,2} <i>Aristida adscensionis</i>	$\sqrt{w}$	$\sqrt{w}$	$\sqrt{w}$		$\sqrt{}$	Increaser 2	Low
^{1,2} <i>Aristida congesta</i>	$\sqrt{w}$					Increaser 2	Low
¹ <i>Aristida effusa</i>						Increaser 2	Low
^{1,2} <i>Aristida meridionalis</i>						Increaser 2	Low
¹ <i>Aristida rhiniochloa</i>						Increaser 2	Low
^{1,2} <i>Bachiaria deflexa</i>						Increaser 2	Average
¹ <i>Brachiaria malacodes</i>						?	Low
¹ <i>Brachiaria glomerata</i>						Decreaser	Average
^{1,2} <i>Brachiaria nigropedata</i>						Decreaser	High
^{1,2} <i>Cenchrus ciliaris</i>	$\sqrt{s,w}$	$\sqrt{s}$	$\sqrt{s}$	$\sqrt{}$	$\sqrt{}$	Decreaser	High
^{1,2} <i>Centropodia glauca</i>						Decreaser	High
^{1,2} <i>Chloris virgata</i>		$\sqrt{s}$				Increaser 2	Average
² <i>Cladoraphis spinosa</i>						Increaser 1	Low
^{1,2} <i>Cynodon dactylon</i>						Increaser 2	High
^{1,2} <i>Dactyloctenium aegyptium</i>						Increaser 2	Low
¹ <i>Danthoniopsis ramosa</i>						?	High
^{1,2} <i>Dichanthium annulatum</i>						Decreaser	High
² <i>Diplachne fusca</i>						Decreaser	High
¹ <i>Echinochloa colona</i>						?	Low
² <i>Elionurus muticus</i>						Increaser 2	Low
^{1,2} <i>Enneapogon cenchroides</i>	$\sqrt{w}$	$\sqrt{w}$	$\sqrt{s,w}$	$\sqrt{}$	$\sqrt{}$	Increaser 2	Low
^{1,2} <i>Enneapogon desvauxii</i>	$\sqrt{w}$	$\sqrt{w}$		$\sqrt{}$	$\sqrt{}$	Intermediate	Average
^{1,2} <i>Enneapogon scaber</i>						?	Low

Vertebrate Fauna & Flora - Cunningham

^{1,2} <i>Enneapogon scoparius</i>						Increaser 2	Low
¹ <i>Entoplocamia aristulata</i>	√ ^w				√	Intermediate	Low
^{1,2} <i>Eragrostis annulata</i>						Increaser 2	Low
¹ <i>Eragrostis cylindriflora</i>	√ ^{s,w}		√ ^s	√	√	?	Low
² <i>Eragrostis biflora</i>			√ ^w			Increaser 2	Low
² <i>Eragrostis cilianensis</i>						Increaser 2	Low
^{1,2} <i>Eragrostis echinochloidea</i>	√ ^w				√	Increaser 2	Average
¹ <i>Eragrostis homomalla</i>						?	Low
² <i>Eragrostis lehmanniana</i>						Increaser 2	Average
^{1,2} <i>Eragrostis nindensis</i>	√ ^s	√ ^{s,w}		√	√	Increaser 2	Average
¹ <i>Eragrostis omahekensis</i> [E]						?	Low
¹ <i>Eragrostis porosa</i>	√ ^{s,w}	√ ^w			√	Intermediate	Low
¹ <i>Eragrostis rigidior</i>			√ ^s			Increaser 2	Average
^{1,2} <i>Eragrostis rotifer</i>	√ ^s				√	Intermediate	Low
¹ <i>Eragrostis scopelophila</i>						?	High
^{1,2} <i>Eragrostis superba</i>					√	Increaser 2	Average
^{1,2} <i>Eragrostis trichophora</i>	√ ^w				√	Increaser 2	Average
^{1,2} <i>Eragrostis viscosa</i>						Increaser 2	Low
^{1,2} <i>Fingerhuthia africana</i>		√ ^{s,w}		√		Decreaser	Average
^{1,2} <i>Heteropogon contortus</i>						Increaser 2	Average
^{1,2} <i>Hyparrhenia hirta</i>						Increaser 1	Average
¹ <i>Leptochloa fusca</i>						?	Average
^{1,2} <i>Microchloa caffra</i>						Increaser 2	Low
¹ <i>Monelytrum luederitzianum</i>						?	Average
^{1,2} <i>Melinis repens</i>	√ ^w	√ ^w	√ ^w	√	√	Increaser 2	Low
¹ <i>Odyssea paucinervis</i>						?	Average
^{1,2} <i>Oropetium capense</i>						?	Low
^{1,2} <i>Panicum coloratum</i>						Decreaser	High
^{1,2} <i>Panicum maximum</i>		√ ^w				Decreaser	High
² <i>Panicum repens</i>		√ ^s	√ ^s			Decreaser	High
¹ <i>Pogonarthria fleckii</i>					√	Increaser 2	Low
² <i>Polypogon monspeliensis</i>						?	Average
^{1,2} <i>Schmidtia kalahariensis</i>	√ ^w				√	Increaser 2	Low
^{1,2} <i>Schmidtia pappophoroides</i>						Decreaser	High
¹ <i>Setaria appendiculata</i>						?	Average
^{1,2} <i>Setaria verticillata</i>			√ ^w		√	Increaser 2	Average
¹ <i>Sorghum bicolor</i>						?	Average

Vertebrate Fauna & Flora - Cunningham

^{1,2} <i>Sporobolus festivus</i>		√ ^w				Increaser 2	Low
^{1,2} <i>Stipagrostis ciliata</i>	√ ^s					Decreaser	High
¹ <i>Stipagrostis giessii</i>						?	Average
^{1,2} <i>Stipagrostis hirtigluma</i>						Increaser 2	Low
¹ <i>Stipagrostis hochstetteriana</i>	√ ^{s,w}		√ ^s		√	Decreaser	Average
^{1,2} <i>Stipagrostis namaquensis</i>			√ ^s		√	?	Average
^{1,2} <i>Stipagrostis obtusa</i>						Decreaser	High
^{1,2} <i>Stipagrostis uniplumis</i>	√ ^s	√ ^w	√ ^w	√	√	Increaser 2	Average
^{1,2} <i>Tricholaena monachne</i>						Increaser 2	Average
¹ <i>Triraphis purpurea</i>						?	Low
¹ <i>Triraphis ramosissima</i>		√ ^w		√	√	?	Average
^{1,2} <i>Tragus berteronianus</i>	√ ^s					Increaser 2	Low
¹ <i>Tragus racemosus</i>						Increaser 2	Low
¹ <i>Urochloa brachyura</i>						?	Average
¹ <i>Urochloa panicoides</i>						?	Low

Endemic – (Müller 2007)

? – not classified in literature, but often similar to other species within the genus

Source for literature review: Müller (2007), Van Oudtshoorn (2012)

3.7 Other Species

Other species confirmed by Cunningham (2021) throughout the proposed development area included the following herbs, etc. (Table 7). However, this list is not comprehensive – i.e., many more species are known and/or expected to occur in the area.

The most important species are viewed as the endemic species (*Barleria lanceolata* and *Lantana dinteri*) and near endemic species (*Emilia marlothiana* and *Oxalis purpurascens*) (Mannheimer 2012).

Table 7. Other species – bulbs, herbs, etc. – confirmed in various habitats (P – Plains; H – Hills; R - Rivers) during summer and winter observations throughout the Twin Hills project area (Cunningham 2021).

Species	Habitat		Status
	Summer	Winter	
<i>Abutilon fruticosum</i>	H	R	
<i>Ammocharis coranica</i>	R		
<i>Aptosimum arenarium</i>	P		
<i>Aptosimum lineare</i>	H		
<i>Asparagus</i> spp.	P, H		
<i>Barleria lanceolata</i>	H		End
<i>Barleria lancifolia</i>	H, R	H, R	
<i>Barleria rigida</i>	H		
<i>Blepharis obmitrata</i>	P	R	
<i>Boophone disticha</i>	P		
<i>Citrullus lanatus</i>	P	P	
<i>Cleome elegantissima</i>	H		
<i>Cleome gynandra</i>	P		
<i>Cleome suffruticosa</i>	P, H		
<i>Commelina bendhalensis</i>	H		
<i>Corallocarpus welwitschii</i>	P		
<i>Crotalaria argyraea</i>	P	P	
<i>Cryptolepis decidua</i>	H		
<i>Cucumis meeusei</i>	P		
<i>Cyperus fulgens</i>	R		
<i>Cyperus schinzii</i>	H		
<i>Cyphostemma congestum</i>	P		
<i>Dactyliandra welwitschii</i>		P, R	N-end
<i>Dicoma tomentosa</i>		P	
<i>Dicoma</i> spp.		R	
<i>Dipcadi crispum</i>	P		
<i>Dipcadi glaucum</i>	P		
<i>Emilia marlothiana</i>	H		N-end
<i>Eriospermum rautanenii</i>	P		
<i>Euphorbia glanduligera</i>		P	
<i>Ferraria glutinosa</i>	P		
<i>Geigeria pectidia</i>	P	P	
<i>Gisekia africana</i>	P		

<i>Gossypium anomalum</i>	R	P	
<i>Harpagophytum procumbens</i>	P		
<i>Heliotropium lineare</i>	P		
<i>Hermania modesta</i>		P	
<i>Hermbstaedtia argenteiformis</i>		R	
<i>Hermbstaedtia odorata</i>	P, R	P	
<i>Hibiscus calyphyllus</i>	P		
<i>Hibiscus elliottiae</i>	P, H	P	
<i>Hibiscus palmatus</i>	P		
<i>Ingigophera alternans</i>	P		
<i>Indogophera cryptantha</i>		R	
<i>Indogophera pechuelii</i>		H,R	
<i>Ipomoea obscura</i>	P		
<i>Jamesbrittenia tenella</i>		R	N-end
<i>Jamesbrittenia</i> spp.	H		
<i>Kohautia caespitosa</i>	P		
<i>Lantana dinteri</i>	H		End
<i>Ledebouria undulata</i>	P		
<i>Leonotis ocymifolia</i>		R	
<i>Leucas pechuelii</i>		P,R	
<i>Leucasphaera bainesii</i>	P,H,R	P,H,R	
<i>Limeum aethiopicum</i>	P		
<i>Mollugo cerviana</i>	P		
<i>Momordica humilis</i>	P		
<i>Monechma divaricatum</i>		R	
<i>Monechma genistifolium</i>	P	P	
<i>Myrothamnus flabellifolius</i>	H	H	
<i>Nerine laticoma</i>	P		
<i>Oxalis purpurascens</i>	H		N-end
<i>Pergularia daemia</i>		P,R	
<i>Petalidium</i> spp.	P,H,R	P,H,R	
<i>Phyllanthus maderaspatensis</i>	P	P,R	
<i>Pseudogaltonia clavata</i>	P, R		
<i>Senna italica</i>		P	
<i>Sesamum triphyllum</i>		R	
<i>Sesbania sesban</i>	P	P	
<i>Solanum multiglandulosum</i>	P	R	
<i>Sesamum triphylum</i>	R		
<i>Talinum cafferum</i>	P		
<i>Tapinanthus oleifolius</i>	P		
<i>Tribulocarpus dimorphanthus</i>	P	P	
<i>Tribulus terrestris</i>	P, R, H		

Fewer herbs (including bulbs, etc.) were observed during the winter observations and can be ascribed to most of the herbs, etc. being annuals, with above ground structures having died and withered. More herbs, etc. were observed in rivers during the winter observations as this habitat retains moisture for longer and the riparian vegetation provide shade and protection against herbivores.

Invasive alien species

Invasive alien species confirmed by Cunningham (2021) were associated with and/or spread from various farming activities – e.g., kraal, farmstead, etc. – and include:

- *Cryptostegia grandiflora* (rubber vine)
- *Datura ferox* (thorn apple spp.)
- *Datura innoxia* (thorn apple spp.)
- *Eucalyptus* spp. (Australian gum spp.)
- *Flaveria bidentis* (smelter's bush)
- *Leucaena leucocephala* (giant wattle)
- *Opuntia* spp. (prickly pear spp.)
- *Prosopis* spp. (mesquite spp.)

Some of these above-mentioned species have already started invading the area, especially along the drainage lines, close to the farmstead (e.g., *Opuntia* and *Prosopis* spp.) and should be eradicated where/when encountered. Furthermore, mine related soil disturbances could favour some of the invasive alien species (e.g., *Datura* spp. increase in disturbed areas) and/or increase their range throughout the area.

3.8 Important Species

Reptiles

The high percentage of endemic reptile species (45.3%) associated with the rocky escarpment region of central western Namibia underscores the importance of this area without formal state protection. The most important species expected to occur in the general area (See Table 1) are viewed as the tortoises (*Stigmochelys pardalis* and *Psammobates oculiferus*); pythons (*Python anchietae* and *P. natalensis*); Namibian wolf snake (*Lycophidion namibianum*); monitor lizard (*Varanus albigularis*) and some of the endemic and little-known gecko species – e.g., *Pachydactylus* species. Tortoises, snakes, and monitor lizards are routinely killed for food or as perceived threats. Other important species are those viewed as “rare” – i.e., *Rhinotyphlops lalandei*, *Mehelya vernayi* and *Afroedura africana* – although very little is known about these species.

Amphibians

Of the 7 species of amphibians that potentially could occur in the general area, 2 species are endemic (*Poyntonophrynus hoeschi* and *Phrynomantis annectens*) (Griffin 1998b) and 1 species is classified as “near threatened” (*Pyxicephalus adspersus*) (Du Preez and Carruthers 2009) – i.e., high level (42.9%) of amphibians of conservation value from the general area (See Table 2). Except for these important species and because there is little open permanent surface water in the area, amphibians are not viewed as very important in the general area.

Mammals

Of the 87 species of mammals known and/or expected to occur in the general Karibib area, 10 species (11.5%) are classified as endemic. At least 31% (27 species) of the mammalian fauna that occur or are expected to occur in the general Karibib area are represented by rodents, of which 5 species (18.5%) are endemic. This is followed by bats 27.6% (24 species), of which 1 species is classified as “rare”. These are the mammal group's least studied in Namibia. Species of greatest concern in the general area are those viewed as rare in Namibia – i.e., Namibian wing-gland bat and Southern African hedgehog – and species classified as vulnerable (cheetah, leopard, Hartmann's mountain zebra, giraffe) and near threatened (African straw-coloured fruit bat, Commerson's roundleaf bat, striped leaf-nosed bat, brown hyena) by the IUCN (2022) (See Table 3). Another important and unique species, although not observed, but known to occur in the general area, is the endemic

Kaokoland slender or black mongoose (See: Cowley and Cunningham 2004, Warren *et al.* 2009).

Birds

At least 217 bird species [mainly terrestrial “breeding residents”] occur and/or could occur in the general Karibib area at any time and include 12 of the 14 Namibian endemics (85.7% of all Namibian endemic species or 5.6% of all the species expected to occur in the area). The most important bird species from the general area are those classified as endemic to Namibia, of which the Damara hornbill and Herero chat are viewed as the most important due to the overall lack of knowledge of these species. Although also viewed as important, Rüppels korhaan is migratory throughout its range, while the rockrunner inhabits inaccessible terrain and is widespread throughout mountainous areas in Namibia. Other species of concern are those classified as endangered (violet wood-hoopoe, Ludwig’s bustard, black harrier, tawny eagle, booted eagle, martial eagle, black stork) and near threatened (Rüppel’s parrot, Verreaux’s eagle, peregrine falcon, marabou stork) (Simmons *et al.* 2015) and those species classified by the IUCN (2022) as critically endangered (white-backed vulture), endangered (Ludwig’s bustard, lack harrier, lappet-faced vulture, martial eagle, secretarybird), vulnerable (tawny eagle) and near threatened (kori bustard) (See Table 4). Although white-backed vulture, lappet-faced vulture and secretarybird are not known to breed in the area (Eddie Nederlof *pers.com.*), such nesting sites, should these be established and/or located in future, are viewed as extremely important and should be avoided at all costs.

Flora

Trees/shrubs and Grasses

At least 91 to 101 larger species of trees and shrubs are known and/or expected to occur in the general area of which 8 species (7.9%) expected to occur in the general Karibib area are classified as endemic, 4 species as near endemic (4%), 21 species (20.8%) are protected by the Forest Act No 12. of 2001, 5 species (5%) are protected under the Nature Conservation Ordinance No. 4 of 1975 while 6 species (5.9%) are classified as CITES Appendix 2 species. The IUCN (2022) classifies *Aloidendron (Aloe) dichotoma* (quiver tree) as vulnerable. Although all the trees with some kind of conservation and/or protected status (including endemic/near endemic species) are viewed as important in the general Karibib area, the most important species are viewed as *Aloidendron (Aloe) dichotoma*, *Commiphora dinteri*, *Commiphora saxicola*, *Commiphora virgata*, *Cyphostemma bainesii*, *Cyphostemma currorii* and *Erythrina decora* (See Table 5). The endemic grass – *Eragrostis omahekensis* – is viewed as the most important species potentially occurring in the general area.

Important plant species known and/or expected from the general Karibib area and included in the Red Data Book for Namibia include at least 16 species of which 1 species is listed as rare (*Diclis tenuissima*), 1 species as vulnerable (*Lithops wernerii*) and 1 species as near threatened (*Adenia pechuelii*) (Table 8) (Loots 2005). All the species included in Table 8 are viewed as important.

Table 8. Important species – i.e., Red Data spp. – known to occur in the general Karibib area according to Loots (2004).

Species: Scientific name	Conservation status
<i>Adenia pechuelii</i>	Endemic, NT
<i>Aloe dinteri</i>	Endemic, NC, C2, LC
<i>Aloe namibensis</i>	Endemic, NC, C2, LC
<i>Australluma peschii</i>	Endemic, LC
<i>Chamaegigas intrepidus</i>	Endemic, LC
<i>Crassula capitella</i> subsp. <i>nodulosa</i>	LC
<i>Cyphostemma bainesii</i>	Endemic, LC
<i>Diclis tenuissima</i>	Endemic, Rare

<i>Dombeya rotundifolia</i> var. <i>velutina</i>	Endemic, LC
<i>Euphorbia monteiroi</i> subsp. <i>brandbergensis</i>	Endemic, C2, LC
<i>Lithops gracilidelineata</i> subsp. <i>gracilidelineata</i>	NC, LC
<i>Lithops ruschiorum</i>	Endemic, NC, LC
<i>Lithops wernerii</i>	Endemic, NC, V
<i>Namacodon schinzianum</i>	Endemic, LC
<i>Nicotiana africana</i>	Endemic, LC
<i>Trema orientalis</i>	LC

Endemic (Loots 2005)

NC – Nature Conservation Ordinance No. 4 of 1975

Rare; V – Vulnerable; NT – Near Threatened; LC – Least Concern (Loots 2005)

C2 – CITES Appendix 2 spp.

Other

Aloes

Aloes are protected throughout Namibia with 3 other aloe species not included in Table 5, but which potentially occur in the general area, and viewed as important are *Aloe asperifolia*, *A. hereroensis* and *A. zebrina* (Rothmann 2004).

Commiphora

Many endemic *Commiphora* species are found throughout Namibia with Steyn (2003) indicating that *Commiphora crenato-serrata* (not included in the Table 5) potentially also occurring in the general area. *Commiphora* species have economic potential (i.e., resin properties used in the perfume industry – e.g., *C. wildii*) making them an important species (Nott and Curtis 2006).

Lithops

Lithops species – all protected (See Nature Conservation Ordinance No. 4 of 1975) – are also known to occur in the general area and often difficult to observe, especially during the dry season when their aboveground structures wither. The closest species are currently only known to occur west of Usakos and include *Lithops gracilidelineata* var. *gracilidelineata* and *L. wernerii* (Cole and Cole 2005, Earle and Round n.d.).

Ferns

At least 64 species of ferns, of which 13 species being endemic, occur throughout Namibia. Ferns in the general Karibib area include at least 15 indigenous species (*Actiniopteris radiata*, *Asplenium cordatum*, *Cheilanthes dinteri*, *C. eckloniana*, *C. marlothii*, *C. parviloba*, *Marselia aegyptiaca*, *M. ephippiocarpa*, *M. farinosa*, *M. macrocarpa*, *M. nubica*, *M. unicornis*, *M. vera*, *Ophioglossum polyphyllum* and *Pellaea calomelanos*) (Crouch et al. 2011). The general area is undercollected with more species probably occurring in the general area than presented above.

Lichens

The overall diversity of lichens is poorly known from Namibia, especially the coastal areas and statistics on endemism is even sparser (Craven 1998). More than 100 species are expected to occur in the Namib Desert, with the majority being uniquely related to the coastal fog belt (Wirth 2010). Lichen diversity is related to air humidity and generally decreases inland from the Namibian coast (Schults and Rambold 2007). Off road driving is the biggest threat to these lichens which are often rare and unique to Namibia. To indicate how poorly known lichens are from Namibia, the recent publication by Schultz et al. (2009) indicating that 37 of the 39 lichen species collected during BIOTA surveys in the early/mid 2000's was new to science (i.e., new species), is a case in point. Lichens are known to occur on rocky terrain in the mountainous terrain in the general area.

Other species with commercial potential that could occur in the general Karibib area include *Harpagophytum procumbens* (Devil's claw) – harvested for medicinal purposes and often

over-exploited – *Citrullus lanatus* (Tsamma melon) which potentially has a huge economic benefit and *Ximenia americana* (sour plum) for its oil (Mendelsohn *et al.* 2002, Jarvis *et al.* 2022).

3.9 Important Areas

The most important areas in the Twin Hills project area are:

1. Limestone/marble hills

Rocky areas generally have high biodiversity and consequently viewed as important habitat for all vertebrate fauna and flora in the general Karibib area. Protected species associated with and confirmed from the hills in the Twin Hills project area include unique species such as *Commiphora glaucescens*, *Commiphora virgata*, *Cyphostemma currorii*, *Euphorbia avasmontana*, *Ficus cordata*, *Moringa ovalifolia* and *Sterculia africana* (See Table 5).

2. Ephemeral drainage lines

The various ephemeral drainage lines are important habitat to larger trees, especially *Acacia erioloba*, *Euclea pseudebenus*, *Faidherbia albida* and *Ziziphus mucronata* (See Table 5). The most important drainage line is the Okawayo River bisecting the Twin Hills project area (See Figures 1, 9, 12). It is recommended that the Okawayo River not be channelled into an embankment dam or the pit but rather bisect the adjacent WRD and pit and rejoin the river downstream. This would ensure continued flow with the least impact on the riparian vegetation and downstream ecological processes and associated and/or dependent vertebrate fauna.



Figure 12. Okawayo River diversion and embankment dam site. The white dashed arrow indicates the proposed direction of flow of the Okawayo River rather than damming it into the proposed holding dam.

3. Ephemeral dams and pans

The various ephemeral ground dams, albeit artificial, and pans are important habitat, mainly for amphibians, although the larger trees associated with such features serve as habitat to a variety of vertebrate fauna.

4. Bird flyways

Although very little is known regarding bird flight paths in Namibia, especially species moving/migrating at night, most birds seem to follow the shortest routes between selected habitats – e.g., dams, estuaries, bays, etc. However, unpredictable rainfall events may lure species into areas not normally frequented and storms (e.g., berg winds) may also force birds into areas not regularly visited. Planning for all eventualities is therefore not always possible.

Avifauna is expected to be potentially affected by the 11 kV overhead transmission lines. Although, none of the unique/important bird species are exclusively associated with the proposed development area, the effect of aboveground transmission line infrastructure(s) is expected to be detrimental to certain birds – e.g., “pylon sensitive” species. Species potentially affected by the proposed overhead transmission line once operational and at greatest risk would be those larger species flying at pylon height (e.g., bustards, eagles, vultures); nocturnal travellers (e.g., flamingos and Palaearctic species) and species potentially visiting the area for roosting/foraging, etc. (e.g., bustards, crows).

Although very little is known regarding the actual flight paths used by the birds frequenting the general area, Figures 11, 13-14 indicate important areas; potential flight paths and documented bird mortalities caused by transmission lines in Namibia.

As vultures are known to breed in the general area; are viewed as an a known “pylon sensitive” species (See Scot and Scot n.d.); species of conservation concern (critically endangered – IUCN 2022); located between known bird mortality “hotspot” areas and known to be negatively affected by transmission lines, anti-perching devices should be placed on pylons and anti-collision mechanisms – BFD’s (bird flight diverters) such as coils, flappers, etc. – should be attached to the transmission lines (See Figures 11 & 13). Other important species that would also benefit from BFD’s and known to frequent the area after localised rainfall events, are kori and Ludwig’s bustards.

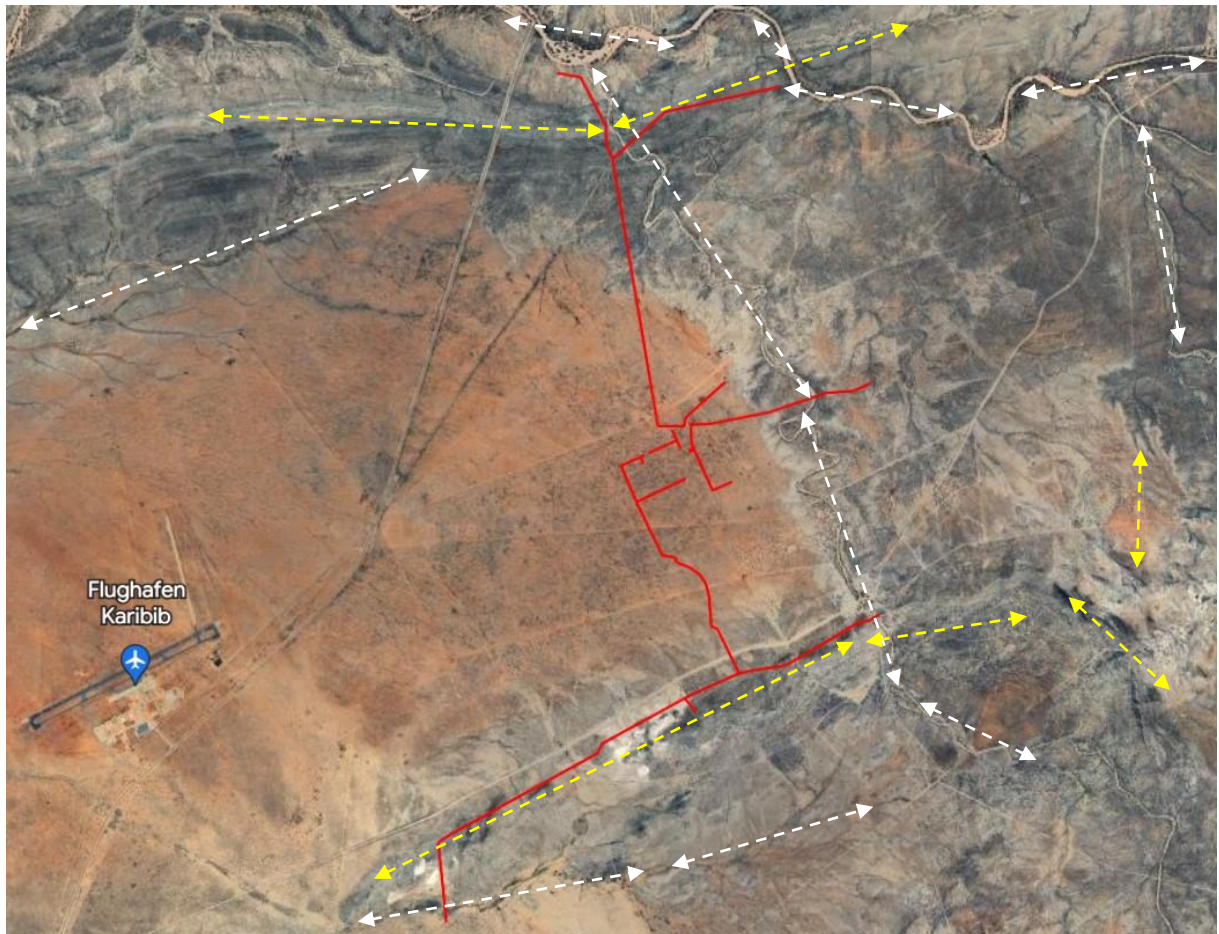
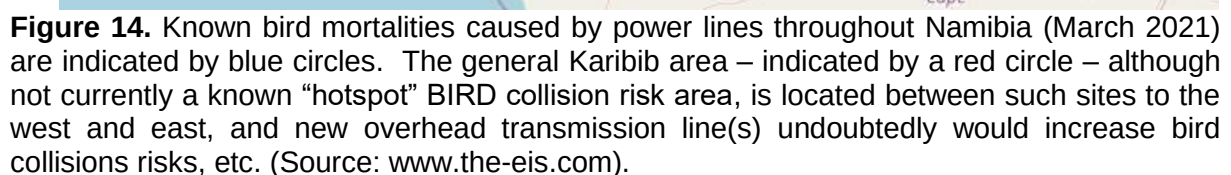


Figure 13. Expected bird flight paths along ephemeral drainage lines (white dashed arrows) and between mountainous areas (yellow dashed arrows) in the general area. The 11 kV TL's are indicated by the solid red lines. Figure 10 indicates areas where BFD's should be installed along the various 11 kV TL's.



The Twin Hills developments fall within the ecosystem zone known as the Western Highlands. Ecosystem services provide benefits that are used by humans and in doing so affect human wellbeing such as livestock, ground/surface/fresh/salt water, fish, soil formation/composition, tourism, recreation, spiritual interactions, etc. According to Harper-Simmonds *et al.* (n.d.) the key ecosystem services in Namibia include:

- The broad drivers of change in the Western Highlands ecosystem zone, with their ecosystem specific pressures (in parenthesis), are viewed as:

- Twin Hills Mining Project: Amendments to infrastructure layout 2023 (Karibib area) – August 2023***

- Invasive species (no relevant pressures identified);
- Climate change (more extreme climatic conditions such as current drought being experienced); and
- Illegal use (poaching).

Although the proposed Twin Hills developments are not expected to negatively impact most of the recognised ecosystem services within the Western Highlands zone (i.e., general Karibib area), some potentially could be affected, if not addressed adequately prior/during/after construction/operational phases, and would include:

Provisioning services

- Livestock (habitat change – i.e., convert farming area to non-farming area with livestock implications);
- Wild animals (habitat change – i.e., increased disturbances and poaching affect game farming and own use hunting);
- Plants for material and energy use (areas affected that could be used for charcoal, firewood, devils claw, etc.);
- Surface water (dam and soil disturbances affect runoff and downstream ecological processes);
- Ground water (abstraction affect overall groundwater quality and quantity).

Affected population:

Mainly local (some international – e.g., trophy hunting).

Change in flow over past 50 years:

The change in flow of all provisioning services has increased due to an increase in human population and exploitation.

Pressures & expected impacts on flow:

The exploitation of provisioning services related to food are expected to increase as human population increases.

Due to the fragile ecosystem, rangeland degradation due to overgrazing is expected to increase while the carrying capacity is expected to decrease.

Climate change expected to exacerbate farming practices as areas becomes more arid.

Surface and groundwater exploitation expected to increase with increase in human population.

Wood for fuel and building expected to continue.

Regulation and Maintenance services

- Soil formation & composition (land clearing & erosion);
- Ground water recharge (increased runoff, increased abstraction, erosion, dams);
- Mediation of waste & pollution (chemical use issues);
- Global & Regional climate regulation (land clearing, erosion);
- Ventilation & transpiration (clearing vegetation).

Affected population:

Local – soil formation & composition issues.

Regional – waste, toxins & disturbances + precipitation & temperature influences.

Global – carbon sequestration issues.

Change in flow over past 50 years:

Overgrazing has resulted in rangeland deterioration, decline in soil fertility and erosion.

Absorption and dilution of pollutants in the ecosystem, albeit viewed as insignificant, has increased due to an increase in human population.

No significant groundwater recharge and carbon sequestration in this zone.

Pressures & expected impacts on flow:

Absorption and dilution of pollutants expected to increase as population grows.

Negative soil fertility expected to increase especially with desertification.

Rainfall patterns could be negatively affected by climate change.

Cultural services

- Physical interactions (interactions depending on workforce);
- Spiritual, symbolic, and intellectual interactions (tribal interactions depending on workforce).

Affected population:

Tourists to the zone are mainly associated with services related to wildlife (i.e., international visitors, scientific, aesthetic, and symbolic).

Change in flow over past 50 years:

Recreational tourism has increased significantly.

Pressures & expected impacts on flow:

Recreational tourism expected to increase due to improved access and facilities.

Poaching of wildlife could affect tourism.

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

The impact during construction and operation, are expected to be detrimental to some ecosystem services in the general area, albeit localised.

WRD sites

The impact of the waste rock dumps is expected to be detrimental to ecosystem services as this would involve clearing and covering the areas with rock and other excavated material. The northernmost WRD site would cover parts of the northern tributaries of the Okawayo River and should be avoided (See Figure 2 dashed arrow).

TSF

The impact of the TSF is expected to be detrimental to ecosystem services as this would involve clearing then covering the areas with rock and other excavated material (See Figure 3).

Solar PV Plant

Other than local habitat alteration/destruction, the impact of the Solar PV Plant infrastructure is not expected to be detrimental to any ecosystem services (See Figure 4).

Transmission lines (11 kV)

The impact of heavy machinery during construction, and especially the excavation of holes to plant pylons for the proposed transmission line are expected to be detrimental to ecosystem services associated with the affected area/habitat. This would affect a relatively small area over a short/limited period.

The impact of aboveground transmission line infrastructure is not expected to be detrimental to ecosystem services (See Figure 5).

Access route

The impact of an access route is expected to be detrimental to ecosystem services as this would involve clearing the route. However, track discipline should be maintained (e.g., minimise speed (e.g., 40km/h), no off-road driving, limited nocturnal driving, etc.), speed

humps and vehicle calming devices should be incorporated along the route. This should act as mitigation measure to minimise dust pollution and/or the destruction of flora during offroad driving.

A tarmac access route would result in less dust pollution and make installing the speed humps and vehicle calming devices, etc. easier than a gravel route (See Figure 6).

Pits

The impacts of the open pit(s) are expected to be detrimental to ecosystem services as this would involve the excavation and removal of all flora on site.

The impacts of the mining activities are expected to be detrimental to ecosystem services along various roads/tracks and other development areas – i.e., removal/destruction in/along certain areas and/or dust pollution and other contaminants. All vehicle activities (including long hauling) should abide by the speed limits to minimise dust pollution (See Figure 7).

Runway

The impact of heavy machinery during construction, are expected to be detrimental to ecosystem services as this would involve clearing the runway. Herbicides should not be used to control grass on runway verges as these could have long lasting and/or widespread implications affecting flora in adjacent areas (See Figure 8).

Okawayo River diversion

The impact during construction and operation, are expected to be detrimental to ecosystem services as this would involve clearing the route.

The riparian vegetation habitat would be negatively affected although the proposed diversion would become vegetated over time and eventually serve the same purpose. The diversion and embankment dam are expected to affect the downstream riparian vegetation, probably even the Khan River riparian vegetation due to reduced flow, and consequently all associated ecosystem services, associated with this habitat (See Figure 9).

D1941 diversion

The impact of heavy machinery during construction, are expected to be detrimental to ecosystem services as this would involve clearing the route. Herbicides should not be used to control grass on road verges as these could have long lasting and/or widespread implications affecting ecosystem services throughout the areas (See Figure 10).

The Twin Hills area has been heavily impacted due to current/past mining (e.g., marble quarrying) and farming activities. Overall, Harper-Simmonds *et al.* (n.d.) expect no major declines in ecosystem services in the Western Highlands zone.

Construction / decommissioning mitigation

1. Avoid clearing areas not directly associated with the mining operations and infrastructures;
2. Prevent poaching activities;
3. Prevent affecting water sources;
4. Avoid the destruction of important habitats;
5. Avoid the excessive clearing of vegetation along the access & transmission line route(s) – limit clearing to access route(s) only and avoid clearfelling the entire servitude area;
6. Avoid the destruction of graves and other historic features;
7. Use local workers with the same culture where possible and/or include respect for cultural differences in environmental awareness training; and
8. Implement erosion control, especially in erosion prone or through/adjacent water sources and other important habitats.

Operational mitigation

1. Chemicals should be used judiciously if/when used for transmission line and other access route maintenance;
2. Remove individual trees that pose a threat to the infrastructure only (not clear fell routes); and
3. Implement erosion control, especially in erosion prone areas or through/adjacent water sources and other important habitats.

4 Conclusion

As all development have potential negative environmental consequences, identifying the most important faunal species including high risk habitats beforehand, coupled with environmentally acceptable mitigating factors, lessens the overall impact of such development.

Vertebrate fauna species most likely to be adversely affected by the proposed mining/prospecting in the Twin Hills project areas would be sedentary species (i.e. species with limited mobility) such as unique reptiles (i.e. tortoises *Stigmochelys pardalis* and *Psammobates oculiferus*; pythons – *P. anchietae* and *P. natalensis*; Namibian wolf snake (*Lycophidion namibianum*) – *Varanus albigularis*; some of the endemic and little known gecko species – e.g. *Pachydactylus* species and species viewed as “rare” – i.e. *Rhinotyphlops lalandei*, *Mehelya vernayi* and *Afroedura africana* – although very little is known about these species. Amphibians are not viewed as important in the area and mammals are more mobile and although important species are known to occur and/or pass through the area (see elsewhere in this report) none are expected to be specifically associated and/or expected to be negatively affected by the developments. Although general disturbances could affect bird species of concern – i.e., species classified as endangered (violet wood-hoopoe, Ludwig’s bustard, white-backed vulture, black harrier, tawny eagle, booted eagle, martial eagle, black stork), vulnerable (lappet-faced vulture, secretarybird) and near threatened (Rüppel’s parrot, kori bustard, Verreaux’s eagle, peregrine falcon, marabou stork) – birds are also mobile and not limited to the area.

Flora species most likely to be adversely affected by mining/prospecting would be the various protected species although these species are not specifically associated with the development sites.

Important areas in the general vicinity are viewed as hills (limestone/marble hills), ephemeral drainage lines, ground dams and pans and bird flight paths.

Certain ecosystem services may be affected as large areas would be cleared of vegetation and/or covered by rock with potential negative erosion and groundwater impacts (mainly provisioning, but also regulation and maintenance services (See 3.10).

Alternative infrastructure impacts

[WRD; TSF; Solar PV Plant; 11 kV transmission lines; access route; pits; runway; Okawayo River diversion & D1941 diversion]

WRD	No significant impact. However, the northern WRD site would cover parts of the northern tributaries of the Okawayo River should be avoided.
TSF	No significant impact.
Solar PV Plant	No significant impact. However, the collision mortality impacts of birds with PV panels may be underestimated and ongoing

	long-term monitoring is viewed as imperative to determine local bird mortalities.
11kV TL's	Significant impact. As many of the "pylon sensitive" bird species occur in the general area, it is recommended that BFD's (Bird Flight Diversifiers – e.g., coils, flappers, etc.) are installed along the most important portions of the transmission lines to minimise/prevent avifauna mortalities (See Figures 5, 11 & 13).
Access route	No significant impact.
Pits	No significant impact.
Runway	No significant impact.
Okawayo River diversion	Significant impact. It is recommended that the Okawayo River not be channelled into an embankment dam and pit but rather bisect the adjacent WRD and pit and rejoin the river downstream. This would ensure continued flow with the least impact on the riparian vegetation and downstream ecological processes and associated and/or dependent vertebrate fauna.
D1941 diversion	No significant impact

Except for the 11kV TL's and Okawayo River diversion (see above and elsewhere in report), it is not expected that most of the mine infrastructure amendments will adversely affect any unique vertebrate fauna and flora in the Twin Hills project areas, especially if the proposed recommendations (mitigation measures) are incorporated – See this report under each section and Cunningham (2021a, b). This report does not include all the other developments dealt with previously in Cunningham (2021a, b) – e.g., water pipeline, 66kV TL, etc.

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