Report on the ecological and wetland assessment for the proposed Harmony Joel PV solar development situated near Theunissen, Free State Province.

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DECLARATION OF INDEPENDENCE

DPR Ecologists and Environmental Services is an independent company and has no financial, personal or other interest in the proposed project, apart from fair remuneration for work performed in the delivery of ecological services. There are no circumstances that compromise the objectivity of the study.

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Ecological and wetland assessment.

1. INTRODUCTION

Natural vegetation is an important component of ecosystems. Some of the vegetation units in a region can be more sensitive than others, usually as a result of a variety of environmental factors and species composition. These units are often associated with water bodies, water transferring bodies or moisture sinks. These systems are always connected to each other through a complex pattern. Degradation of a link in this larger system, e.g. tributary, pan, wetland, usually leads to the degradation of the larger system. Therefore, degradation of such a water related system should be prevented.

Though vegetation may seem to be uniform and low in diversity it may still contain species that are rare and endangered. The occurrence of such a species may render the development unviable. Should such a species be encountered the development should be moved to another location or cease altogether.

South Africa has a large amount of endemic species and in terms of plant diversity ranks third in the world. This has the result that many of the species are rare, highly localised and consequently endangered. It is our duty to protect our diverse natural resources.

South Africa's water resources have become a major concern in recent times. As a water scarce country, we need to manage our water resources sustainably in order to maintain a viable resource for the community as well as to preserve the biodiversity of the system. Thus, it should be clear that we need to protect our water resources so that we may be able to utilise this renewable resource sustainably. Areas that are regarded as crucial to maintain healthy water resources include wetlands, streams as well as the overall catchment of a river system.

In order to better manage our water resources several guidelines and research sources have been developed. Amongst these are the National Freshwater Ecosystem Priority Areas for South Africa 2011 (NFEPA).

The human population has become a power-hungry system where non-renewable resources are being utilised at an alarming rate. These resources are nearing depletion and are often associated with some form of pollution (air-, water-, atmospheric pollution). The unlimited use of these non-renewable resources is not sustainable. In recent times people have become aware of this and are attempting to alleviate this by using renewable energy sources. This has become increasingly popular and are commonplace in many first world countries. Recently it has come to light that South Africa is optimally situated for solar power production. The use of solar power will alleviate the pressure experienced by Eskom, will reduce carbon emissions and will promote the use of renewable energies. The development of solar facilities should be encouraged. Solar parks do have their disadvantages. These include the use of fertile soil for power production rather than food supply and the disturbance and removal of natural vegetation.

The study area is situated between the towns of Theunissen (approximately 20 km) and Virginia (approximately 15 km) and within the Joel Gold mining operations. The study area is fairly large with an approximate extent of 200 hectaes and dominated by thicket, of which a large portion are considered riparian thicket associated with the Doring River adjacent to the site. The majority of the site still consists of natural vegetation without previous modification

although mining operations situated on and around the site do result in transformation of the surroundings.

A site visit was conducted on 15 June 2022. The entire footprint of the proposed development area, including terrestrial and riparian areas, was surveyed over the period of one day. The site survey was conducted during early winter and though vegetation was in the process of going dormant, late rains and light frost to date did allow for adequate vegetation identification and an active hydrological regime was present. This ensured accurate identification of watercourses and wetlands.

For the above reasons it is necessary to conduct an ecological and wetland assessment of an area proposed for development.

The report together with its recommendations and mitigation measures should be used to minimise the impact of the proposed solar development.

1.1 Background of the development

The following summary has been provided by the applicant and provides a brief description of the planned development:

Free Gold Harmony (Pty) Ltd, is looking to supplement its energy supply by implementing Photovoltaic (PV) generation, aiding their transition to a more sustainable and environmentally friendly energy mix.

Located north east of the Harmony Joel operations, approximately ~20km north east of the town of Theunissen within the Masilonyana Local Municipality and within the Lejweleputswa District Municipality, Free State Province.

The PV facility is located on Portion 0 of the Farm Leeuwbult 580.
A technically feasible project site, with an extent of 43.2 ha has been identified by Free Gold Harmony (Pty) Ltd as a technically suitable area for the development of the Project. A development area of ~36 ha was demarcated within this project site and allows an adequate footprint for the installation of a solar PV facility with a contracted capacity of up to 18MW, while allowing for the avoidance of environmental site sensitivities. The size of the development footprint within the development area will be confirmed in the EIA Phase once the facility layout is available for assessment.

The development footprint will contain the following infrastructure to enable the Solar PV Facility to generate up to 18MW:

- PV modules and mounting structures
- Inverters and transformers a SCADA room, and maintenance room
- Cabling between the project components, to be laid underground where practical
- Access roads, internal roads and fencing around the development area.
- Temporary and permanent laydown areas and O&M buildings.
- Overhead Power Lines (OHPL)
- Grid connection solution which will tie-in to Shafts 1 & 2 HJ Joel Mining (6.6/132 kV), via a 1.2km South West overhead line with a capacity of 44 kV.

1.2 The value of biodiversity

The diversity of life forms and their interaction with each other and the environment has made Earth a uniquely habitable place for humans. Biodiversity sustains human livelihoods and life itself. Although our dependence on biodiversity has become less tangible and apparent, it remains critically important.

The balancing of atmospheric gases through photosynthesis and carbon sequestration is reliant on biodiversity, while an estimated 40% of the global economy is based on biological products and processes.

Biodiversity is the basis of innumerable environmental services that keep us and the natural environment alive. These services range from the provision of clean water and watershed services to the recycling of nutrients and pollution. These ecosystem services include:

- Soil formation and maintenance of soil fertility.
- Primary production through photosynthesis as the supportive foundation for all life.
- Provision of food, fuel and fibre.
- Provision of shelter and building materials.
- Regulation of water flows and the maintenance of water quality.
- Regulation and purification of atmospheric gases.
- Moderation of climate and weather.
- Detoxification and decomposition of wastes.
- Pollination of plants, including many crops.
- Control of pests and diseases.
- Maintenance of genetic resources.

1.3 Value of wetlands and watercourses

Freshwater ecosystems provide valuable natural resources, which contributes toward economic, aesthetic, spiritual, cultural and many recreational values. Yet the integrity of freshwater ecosystems in South Africa is rapidly declining in recent times. This crisis is largely a consequence of a variety of challenges that are practical (managing vast areas of land to maintain connectivity between freshwater ecosystems), socio-economic (the need to utilise these recourses between different stakeholders, i.e. individuals, communities, corporate and industrial) and institutional (Implementing appropriate governance and management). Water affects every activity and aspiration of human society and sustains all ecosystems.

Freshwater ecosystems provide many of our fundamental needs, enable important regulating ecosystem services, supports functional faunal and floral communities:

- Water for drinking and irrigation
- Food such as fish and water plants.
- Building material such as clay and reeds.
- Preventing floods and easing the impacts of droughts.
- Remove excess nutrients and toxic substances from water
- Rivers, wetlands and groundwater systems maintain water supplies and buffer the effects of storms, reducing the loss of life and property to floods.
- Riverbanks help to trap sediments, stabilise

- river banks and break down pollutants draining from the surrounding land.

1.4 Details and expertise of specialist

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Professional registration:
South African Council for Natural Scientific Professions No. (400284/13) (Ecological Science).

Membership with relevant societies and associations:

- South African Society of Aquatic Scientists (SASAQS0091)
- South African Association of Botanists
- South African Wetlands Society (3SLY4IG4)

Expertise:

- Qualifications: B.Sc. (Hons) Botany (2008), M.Sc. in Vegetation Ecology (2012) with focus on ephemeral watercourses.
- Vegetation ecologist with over 10 years experience of conducting ecological assessments.
- Founded DPR Ecologists & Environmental Services (Pty) Ltd in 2016.
- Has conducted over 200 ecological and wetland assessments for various developments.
- Regularly attend conferences and courses in order to stay up to date with current methods and trends:

  2017: Kimberley Biodiversity Symposium.
  2018: South African Association of Botanists annual conference.
  2018: National Wetland Indaba Conference.
  2019: SASS5 Aquatic Biomonitoring Training.
  2019: Society for Ecological Restoration World Congress 2019.
  2019: Wetland rehabilitation: SER 2019 training course.
  2020: Tools For Wetlands (TFW) training course.

2. SCOPE AND LIMITATIONS

- To evaluate the present state of the vegetation and ecological functioning of the area proposed for the solar development.
- To identify possible negative impacts that could be caused by the proposed clearing of vegetation and establishment of solar development.
    - Severity relates to the nature of the event, aspect or impact to the environment and describes how severe the aspects impact on the ecosystem.
    - Duration refers to the amount of time that the environment will be affected by the event, risk or impact, if no intervention e.g. remedial action takes place.
    - Extent refers to the spatial influence of an impact.
    - Frequency refers to how often the specific activity, related to the event, aspect or impact, is undertaken.
    - Probability refers to how often the activity/event or aspect has an impact on the environment.
- To provide a description of watercourses, wetlands and riparian vegetation included within the study area.
- Identify watercourses including rivers, streams, pans and wetlands and determine the presence of wetland conditions within these systems.
- Where wetland conditions have been identified the classification of the wetland system will be given.
- To evaluate the present state of the wetlands and riparian vegetation in close proximity to the site. The importance of the ecological function and condition will also be assessed.
- Determine the Present Ecological State (PES) and Ecological Importance & Sensitivity (EIS) for the watercourses in close proximity to operations.
- Conduct a risk assessment and determine the likelihood that watercourses and wetlands will be adversely affected by the development.

2.1 Vegetation

Aspects of the vegetation that will be assessed include:

- The vegetation types of the region with their relevance to the proposed site.
- The overall status of the vegetation on site.
- Species composition with the emphasis on dominant-, rare- and endangered species.

The amount of disturbance present on the site assessed according to:

- The amount of grazing impacts.
- Disturbance caused by human impacts.
- Other disturbances.

2.2 Fauna

Aspects of the fauna that will be assessed include:

- A basic survey of the fauna occurring in the region using visual observations of species as well as evidence of their occurrence in the region (burrows, excavations, animal tracks, etc.).

- The overall condition of the habitat.

2.3 Wetlands and watercourses

Aspects of the wetlands that will be assessed include:

- Identification and delineation of watercourses including rivers, streams, pans and wetlands.
- Determine the presence of wetland conditions and riparian vegetation using obligate wetland and riparian species.
- Describe watercourses and wetlands and importance relative to the larger system.
- Conduct habitat integrity assessment of perennial systems to inform the condition and status of watercourses.

2.4 Limitations

- Due to the season of the survey several bulbs, seasonal herbs and subterranean succulents may have been overlooked as leaves and flowers may be absent due to their seasonal or deciduous nature.
- Although a comprehensive survey of the site was done it is still likely that several species were overlooked.
- Smaller drainage lines may have been overlooked where a distinct channel or riparian vegetation is absent.
- The area is dominate by alluvial soil deposits which complicates the delineation of the riparian zone and floodplain of the river and an additional 1:100 year floodline determination should be undertaken.
- Due to time constraints only limited surveys of wetlands were done.
- Some animal species may not have been observed as a result of their nocturnal and/or shy habits.

3. METHODOLOGY

3.1 Several literature works were used for additional information.

General ecology:

- Red Data List (Raymondo *et al.* 2009).
- Vegetation types (Mucina & Rutherford 2006).
- NBA 2018: South African Inventory of Inland Aquatic Ecosystems (SAIIAE).
- NBA 2018 Technical Report: Inland Aquatic (Freshwater) Realm.
- NBA 2018 Technical Report Volume 1: Terrestrial Realm.
- National Freshwater Ecosystem Priority Areas 2011 (NFEPA).
- Strategic Water Source Areas 2018 (SWSA).
- SANBI (2011): List of threatened ecosystems.
- NEM:BA: List of threatened ecosystems and Threatened Or Protected Species (TOPS).
- Biodiversity Plan Free State Province (2018).

Vegetation:

- Red Data List (Raymondo *et al.* 2009).
- Vegetation types (Mucina & Rutherford 2006).
- Field guides used for species identification (Bromilow 1995, 2010, Coates-Palgrave 2002, Fish *et al* 2015, Gerber *et al* 2004, Gibbs-Russell *et al* 1990, Griffiths & Picker 2015, Manning 2009, Moffett 1997, Pooley 1998, 2003, Retief & Meyer 2017, Van Ginkel & Cilliers 2020, Van Ginkel *et al* 2011, Van Oudtshoorn 2004, Van Wyk & Malan 1998, Van Wyk & Van Wyk 1997, Venter & Joubert 1985).

Terrestrial fauna:

- Field guides for species identification (Smithers 1983, Child *et al* 2016, Cillié 2018).

Wetland methodology, delineation and identification:
Department of Water Affairs and Forestry 2004, 2005, 2008, Collins 2006, Duthie 1999, Kleynhans *et al* 2008, Marnewecke & Kotze 1999, Macfarlane, Ollis & Kotze 2020, Ollis *et al* 2013, Nel *et al* 2011, SANBI 2009.

3.2 Survey

The site was assessed by means of transects and sample plots. Observation w.r.t. the general ecology of the area includes:

- Noted species include rare and dominant species.
- The broad vegetation types present at the site were determined.
- The state of the environment was assessed in terms of condition, grazing impacts, disturbance by humans, erosion and presence of invader and exotic species.
- The state of the habitat was also assessed.

Ecological aspects surveyed and recorded includes:

- The overall ecology of an area including the diversity of species, uniformity or diversity of habitats and different vegetation communities.

- Identification and delineation of distinct vegetation communities ad habitats and the ecological drivers responsible for these distinct communities, i.e. soil, geology, topography, aspect, etc.
- A comprehensive plant species survey including the identification of protected, rare or threatened species.
- Any ecological process or function which is important to the ecosystem including ecological drivers such as fire, frost, grazing, browsing, etc. and any changes to these processes.

Animal species were also noted as well as the probability of other species occurring on or near the site according to their distribution areas and habitat requirements.
The state of the habitat was also assessed.

In order to provide a visually representative overview of the results obtained from the survey, site sensitivity mapping will also be done. This should indicate the relative importance of different ecological elements on the site as obtained from the survey. In general, these levels of sensitivity will include:

- Low Sensitivity – normally confined to areas that are completely transformed from the natural condition or degraded to such an extent that they are no longer representative of the natural ecosystem. Such areas will also no longer contain any ecological processes of importance relative to the surrounding areas, i.e. in some instances such as watercourses which are completely transformed but still provide important ecological functions, a low level of sensitivity will not apply.

- Moderate Sensitivity – normally applicable to areas that are still natural and therefore does still have some ecological importance but which do not contain elements of high conservation value and are not essential to the continued functioning of surrounding areas. Areas of Moderate Sensitivity usually require some mitigation but can be developed without resulting in high impacts.

- High Sensitivity – areas of high sensitivity contain one or more ecological elements which are considered of high conservation value. Such areas are normally preferred to be excluded from a development but where this is not possible, will require comprehensive mitigation and is also likely to result in high impacts.

- Very High Sensitivity – these areas are critical to the continued functioning of the ecosystem on and around the site. Development of such areas normally represent a fatal flaw and should be excluded from development. No manner of mitigation is able to decrease the anticipated impact in these areas.

All rivers, streams, pans and wetlands were identified and surveyed where they occurred in the study area. These systems were determined by use of topography (land form and drainage pattern) and riparian vegetation with limited soil sampling (Appendix B & C). The following outlines the process applied during the on-site survey in order to obtain all required data:

- Perform desktop overview of the study area utilising available resources (Section 3.1). From the desktop overview identify the different landscape forms, possible wetland areas, watercourses and their relative flow patterns. Using this information, identify transects and sample plots for possible on-site survey. This should be both

representative of the wetland or watercourse as a whole but should also include any prominent or significantly unique features.

- Possible sites identified during the desktop overview should be surveyed on-site. Where access is not possible or where desktop features are considered poor representatives of the wetland or watercourse the survey site or transect should be moved to another location, without compromising a comprehensive overview of the system.
- Where a lateral transect is taken of a watercourse this is done from the water's edge, across the marginal, lower and upper zones and extended across the floodplain until the edge of the riparian zone is reached.
- Where a transect is taken of a wetland system, this should preferably be taken across the entire wetland at its widest part or where it is most relevant to the proposed development, from the terrestrial surroundings, across the temporary, seasonal and perennial zones across the wetland.
- Soil samples are taken at 10 meter intervals along the survey transect, or where a distinct transition into a different zone is observed.
- A survey of the plant species within each distinct riparian or wetland zone is undertaken and includes the identification of obligate wetland species, riparian species, terrestrial species, exotic species and the general species composition and vegetation structure which allows for an accurate description of the watercourse or wetland.
- Visual survey of the general topography which substantiates the presence of riparian zones and wetland forms.
- Other general observations include any impacts observed, the overall ecosystem function, presence of fauna, surrounding land uses and the overall condition of the watercourse or wetland.
- Data is recorded by means of photographs with GPS coordinates taken at all relevant soil sampling sites and borders of riparian and wetland zones.

Data obtained during the on-site survey is utilised to provide the following information on the system:

- Desktop overview and assimilation of information on the likely impacts and functioning of the wetland system.
    - Review all available spatial data and resources in order to provide an estimate of the likely impacts and condition of the wetland or watercourse system.
- Confirm the presence of the wetland or watercourse system and provide an estimate of its borders.
    - The border of wetland conditions or the edge of the riparian zone will be confirmed by using soil sampling, obligate wetland vegetation and topography. This will also include the delineation of any temporary, seasonal or perennial zones of wetness along wetlands and the marginal, lower, upper and riparian zones along watercourses.
- Provide a description of the wetland or watercourse.
    - Provide the hydrogeomorphic setting of the wetland, a longitudinal profile which will aid in determining the erodibility of the wetland and provide an overall description of the wetland and impacts affecting it.
    - Provide a general description of the lateral zonation of the watercourse banks including the marginal, lower, upper and riparian zones and a description of the riparian vegetation along the banks of the watercourse. This will also include the description of any impacts or modification of the watercourse.

- Assess the current condition of the wetland or watercourse.
    - Utilising information obtained from the assessments listed above, determine the condition of this portion of the wetland by applying the WET-Health 2 tool.
    - Utilising information obtained from the assessments listed above, determine the condition of the relevant section of the watercourse by applying the Index of Habitat Integrity (IHI) tool.
- Utilising all of the information obtained from the assessment, provide recommendations to mitigate anticipated impacts that the development will have.

The following guidelines and frameworks were also used to determine the presence of the rivers, streams, pans and wetlands in the study area:

- Department of Water Affairs and Forestry. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Edition 1. Department of Water Affairs and Forestry, Pretoria.
- Marnewecke & Kotze 1999. Appendix W6: Guidelines for delineation of wetland boundary and wetland zones. In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

The following guidelines and frameworks were used to determine the sensitivity or importance of these identified watercourses or wetlands in the study area:

- Nel *et al.* (2011). Technical Report for the National Freshwater Ecosystem Priority Areas project. WRC Report No. K5/1801.

- Government of South Africa. 2008. National Protected Area Expansion Strategy for South Africa 2008: Priorities for expanding the protected area network for ecological sustainability and climate change adaptation. Government of South Africa, Pretoria.

- Duthie, A. 1999. Appendix W5: IER (floodplain and wetlands) determining the Ecological Importance and Sensitivity (EIS) and Ecological Management Class (EMC). In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

These guidelines provide the characteristics which can be utilised to determine if a wetland or watercourse is present and also aids in determining the boundary of these systems.

The following were utilised to inform the condition and status of watercourses:

- Kleynhans, C.J., Louw, M.D. & Graham, M. 2008. Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity. Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 377-08.

The following were utilised to inform the condition and status of wetlands:

- Macfarlane, D.M., Ollis, D.J. & Kotze, D.C. 2020. WET-Health (Version 2.0): a refined suite of tools for assessing the present ecological state of wetland ecosystems. WRC Report No. TT 820/20.

A Risk Assessment will be conducted for the proposed development in or near watercourses and wetlands in accordance with the Department of Water & Sanitation's requirements for risk assessment and the provisional Risk Assessment Matrix for Section 21(c) & (i) water use.

3.3 Criteria used to assess sites

The following criteria is also applied during the site survey to further inform the general sensitivity and conservation value of the site or specific elements on the site. These criteria were used to assess the site and determine the overall status of the environment.

3.3.1 Vegetation characteristics

Characteristics of the vegetation in its current state. The diversity of species, sensitivity of habitats and importance of the ecology as a whole.

Habitat diversity and species richness: normally a function of locality, habitat diversity and climatic conditions.
Scoring: Wide variety of species occupying a variety of niches – 1, Variety of species occupying a single nich – 2, Single species dominance over a large area containing a low diversity of species – 3.

Presence of rare and endangered species: The actual occurrence or potential occurrence of rare or endangered species.
Scoring: Occurrence actual or highly likely – 1, Occurrence possible – 2, Occurrence highly unlikely – 3.

Ecological function: All plant communities play a role in the ecosystem. The ecological importance of all areas though, can vary significantly e.g. wetlands, drainage lines, ecotones, etc.
Scoring: Ecological function critical for greater system – 1, Ecological function of medium importance – 2, No special ecological function (system will not fail if absent) – 3.

Degree of rarity/conservation value:
Scoring: Very rare and/or in pristine condition – 1, Fair to good condition and/or relatively rare – 2, Not rare, degraded and/or poorly conserved – 3.

3.3.2 Vegetation condition

The sites are compared to a benchmark site in a good to excellent condition. Vegetation management practises (e.g. grazing regime, fire, management, etc.) can have a marked impact on the condition of the vegetation.

Percentage ground cover: Ground cover is under normal and natural conditions a function of climate and biophysical characteristics. Under poor grazing management, ground cover is one of the first signs of vegetation degradation.
Scoring: Good to excellent – 1, Fair – 2, Poor – 3.

Vegetation structure: This is the ratio between tree, shrub, sub-shrubs and grass layers. The ratio could be affected by grazing and browsing by animals.

Scoring: All layers still intact and showing specimens of all age classes – 1, Sub-shrubs and/or grass layers highly grazed while tree layer still fairly intact (bush partly opened up) – 2, Mono-layered structure often dominated by a few unpalatable species (presence of barren patches notable) – 3.

Infestation with exotic weeds and invader plants or encroachers:
Scoring: No or very slight infestation levels by weeds and invaders – 1, Medium infestation by one or more species – 2, Several weed and invader species present and high occurrence of one or more species – 3.

Degree of grazing/browsing impact:
Scoring: No or very slight notable signs of browsing and/or grazing – 1, Some browse lines evident, shrubs shows signs of browsing, grass layer grazed though still intact – 2, Clear browse line on trees, shrubs heavily pruned and grass layer almost absent – 3.

Signs of erosion: The formation of erosion scars can often give an indication of the severity and/or duration of vegetation degradation.
Scoring: No or very little signs of soil erosion – 1, Small erosion gullies present and/or evidence of slight sheet erosion – 2, Gully erosion well developed (medium to large dongas) and/or sheet erosion removed the topsoil over large areas – 3.

3.3.3 Faunal characteristics

Presence of rare and endangered species: The actual occurrence or potential occurrence of rare or endangered species on a proposed site plays a large role on the feasibility of a development. Depending on the status and provincial conservation policy, presence of a Red Data species or very unique and sensitive habitats can potentially be a fatal flaw.
Scoring: Occurrence actual or highly likely – 1, Occurrence possible – 2, Occurrence highly unlikely.

3.4 Biodiversity sensitivity rating (BSR)

The total scores for the criteria discussed in section 3.3 were used to determine the biodiversity sensitivity ranking for the sites. On a scale of 0 – 30, five different classes are described to assess the biodiversity of the study area. The different classes are described in the Table 1:

Table 1: Biodiversity sensitivity ranking

BSR	BSR general floral description	Floral score equating to BSR class
Totally transformed (5)	Vegetation is totally transformed or in a highly degraded state, generally has a low level of species diversity, no species of concern and/or has a high level of invasive plants. The area has lost its inherent ecological function. The area has no conservation value and potential for successful rehabilitation is very low.	29 – 30
Advanced Degraded (4)	Vegetation is in an advanced state of degradation, has a low level of species diversity, no species of concern and/or has a high level of invasive plants. The area's ecological function is seriously hampered, has a very low conservation value and the potential for successful rehabilitation is low.	26 – 28
Degraded (3)	Vegetation is notably degraded, has a medium level of species diversity although no species of concern are present. Invasive plants are present but are still controllable. The area's ecological function is still intact but may be hampered by the current levels of degradation. Successful rehabilitation of the area is possible. The conservation value is regarded as low.	21 – 25
Good Condition (2)	The area is in a good condition although signs of disturbance are present. Species diversity is high and species of concern may be present. The ecological function is intact and very little rehabilitation is needed. The area is of medium conservation importance.	11 – 20
Sensitive/Pristine (1)	The vegetation is in a pristine or near pristine condition. Very little signs of disturbance other than those needed for successful management are present. The species diversity is very high with several species of concern known to be present. Ecological functioning is intact and the conservation importance is high.	0 - 10

4. ECOLOGICAL OVERVIEW OF THE SITE

For the purpose of this report the terrestrial ecology of the study area will first be discussed followed by a discussion of the watercourses and wetland systems.

4.1 Overview of ecology and vegetation types

Refer to the list of species encountered on the site in Appendix B.

According to Mucina & Rutherford (2006) the immediate surroundings consist of Central Free State Grassland (Gh 6). The vegetation type is currently listed as being of Least Concern (LC) according to the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) (Appendix A: Map 2). Although it is quite heavily affected by transformation for dryland crop cultivation, it is not yet considered as severe enough to be regarded a Threatened Ecosystem. Remaining natural areas of this vegetation type will therefore not have a high conservation value, however, elements of conservation concern may still be present in natural areas. However, the site is also situated adjacent to the Doring River and from the survey it was also evident that the vegetation on the site is much more representative of the Highveld Alluvial Vegetation (AZa 5) type which is associated with riparian areas. This vegetation type is also listed as being of Least Concern (LC) which will also be taken into account in the assessment of the site.

The Free State Province Biodiversity Management Plan (2015) has recently been published and has identified areas which are essential to meeting conservation targets for specific vegetation types, i.e. Critical Biodiversity Areas. The site for the proposed solar development is listed as being an Ecological Support Areas 1 & 2 (ESA 1 & 2) (Appendix A: Map 3). This indicates that the area is not essential to meeting conservation targets but forms part of the functioning of the Doring River adjacent to the site and as a result does provide important functions in the support of this system. A Critical Biodiversity Area 2 (CBA 2) is situated to the west of the site and marginally intersects with the western border of the site. This CBA 2 is associated with surrounding natural grassland of Vaal-Vet Sandy Grassland, an Endangered vegetation type though the marginal portion extending into the study area overlaps with the existing mining plant and is therefore not relevant to the development.

The study area is situated between the towns of Theunissen (approximately 20 km) and Virginia (approximately 15 km) and within the Joel Gold mining operations. The study area is fairly large with an approximate extent of 200 hectares and dominated by thicket, of which a large portion are considered riparian thicket associated with the Doring River adjacent to the site. The majority of the site still consists of natural vegetation without previous modification although mining operations situated on and around the site do result in transformation of the surroundings.

As previously stated, the study area is still largely natural (apart from the portion occupied by the mining operations). The study will largely focus on these areas of remaining natural vegetation with the mining plant only discussed in overview. This is also confirmed by the National Biodiversity Assessment (2018) which indicates the site to still consist of natural Central Free State Grassland. The site is however also situated adjacent to the Doring River and the vegetation structure is much better affiliated with Highveld Alluvial Vegetation (Aza 5) which is a riparian vegetation type and dominated by riparian thicket which is quite prominent on the site. The site is fairly uniform and dominated by a mosaic of fairly dense thicket and

open grassland and will be discussed as a whole. A small portion in central portion of the development area is clearly transformed and associated with a historical tailings dump but has a limited extent of approximately 5 hectares and is the only prominently transformed area of the site (apart from the existing mining plant).

Figure 1: The study area is generally dominated by fairly dense thicket vegetation with a well-developed grass layer also being present.

Figure 2: A historical tailings dump in the central portion of the site is the only significant transformation of the natural portion of the study area.

The Doring River is situated adjacent to the site along the eastern, northern and western borders and may in some areas occur in close proximity to it and is therefore also relevant to the development. Associated with the Doring River is an extensive floodplain which may also extend onto the site. This is also dependent on the 1:100 year floodline of this watercourse. Within this floodplain an area of temporary saturation has also been identified which forms part of a floodplain wetland area although observed wetland conditions are only of a temporary nature and this area is therefore not clearly defined. These areas will all be assessed in detail in the wetland assessment section of the report.

Figure 3: The Doring River is situated adjacent to the site and is a fairly large watercourse.

Figure 4: A grass dominated floodplain wetland areas is also associated with the Doring River.

The main impacts affecting the area is associated with the mining operations here (Appendix A: Map 1). The plant itself covers a fairly large area which is completely transformed, associated with the mining plant is also a network of infrastructure which includes roads, dirt tracks and pipelines which contributes toward transformation. Along the east of the plant and centrally within the study area is a prominent tailings dump which also completely transforms the footprint of approximately 5 hectares both in terms of vegetation and topography. This transformation is however of limited extent and the majority of the area still consists of natural vegetation. The area is also being utilised as grazing for domestic livestock and this also contributes toward at least a moderate level of overgrazing and trampling. It should be clear that though significant transformation is caused by the mining operations, the majority of the site is still in a natural condition.

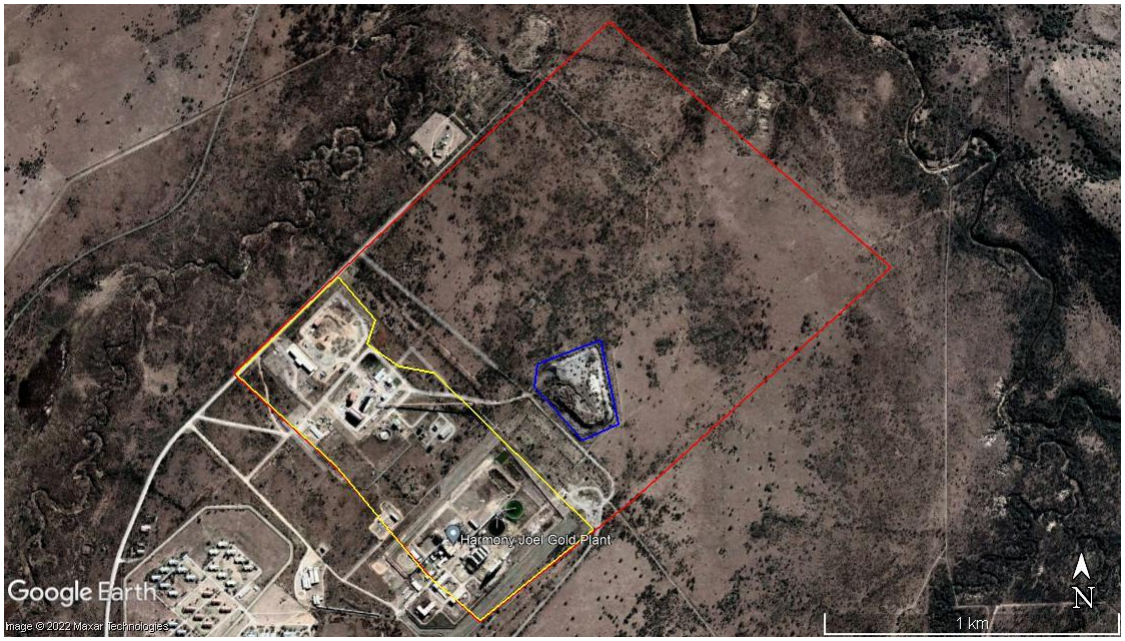


Figure 6: Impacts in the study area (red) are largely associated with the existing mining operations (yellow) with a tailings dump (blue) also situated in the central portion of the site. Overall the site is however dominated by natural vegetation (Google Earth 2022).

In general, the surface topography is still largely intact except for those areas consisting of mining operations as well as the tailings dump. The natural topography in the area consists of a plain but with a gentle slope towards the Doring River situated adjacent to the site. In closer proximity to the river, the slope also increases and erosion gullies and uneven terrain also become more prominent.

The site and the surrounding area is situated in a region experiencing moderate rainfall, with cold, dry winters and warm summers. Climate for the site can be extrapolated from rainfall and evaporation data from the weather station C4E009 (Zeebrugge@Sand-Vet). The site is located in an area with a rainfall of between 500 mm and 600 mm per annum with an average of 508.7 mm per year. Rainfall occurs largely as summer rainfall with a mean annual evaporation of between 1600 and 1799 mm/annum. The surface water runoff in the area is therefore not significantly high which results in a relatively low runoff for the area of between 20 - 50 mm according to a study by the Water Research Commission. As a result wetlands are uncommon in the area although several wetland areas are associated with the floodplain of the Doring River and the drainage lines and seasonal streams transecting the floodplain of the river.

The study area is situated on geology associated with the Volksrust Formation. The Volksrust Formation of the Ecca Group in the vicinity of Theunissen is dominated by underlying mudrock. However, the site and surroundings are dominated by quite deep alluvial deposits consisting of fine sand and silt soils. This is also one of the main drivers of the vegetation composition of the area.

As previously indicated, the terrestrial component of the study area is fairly uniform and dominated by thicket vegetation with interspersed grassland layer. The study area will therefore be discussed as a whole and elements of conservation value indicated where these were observed.

The majority of the site still consists of natural vegetation which is dominated by a fairly dense thicket vegetation while a well-developed grass layer is also prominent. The density of thicket also varies over the site with the northern portion being densest. The survey has indicated that though a moderate level of disturbance is present the vegetation is still natural. Available resources indicate the area to consist of Central Free State Grassland which is characterised by undulating plains dominated by grassland while lower lying areas may be affected by increased encroachment by the tree, *Vachellia karroo*, where overgrazing and trampling occurs (Mucina & Rutherford 2006). This was also found to be the case for this site. However, the lower lying areas along the rivers in this region, such as the Doring River, is normally dominated by Highveld Alluvial Vegetation. This vegetation type is characterised by flat topography with riparian thickets dominated by *Vachellia karroo,* accompanied by seasonally flooded grassland and disturbed herblands often dominated by exotic weeds (Mucina & Rutherford 2006). Again, this is also a very good description for the site. We can therefore conclude that the area consists of a mixture of Central Free State Grassland and Highveld Alluvial Vegetation which may also have been affected by increased encroachment of *Vachellia karroo* as a result of overgrazing and trampling. This sets a good baseline for the description of the site on which the following vegetation composition is based.

The thicket layer is dominated to a large degree by *Vachellia karroo* (Sweetthorn) and as discussed in the previous paragraph, this is a natural component of the vegetation though may have increased in density due to previous overgrazing and trampling. Other trees and shrubs also common within this thicket vegetation also include *Diospyros lycioides, Ziziphus mucronata, Searsia pyroides, Asparagus larcinus* and *Searsia lancea*. These species are often also associated with riparian conditions and is likely associated with the floodplain of the Doring River. Associated with the understorey beneath these trees are also plants adapted to shade such as the grass, *Setaria verticillata* The grass layer interspersed in the thicket layer is also dense and dominated by a variety of grasses which include climax grasses such as *Themeda triandra, Cymbopogon pospischillii, Eragrostis chloromelas, Digitaria eriantha, Fingerhuthia africana* and *Themeda triandra* while pioneer grasses are also common and include *Aristida congesta, Chloris virgata, Eragrostis echinochloide, Melinis nerviglumis* and *Eragrostis gummiflua*. This is indicative of a natural grass layer but with a level of disturbance also present which is characteristic of the vegetation type in the area but is also a consequence of overgrazing and trampling by domestic livestock. It is also notable that a few riparian grasses which are listed as Facultative Wetland grasses are also abundant in the area. These include *Panicum coloratum, Setaria sphacelatum* and *Cynodon dactylon*. This also indicates the presence of a floodplain and areas of higher moisture regime where a shallow groundwater table may be present. It will therefore also be important for the development to undertake a 1:100 floodline determination in order for the development to remain outside the floodplain of the river or implement sufficient mitigation to offset the impact. A significant herbaceous component is also imbedded within the grass layer and include species such as *Nidorella resedifolia, Solanum incanum, Blepharis subvolubilis, Gomphocarpus fruticosus, Hermannia depressa, Sebaea pentandra, Salvia verbenaca* and *Arctotis arctotoides*. Many of these are also pioneer species and while they are characteristic of the local vegetation type, they also indicate a low level of disturbance. The Highveld Alluvial Vegetation type in this region is also associated with a prominent geophytic component (plants with underground storage organs) and this was also the case for the site. Geophytic species observe include *Moraea pallida, Oxalis depressa, Boophone distichia, Eriospermum porphyrium, Colchicum burkei, Eucomis autumnalis, Bulbine abyssinica* and *Chlorophytum sp.* Of these, *B. distichia* and *E. autumnalis* are also listed as protected in the Free State Province and are therefore of significant conservation value. Where the development will affect these species, permits will also have to

be obtained and affected plants transplanted to adjacent areas where they will remain unaffected. A few small specimens of the protected Wild Olive Tree (*Olea europaea* susp. *africana*) also occur on the site and permits will also have to be obtained to remove these. As indicated, some disturbance is present in the area and the natural vegetation type is also characterised by the establishment of some weeds. As a result, several exotic weeds are present on the site and include *Bidens bipinnata, Tagetes minuta, Conyza bonariensis, Opuntia humifusa, Xanthium spinosum, Verbena bonariensis* and *Verbena tenuisecta*. Where degradation is evident, such as the tailings dump on the site, more invasive plants have also established such as *Melia azedarach, Tamarix chinensis* and *Cortaderia selloana*.

The vegetation on the site is clearly still natural and is mostly affiliated with Highveld Alluvial Vegetation though it does also contain elements of Central Free State Grassland. Both of these vegetation types are however listed as being of Least Concern (LC) and does not significantly contribute toward the sites conservation value. Though natural, the vegetation on the site also contains a significant degree of disturbance. The site also does not contain a significant species diversity and does not contain elements of high conservation value. However, as a natural area it must retain at least a Moderate level of sensitivity.

Figure 7: The thicket vegetation on the site can become quite dense in some areas and is characteristic of Highveld Alluvial Vegetation type.

Figure 8: Areas of open grassland is also present and is then more characteristic of Central Free State Grassland.

Figure 9: A panorama of the site clearly illustrates the mosaic vegetation pattern of thicket and open grassland.

Conclusions

4.2 Overview of terrestrial fauna (actual & possible)

Signs and tracks of mammals are present on the site but notably less when compared to the natural condition. This is most likely a consequence of the proximity of the mining operations and frequent human activities in the area. Being dominated by natural vegetation the site itself will therefore still have capacity for a natural mammal population though the actual mammal population will be smaller and dominated by generalist species. . Rare and endangered mammals are often reclusive and avoid areas in close proximity to human activities and are also dependant on habitat in pristine condition. Such species are therefore considered unlikely to occur in the area though the Doring River may still provide suitable habitat for Cape Clawless Otter (*Aonyx capensis*) though should remain largely unaffected by the development as long as the development footprint is kept outside the 1:100 year floodline of the river.

Wetland and riparian habitats also generally provide a higher abundance of resources and subsequently are also able to sustain a diverse and large mammal population (Appendix A: Map 3). This will also be the case for the Doring River adjacent to the site. It is therefore also important that this system not be affected by the development. As long as the development footprint is kept outside the 1:100 year floodline of the river, the impact on the mammal population along the river should remain low.

The mammal survey of the site was conducted by means of active searching and recording any tracks or signs of mammals and actual observations of mammals. From the survey the following actual observations of mammals were recorded:

- Soil mounds of the Common Molerat (*Cryptomys hottentotus*) were common in most areas of the study area. This is a widespread species which has even become adapted to urban areas. It is a generalist species anticipated to occur in this area.

- Scat and burrows of Yellow Mongoose (*Cynictis penicillata*) occur in the study area. This species is widespread and common and found in most natural or disturbed habitats.

- Several burrows of small mammals were noted which could not be identified but do indicate a significant mammal population in the area.

- Observation of a Steenbok (*Raphicerus campestris*). This species is widespread but confined to fairly natural or agricultural areas and generally avoid urban areas.\

- An active burrow of Aardvark (*Orycteropus afer*) occurs in the study area. This is also a fairly widespread and common species but is highly reclusive and is also listed as a protected species and is therefore of significant conservation value.

These species identified on the site indicate only a moderate species diversity of largely widespread and generalist species and is indicative of a modified natural mammal population. A similar mammal population should also be able to re-establish in the solar development footprint after construction has taken place.

The most significant impact on mammals anticipated on the site itself is primarily concerned with the loss and fragmentation of available habitat. Transformation of the natural vegetation on the site will result in a decrease in the population size as available habitat decreases. As indicated, the site does still consist of natural vegetation though it is still fairly uniform and with moderate habitat diversity and consequently the mammal population is also not anticipated to be diverse. The impact on the loss of habitat would therefore be significant but is unlikely exceed high values. In addition, extensive natural areas still remain in the surroundings into which mammals on the site move to without resulting in high habitat pressures.

It is also considered likely that several mammal species were overlooked during the survey and it may also be likely that other rare and endangered species may be present on the site.

Construction itself may also affect the mammal population and care should therefore be taken to ensure none of the faunal species on site is harmed. The hunting, capturing or harming in any way of mammals on the site should not be allowed. Voids and excavations may also act as pitfall traps to fauna and these should continuously be monitored and any trapped fauna removed and released in adjacent natural areas.

Mammals species likely to occur on the site has been determined by means of FitzPatrick Institute of African Ornithology (2022).

Table 2: Red Listed mammals occurring or likely to occur in the study area (Child *et al* 2016).

Scientific name	Common name	Status
Mystromys albicaudatus	African White-tailed Rat	**Vulnerable (VU)**
Damaliscus lunatus lunatus	(Southern African) Tsessebe	**Vulnerable (VU)**
Hippotragus equinus	Roan Antelope	**Endangered (EN)**
Hippotragus niger niger	Sable Antelope	**Vulnerable (VU)**
Kobus leche	Lechwe	**Near Threatened (NT)**
Pelea capreolus	Vaal Rhebok	**Near Threatened (NT)**
Felis nigripes	Black-footed Cat	**Vulnerable (VU)**
Hyaena brunnea	Brown Hyena	**Near Threatened (NT)**

The survey has indicated that though the mammal population will consist largely of widespread, generalist species, there remains a low likelihood that some of these Red Listed species may occur in the area.

Table 3: Likely mammal species in the region.

Family	Scientific name	Common name	Status
Bathyergidae	*Cryptomys hottentotus*	Southern African Mole-rat	Least Concern
Bovidae	*Aepyceros melampus*	Impala	Least Concern
	Alcelaphus buselaphus	Hartebeest	Least Concern
	Antidorcas marsupialis	Springbok	Least Concern
	Connochaetes gnou	Black Wildebeest	Least Concern
	Connochaetes taurinus taurinus		Least Concern
	Damaliscus lunatus lunatus	(Southern African) Tsessebe	**Vulnerable**
	Damaliscus pygargus phillipsi	Blesbok	Least Concern
	Hippotragus equinus	Roan Antelope	**Endangered**
	Hippotragus niger niger	Sable Antelope	**Vulnerable**
	Kobus ellipsiprymnus ellipsiprymnus		Least Concern
	Kobus leche	Lechwe	**Near Threatened**
	Oryx gazella	Gemsbok	Least Concern
	Pelea capreolus	Vaal Rhebok	**Near Threatened**
	Raphicerus campestris	Steenbok	Least Concern
	Redunca arundinum	Southern Reedbuck	Least Concern
	Redunca fulvorufula	Mountain Reedbuck	Least Concern
	Sylvicapra grimmia	Bush Duiker	Least Concern
	Syncerus caffer	African Buffalo	Least Concern
	Taurotragus oryx	Common Eland	Least Concern
	Tragelaphus angasii	Nyala	Least Concern
	Tragelaphus scriptus	Bushbuck	Least Concern
	Tragelaphus strepsiceros	Greater Kudu	Least Concern
Canidae	*Canis mesomelas*	Black-backed Jackal	Least Concern
	Vulpes chama	Cape Fox	Least Concern
Cercopithecidae	*Chlorocebus pygerythrus*	Vervet Monkey	Least Concern
Equidae	*Equus quagga*	Plains Zebra	Least Concern
Felidae	*Felis nigripes*	Black-footed Cat	**Vulnerable**
Giraffidae	*Giraffa giraffa giraffa*	South African Giraffe	Least Concern
Herpestidae	*Cynictis penicillata*	Yellow Mongoose	Least Concern
	Herpestes sanguineus	Slender Mongoose	Least Concern
	Suricata suricatta	Meerkat	Least Concern
Hippopotamidae	*Hippopotamus amphibius*	Common Hippopotamus	Least Concern

Hyaenidae	*Hyaena brunnea*	Brown Hyena	**Near Threatened**
	Proteles cristata	Aardwolf	Least Concern
Hystricidae	*Hystrix africaeaustralis*	Cape Porcupine	Least Concern
Leporidae	*Lepus capensis*	Cape Hare	Least Concern
	Lepus saxatilis	Scrub Hare	Least Concern
Muridae	*Aethomys namaquensis*	Namaqua Rock Mouse	Least Concern
	Gerbilliscus brantsii	Highveld Gerbil	Least Concern
	Mastomys coucha	Southern African Mastomys	Least Concern
	Rhabdomys dilectus	Mesic Four-striped Grass Rat	Least Concern
	Rhabdomys pumilio	Xeric Four-striped Grass Rat	Least Concern
Mustelidae	*Ictonyx striatus*	Striped Polecat	Least Concern
Nesomyidae	*Mystromys albicaudatus*	African White-tailed Rat	**Vulnerable**
Sciuridae	*Xerus inauris*	South African Ground Squirrel	Least Concern
Suidae	*Phacochoerus africanus*	Common Warthog	Least Concern
Thryonomyidae	*Thryonomys swinderianus*	Greater Cane Rat	Least Concern
Viverridae	*Genetta genetta*	Common Genet	Least Concern

From historical records (Table 3) it is evident that the area contains a large amount of mammals and numerous Red Listed mammals. Of these the larger antelope are however historical records and would only be found within conservation areas, they are not of consequence to the development. The smaller Red Listed mammal species may still occur in the area, including the Black-footed Cat (*Felis nigripes*), Brown Hyena (*Hyaena brunnea*), and African White-tailed Rat (*Mystromys albicaudatus*). These species are considered somewhat unlikely to occur in the area though this likelihood cannot be completely discounted and the anticipated impact will remain moderate.

A note should also be made of the Sungazer Lizard (*Smaug giganteus*). This is a highly endangered reptile known to occur in the sandy grassland habitats of this region. The survey also specifically targeted this species but was found to be absent from the area. The habitat on the site is also unsuitable for this species while its distribution range is also situated to the north of the site. It is therefore not relevant to this development.

Figure 11: Tracks and signs of mammals on the site include from top to bottom; Scat and scratchings of a Yellow Mongoose (*Cynictis penicillata*), Burrow of an unidentified small rodent, a Steenbok (*Raphicerus campestris*) and burrow of an Aardvark (*Orycteropus afer*).

4.3 Wetland Assessment

4.3.1 Introduction

The surface water features of the study area is dominated by the Doring River which is situated adjacent to the site along its eastern, northern and western borders and may in some areas occur in close proximity to it. Associated with the Doring River is an extensive floodplain which may also extend onto the site. This is also dependent on the 1:100 year floodline of this watercourse. Within this floodplain an area of temporary saturation has also been identified which forms part of a floodplain wetland area although observed wetland conditions are only of a temporary nature and this area is therefore not clearly defined. The river itself is a tributary of the Sand River and is therefore a smaller system though still significant. It is regarded as perennial or nearly so, flowing for the most part of the year. The river also drains a large catchment which seems to be largely natural and the river should therefore be in a quite good condition, however, immediate upstream gold mining operations does seem to significantly contribute toward poor water quality which is likely to have a significant affect on it. The assessment will therefore be based on the Doring River and its associated floodplain.

The term watercourse refers to a river, stream, wetland or pan. The National Water Act (NWA, 1998) includes rivers, streams, pans and wetlands in the definition of the term watercourse. This definition follows:

Watercourse means:

- A river or spring.
- A natural channel in which water flows regularly or intermittently.
- A wetland, lake or dam into which water flows.
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The classification of stream orders from 1 to 3 can be illustrated by means of the Strahler 1952 classification. The Doring River is considered a second order watercourse, flowing into the Sand River to the north which is a third order system.

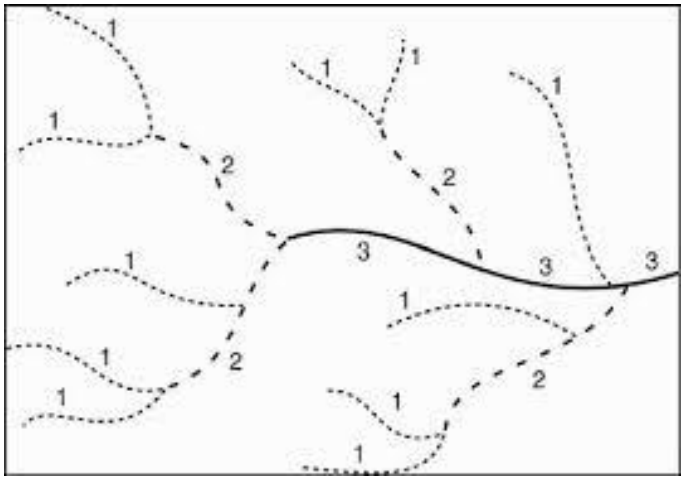


Figure 12: The classification of stream orders from 1 to 3 (Strahler 1952).

4.3.2 Wetland indicators

Riparian habitat is an accepted indicator of watercourses used to delineate the extent of wetlands, rivers, streams and pans (Department of Water Affairs and Forestry 2005). The Doring River and associated floodplain was delineated by use of topography (land form and drainage pattern) and obligate wetland vegetation with limited soil sampling (Appendix C). Due to time constraints and the extent of the study area soil samples were only taken along a few lateral transects of the Doring River to confirm the presence of wetland conditions. The following guidelines and frameworks were used to determine and delineate the watercourses and wetlands in the study area:

- Department of Water Affairs and Forestry. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Edition 1. Department of Water Affairs and Forestry, Pretoria.
- Marnewecke & Kotze 1999. Appendix W6: Guidelines for delineation of wetland boundary and wetland zones. In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

Obligate wetland vegetation was utilised to determine the presence and border of wetland conditions (Appendix B). Due to time constraints soil samples were only taken along a few transects of the Doring River and its associated floodplain. Soil samples were investigated for the presence of anaerobic evidence which characterises wetland soils (Appendix C).

The vegetation survey indicated that obligate wetland vegetation occurs along the banks of the Doring River but does not extend into the floodplain. The floodplain of the river is dominated by alluvial clays which, although they do not contain wetland conditions, are clearly a consequence of alluvial deposition after flooding and which confirms the presence of an extensive floodplain. However, a portion in the north eastern corner of the site contains a grassy floodplain where Facultative Wetland grasses dominate and which therefore indicates a temporary wetland zone. This was also confirmed by soil samples which confirmed temporary soil saturation.

4.3.3 Classification of wetland systems

The wetland conditions associated with the Doring River as well as its floodplain can be classified into a specific wetland type.

The wetland conditions associated with the main channel and banks of the Doring River can be characterised as a channel wetland system (SANBI 2009):

"An open conduit with clearly defined margins that (i) continuously or periodically contains flowing water, or (ii) forms a connecting link between two water bodies. Dominant water sources include concentrated surface flow from upstream channels and tributaries, diffuse surface flow or interflow, and/or groundwater flow. Water moves through the system as concentrated flow and usually exits as such but can exit as diffuse surface flow because of a sudden change in gradient. Unidirectional channel-contained horizontal flow characterises the hydrodynamic nature of these units. Note that, for purposes of the classification system, channels generally refer to rivers or streams (including those that have been canalised) that are subject to concentrated flow on a continuous basis or periodically during flooding, as opposed to being characterised by diffuse flow (see unchannelled valley-bottom wetland). As a result of the erosive forces associated with concentrated flow, channels characteristically have relatively obvious active channel banks. An active channel is a channel that is inundated at sufficiently regular intervals to maintain channel form and keep the channel free of established terrestrial vegetation. These channels are typically filled to capacity during bankfull discharge (i.e. during the annual flood, except for intermittent rivers that do not flood annually)."

This accurately describes the channel of the river system. The wetland conditions are confined to the main channel which experiences surface flow on a perennial basis (Appendix A: Map 1). Here wetland conditions are most prominent along the main channel and decrease in distance from the channel.

The wetland areas forming within the floodplain of the Doring River situated in the north east of the site can be categorised as a floodplain wetland (SANBI 2009):

"A floodplain wetland and lowland river floodplain: the mostly flat or gently sloping wetland area adjacent to and formed by a lowland floodplain river and subject to periodic inundation by overtopping of the channel bank of the river. The location of the wetland adjacent to the river in

the lowland floodplain zone is the key criterion for distinguishing a floodplain wetland from a channelled valley-bottom wetland. Water and sediment input to floodplain wetland areas is mainly via overtopping of a major channel, although there could be some overland or subsurface flow from adjacent valley side-slopes (if present). Water movement through the wetland is dominantly horizontal and bidirectional, in the form of diffuse surface flow and interflow, although there can be significant temporary containment of water in depressional areas (within which water movement is dominantly vertical and bidirectional). Water generally exits as diffuse surface flow and/or interflow, but infiltration and evaporation of water from a floodplain wetland can also be significant, particularly if there are a number of depressional areas within the wetland."

This description fits the wetland conditions in the north eastern portion of the floodplain well. Here, a flat grassy area adjacent to the main channel contains temporary saturation which leads to the establishment of temporary wetland conditions. The river is situated within surrounding plains and though hills and ridges occur to the north, it still forms part of a lowland system, also confirmed by the lowland Sand River situated to the north. This floodplain wetland area also contains a very flat topography, one of the main criterions of a floodplain wetland. This floodplain portion is most probably fed largely by overland flow though overtopping into the floodplain will occur on a very infrequent basis, i.e. during 1:100 year flooding events. The floodplain wetland discharges by diffuse flow though erosional features at its north western end also indicate concentrated flow toward the river.

4.2.4 Description of watercourses and wetlands

The study area is dominated by the Doring River which occurs along the eastern, northern and western borders of the site. An extensive floodplain is also present. A short description of the Doring River and floodplain wetland area will be provided below.

Obligate wetland vegetation was also used to determine the presence of wetland conditions. Obligate wetland species are confined to wetlands and are only able to occur in wetlands. They are therefore reliable indicators of wetland conditions. Field observations over time as well as the following sources were used to determine FW and OW species:

- Marnewecke, G. & Kotze, D. 1999. Appendix W6: Guidelines for delineation of wetland boundary and wetland zones. In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

- DWAF. 2008. Updated manual for the identification and delineation of wetlands and riparian areas, prepared by M.Rountree, A.L. Batchelor, J. MacKenzie and D. Hoare. Stream Flow Reduction Activities, Department of Water Affairs and Forestry, Pretoria, South Africa.

- Van Ginkel, C.E. & Cilliers, C.J. 2020. Aquatic and wetland plants of Southern Africa. Briza Publications, Pretoria.

Table 4: Description of the individual watercourses and wetlands which forms part of the study area (Appendix A: Map 3) (FW – Facultative wetland species, OW – Obligate wetland species, * - Exotic species).

Watercourse name:	**Coordinates of sampling:**	**Flow regime:**

#1 Doring River – a mostly perennial and prominent watercourse	S 28.243091°, E 26.834375° S 28.248495°, E 26.820406°	Perennial

Description of watercourse at the site:

A lateral transect to the north and west of the site along the floodplain and to the main channel was taken for the Doring River. This provides a fairly good description of the banks of the river, the floodplain and the current impacts affecting the system.

The river is still fairly natural, especially when considering the catchment which is still largely natural. However, the main channel does indicate at least some contamination caused by upstream seepage of mining areas. The likelihood that the Joel, Beatrix and Oryx mines are causing pollution of the Doring River has also been confirmed by DWS (2015). Other lesser impacts in the area include a few dirt tracks that act as obstructions to surface flow and trampling caused by domestic livestock which leads to a decrease in riparian vegetation and increased sedimentation of the river. These impacts will contribute to at least some modification of the system.

The river contains a clearly defined, fairly deep main channel with distinct riparian zonation. It follows a meandering flow pattern though generally flows from south east to north west. The river also drains into the Sand River approximately 20 km to the north west of the site. The channel of the river is prominent and fairly wide at approximately 8 meters. An extensive floodplain is situated along the river though the exact border could not be accurately determined. The area is dominated by alluvial soils and thicket which all indicate the presence of a riparian zone though the exact border of the floodplain should be determined by a 1:100 year floodline determination. Toward the north east of the site the floodplain also contains temporary wetland conditions which indicate the presence of a floodplain wetland. Also refer to Section 4.3.5 for a description of the current impacts on the stream. The development should, as far possible, refrain from encroaching into the 1:100 year floodline of the river and where it will not be possible to completely avoid the floodline of the river, that the necessary flood protection structures be implemented.

Obligate wetland vegetation dominates along the main channel, which include a variety of sedges, rushes and grasses in the marginal zone while dense aquatic vegetation may also be present in some portions of the stream. Dense algal mats were also notable and may be a consequence of increase nutrient inflow caused by upstream impacts. The lower zone is also dominated by many obligate wetland plants such as sedges and grasses with terrestrial plants being largely absent. This indicates wetland conditions extending up the banks of the river. The upper zone also contains some obligate wetland plants though terrestrial species are quite abundant and dominates in many areas. This indicates a decrease in the moisture regime in the upper zone which contains only a temporary zone of wetness. Riparian trees and shrubs dominate in the upper zone while being absent in the other zones. However, the floodplain is dominated by thicket which is fairly dense overall. Here terrestrial plants dominate though it was noted that patches of higher moisture regime do also contain facultative wetland grasses which indicate a higher moisture regime in the floodplain. Overall, the species composition along the river and floodplain is in a relatively natural condition although exotic weeds are also quite abundant. This is however to be expected within the riparian thicket. The system is therefore still considered to largely natural although some disturbance is evident. The border between the floodplain or riparian zone and the surrounding terrestrial areas are not well defined with the area being dominated by alluvial clay soils. The approximate floodplain has been delineated though a 1:100 year floodline determination should also be undertaken to

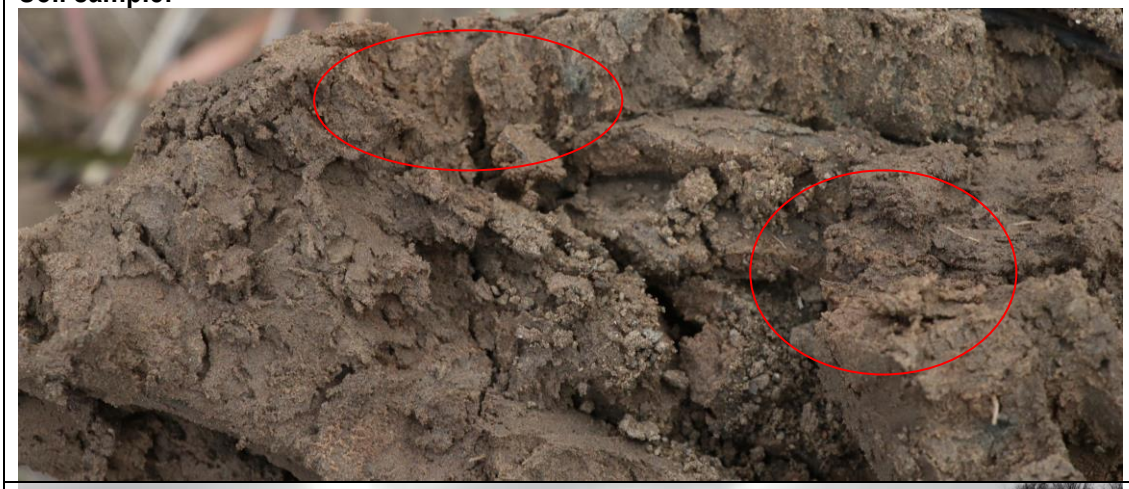
accurately determine the extent that flooding may occur.

Dominant plant species:
Riverbanks: *Artemisia afra, Imperata cylindria* (OW), *Equisetum ramosissimum* var. *ramosissimum, Cyperus marginatus* (OW), *Celtis africana, Pergularia daemia, Typha capensis* (OW).

Floodplain: *Berkheya radula, Setaria verticillata, Gomphocarpus fruticosus, Cynodon dactylon, Ziziphus mucronata, Setaria sphacelata* (FW), *Diospyros lycioides, Vachellia karroo, Salsola rabieana, Microloma aramatum, Kalanchoe rotundifolia.*

Protected plant species:
Pergularia daemia, Microloma armatum.

Soil sample:



The Doring River contains a prominent and fairly wide channel with steep banks.

Dense riparian thicket is clearly present in the floodplain though the border with the surrounding terrestrial areas are not well defined.

Flooding within the river can be extensive during the riany season, here indicated by the level of flood debris in trees (red).

Dense algal mats in the main channel indicate high levels of nutrients which may be consequence of upstream mining impacts.

Watercourse name:	**Coordinates of sampling:**	**Flow regime:**
#2 Floodplain wetland – Area of temporary saturation in the north east of the site	S 28.248697°, E 26.835987° S 28.250044°, E 26.836936°	Temporary

Description of watercourse:

The north eastern portion of the site contains a flat area adjacent to the Doring River which is dominated by facultative wetland grasses and indicates at least temporary saturation during the rainy season. This indicates the presence of a floodplain wetland area. It forms a part of the Doring River but is included separately here in order to give a specific description of this area. It is not a prominent wetland area and is border with surrounding thicket habitats is not well defined though the floodplain wetland itself is still clearly differentiable from the surroundings. This floodplain wetland has an elongated form and drains into the Doring River via an erosion feature in the floodplain. This gulley erosion is a common feature along the watercourses in this region and is still considered as a natural feature. The floodplain wetland has an approximate length of 480 meters. The floodplain wetland is imbedded within the surrounding thicket vegetation but is clearly differentiated from it in that it is almost devoid of trees and shrubs (a possible consequence of temporary saturation) while it is dominated by facultative wetland grasses. This also confirms at least temporary wetland conditions. It will also form part of the floodplain of the river and it is recommended that this portion be completely excluded from development.

The floodplain wetland is a completely flat area situated within the floodplain, adjacent to the river and corresponds well with the characteristics of a floodplain wetland. Vegetation also consists of facultative wetland grasses and therefore indicate at least temporary saturation though it is clear that prominent wetland areas are not present. Soil samples also indicate soils with a very high clay content and with feint mottling also being visible. This also confirms the presence of temporary wetland conditions.

Dominant plant species:

Setaria sphacelata (FW), *Panicum coloratum* (FW).

Protected plant species:

None observed.

Soil sample:

The floodplain wetland clearly do not contain prominent wetland conditions but is dominated by dense facultative grasses which indicate a temporary zone of saturation. Note also the absence of trees and shrubs.

The floodplain wetland also drains into the Doring River via an erosional feature at the north western end.

4.3.5 Condition and importance of the affected watercourse

The determination of the condition of the watercourses and wetlands on the site will consist only of the Doring River. The aim is to provide an overall overview of the condition of the Doring River in the study area. Determination of the condition will be based on an overall determination of the Index of Habitat Integrity (IHI) (Appendix D). This will also take into account upstream impacts as well as impacts within the catchment. This is considered to give a good representation of the condition of this river. The IHI will be taken as representative of the Present Ecological State (PES) of the river system at the site.

Table 5 refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative to the natural or close to the natural reference condition. The purpose of the EcoClassification process is to gain insights and understanding into the causes and sources of the deviation of the PES of biophysical

attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river (Kleynhans & Louw 2007).

Table 6 refers to the Ecological Importance and Sensitivity (EIS) of wetlands. "Ecological importance" of a water resource is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. "Ecological sensitivity" refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. The Ecological Importance and Sensitivity (EIS) provides a guideline for determination of the Ecological Management Class (EMC).

Table 5: Ecological categories for Present Ecological Status (PES).

Ecological Category	Description
A	Unmodified, natural
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominately unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem function has occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Table 6: Ecological importance and sensitivity categories.

Ecological Importance and Sensitivity Category (EIS)	Range of Median	Recommended Ecological Management Class
Very High Wetlands that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these wetlands is usually very sensitive to flow and habitat modifications.	>3 and <=4	A
High Wetlands that are considered to be ecologically important and sensitive. The biodiversity of these wetlands may be sensitive to flow and habitat modifications.	>2 and <=3	B
Moderate Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications.	>1 and <=2	C
Low/marginal Wetlands that are not ecologically important and sensitive at	>0 and <=1	D

any scale. The biodiversity of these wetlands is ubiquitous and not sensitive to flow and habitat modifications.		

According to previous desktop assessments (Kleynhans 2000, Van Deventer *et al* 2018) the Doring River near the site is considered to have a PES varying from Category D: Largely Modified according to the former to Category B: Largely Natural according to the latter assessment. This does indicate the desktop uncertainty with regards to the condition of the system. The more recent desktop assessment (Van Deventer *et al* 2018) is considered the more accurate of the two as it is similar to the results of the current assessment. It is evident that the river system provides vital services including water transportation, storm water, wetland and riparian habitats and groundwater recharge. The entire system should therefore still be considered as sensitive and the impact caused by solar development should be prevented as far as possible. It is therefore recommended that the exact border of the floodplain should be determined by a 1:100 year floodline determination. The development should, as far possible, refrain from encroaching into the 1:100 year floodline of the river and where it will not be possible to completely avoid the floodline of the river, that the necessary flood protection structures be implemented.

As indicated above, the Doring River is still considered to fairly natural though it is affected by a few significant impacts. A summary of the impacts will be provided in the following paragraphs.

The upstream catchment of the river is largely intact and affected by only a few significant impacts (Appendix A: Map 2). The river contains no signifciant impoundments upstream of the site and is therefore still largely unregulated. A few small cropfields are notable in the floodplain and catchment upstream of the site and these will have some impact on the functioning of the river. These cultivated areas will contribute to a fairly low degree towards the removal of the natural vegetation layer, which in turn promotes runoff while decreasing infiltration and this again results in higher erosion rates, which increases both the inflow into the river system, as well as the sediment load within the river. Coupled with this will also be fertiliser runoff, which will increase the nutrient load in the river. Other smaller impacts which will also affect the river include a few low water dirt road crossings which will act as flow obstructions, will result in retardation of flow and consequently will impact on the flow and flooding regime of the river. Trampling by domestic livestock will also contribute toward a decrease riparian vegetation and higher sediment loads within the river.

Figure 13: The catchment of the Doring River is clearly still largely natural though note some agricultural fields upstream as well as a few road crossings (Google Earth 2022).

The immediate surroundings upstream of the site does contain several gold mining areas and this is considered to have several significant impacts on the river. Several areas contain oxidation ponds and containment ponds associated with the mining operations and it is also highly likely that seepage from these areas will enter the Doring River. This also seems to be affecting the water quality within the river which contain dense algal mats and a chemical smell. This has also been identified as a highly likely source by the Department of Water and Sanitation (2015) which has recommended prioritising water quality sampling downstream of the Joel, Beatrix and Oryx mines to determine and monitor the extent contamination.

Figure 14: Oxidation and containment ponds are highly likely to seep into and affect the water quality of the Doring River.

Figure 15: The main channel contains dense algal mats which are indicative of a high nutrient content and also has a chemical smell indicating likely contamination.

From the above described impacts it should be clear that the Doring is still largely natural though being affected by a few large impacts which does result in significant modification. An Index of Habitat Integrity (IHI) was conducted for the river system itself and indicated that it has an Instream IHI of Category B/C: Largely Natural to Moderately Modified and Riparian IHI of Category C: Moderately Modified. This is considered accurate given the still largely natural catchment and unregulated flow while mining will still contribute significant impacts on it.

The EI&S of the Doring River has been rated as being Moderate: Floodplains that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these floodplains are not usually sensitive to flow and habitat modifications.

4.3.6 Risk Assessment

5. ANTICIPATED IMPACTS

6. BIODIVERSITY SENSITIVITY RATING (BSR)

Habitat diversity and species richness:
The site itself is dominated by a mosaic of thicket and grassland and represents a moderate habitat diversity. As a result, species diversity on the site also fairly uniform and does not exceed moderate values. The Doring River and its banks significantly contribute toward habitat and species diversity but does not form part of the development footprint.

Presence of rare and endangered species:
The remaining natural vegetation on the site is generally fairly uniform and species diversity remain moderate over the entire site. There are however still a few protected plant species and these also retain a significant conservation value. These include *Boophone distichia, Eucomis autumnalis* and *Olea europaea* subsp. *africana*.

Ecological function:
The ecological function of the site is still largely intact though some modification, mostly of the surroundings are present. The site functions as habitat for a variety of fauna, supports specific vegetation types and also function in support of the Doring River adjacent to the site. The river itself also maintains several vital functions such as water transportation, wetland and aquatic habitats and bio-remediation and it is therefore crucial that the development not affect this functioning. This should be doable as long as the development does not encroach into the riparian zone of 1:100 year floodline. The surrounding mining transformation contributes to the modification of the functioning of the site as habitat for fauna though the site itself does still support the natural vegetation type. Overall the ecological functioning of the site is considered moderately modified.

Degree of rarity/conservation value:
The natural vegetation types in the area, Highveld Alluvial Vegetation and Central Free State Grassland are both only listed as being of Least Concern and is therefore not of high conservation value.

According to the Free State Province Biodiversity Management Plan (2015) the site for the proposed solar development is listed as being an Ecological Support Areas 1 & 2 (ESA 1 & 2) (Appendix A: Map 3). This indicates that the area is not essential to meeting conservation targets but forms part of the functioning of the Doring River adjacent to the site and as a result does provide important functions in the support of this system.

From the above the site does not seem to have a high conservation value, however, it is clear that the Doring River provides vital services including water transportation, storm water, wetland and riparian habitats and groundwater recharge and therefore has a very high conservation value. As long as the development, refrains from encroaching into the 1:100 year floodline of the river it should not affect the conservation of it.

Overall the site is therefore considered as having a moderate conservation value.

Percentage ground cover:

The percentage vegetation cover on the site still largely natural though disturbances on and adjacent to the development area such as tailings and mining operations does influence the natural vegetation cover.

Vegetation structure:
The vegetation types in the area is characterised by grassland and thicket habitats both which are well represented on the site. However, a increased establishment of thicket, especially the *Vachellia karroo* trees are likely and therefore a moderate modification of the vegetation structure is considered likely.

Infestation with exotic weeds and invader plants:
The site contains a moderate establishment of exotic weeds which include *Bidens bipinnata, Tagetes minuta, Conyza bonariensis, Opuntia humifusa, Xanthium spinosum, Verbena bonariensis* and *Verbena tenuisecta*. Where degradation is evident, such as the tailings dump on the site, more invasive plants have also established such as *Melia azedarach, Tamarix chinensis* and *Cortaderia selloana*. These are also well known invasive and problematic plants.

Degree of grazing/browsing impact:
The area is being utilised as grazing for domestic livestock and significant levels of overgrazing and trampling were also noted. It is however still considered to remain at moderate levels.

Signs of erosion:
Signs of erosion is common, though are for the most part still regarded as natural. This includes natural gulley erosion within the floodplain of the Doring River. This natural erosion has however been moderately increased by the on-site impacts, notably trampling by domestic livestock.

Terrestrial animals:
Signs and tracks of mammals are present on the site but notably less when compared to the natural condition. This is most likely a consequence of the proximity of the mining operations and frequent human activities in the area. Being dominated by natural vegetation the site itself will therefore still have capacity for a natural mammal population though the actual mammal population will be smaller and dominated by generalist species. . Rare and endangered mammals are often reclusive and avoid areas in close proximity to human activities and are also dependant on habitat in pristine condition. Such species are therefore considered unlikely to occur in the area though the Doring River may still provide suitable habitat for Cape Clawless Otter (*Aonyx capensis*) though should remain largely unaffected by the development as long as the development footprint is kept outside the 1:100 year floodline of the river.

Wetland and riparian habitats also generally provide a higher abundance of resources and subsequently are also able to sustain a diverse and large mammal population (Appendix A: Map 3). This will also be the case for the Doring River adjacent to the site. It is therefore also important that this system not be affected by the development. As long as the development footprint is kept outside the 1:100 year floodline of the river, the impact on the mammal population along the river should remain low.

Table 7: Biodiversity Sensitivity Rating for the proposed solar development.

	Low (3)	Medium (2)	High (1)
Vegetation characteristics			
Habitat diversity & Species richness		2	
Presence of rare and endangered species		2	
Ecological function		2	
Uniqueness/conservation value		2	
Vegetation condition			
Percentage ground cover			1
Vegetation structure		2	
Infestation with exotic weeds and invader plants or encroachers	3		
Degree of grazing/browsing impact		2	
Signs of erosion		2	
Terrestrial animal characteristics			
Presence of rare and endangered species		2	
Sub total	3	16	1
Total		20	

7. BIODIVERSITY SENSITIVITY RATING (BSR) INTERPRETATION

Table 8: Interpretation of Biodiversity Sensitivity Rating.

Site	Score	Site Preference Rating	Value
Harmony Joel PV Solar	20	Good Condition	2

8. DISCUSSION AND CONCLUSION (Appendix A: Map 1 - 4)

9. RECOMMENDATIONS

10. REFERENCES

Bromilow, C. 1995. Problem Plants of South Africa. Briza Publications CC, Cape Town.

Bromilow, C. 2010. Problem plants and alien weeds of South Africa. Briza Publications CC, Cape Town.

Child MF, Roxburgh L, Do Linh San E, Raimondo D, Davies-Mostert HT, editors. The 2016 Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.

Cillié, B. 2018. Mammal guide of Southern Africa. Briza Publications CC, Pretoria.

Coates-Palgrave, M. 2002. Keith Coate-Palgrave Trees of Southern Africa, edn 3, imp. 4 Random House Struik (Pty.) Ltd, Cape Town.

Collins, N.B. 2005. Wetlands: The basics and some more. Free State Department of Tourism, Environmental and Economic Affairs.

Conservation of Agricultural Resources Act, 1983 (ACT No. 43 OF 1983) Department of Agriculture.

Department of Water Affairs and Forestry. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Edition 1. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas, Edition 1. Department of Water Affairs and Forestry, Pretoria.

Duthie, A. 1999. Appendix W5: IER (floodplain and wetlands) determining the Ecological Importance and Sensitivity (EIS) and Ecological Management Class (EMC). In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

DWAF. 2008. Updated manual for the identification and delineation of wetlands and riparian areas, prepared by M.Rountree, A.L. Batchelor, J. MacKenzie and D. Hoare. Stream Flow Reduction Activities, Department of Water Affairs and Forestry, Pretoria, South Africa.

Department of Water and Sanitation. 2015. Review, evaluation and optimisation of the resource monitoring network: Specific Monitoring Requirements.

Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T. 2015. Identification guide to the southern African grasses. An identification manual with keys, descriptions and distributions. *Strelitzia* 36. South African National Biodiversity Institute, Pretoria.

FitzPatrick Institute of African Ornithology (2022). mammalmap Virtual Museum. Accessed at https://vmus.adu.org.za/?vm=mammalmap on 2022-08-15.

Gerber, A., Cilliers, C.J., Van Ginkel, C. & Glen, R. 2004. Easy identification of aquatic plants. Department of Water Affairs, Pretoria.

Government of South Africa. 2008. National Protected Area Expansion Strategy for South Africa 2008: Priorities for expanding the protected area network for ecological sustainability and climate change adaptation. Government of South Africa, Pretoria.

Germishuizen, G. & Meyer, N.L. (eds) 2003. Plants of Southern Africa: an annotated checklist. *Strelitzia* 14. National Botanical Institute, Pretoria.

Gibbs Russell, G.E., Watson, L., Koekemoer, M., Smook, L., Barker, N.P., Anderson, H.M. & Dallwitz, M.J. 1990. Grasses of Southern Africa. Memoirs of the Botanical Survey of South Africa No. 58. Botanical Research Institute, South Africa.

Google Earth V 7.3.4.8642. 2022. Harmony Joel Gold Plant, South Africa. S 28.251485°, E 26.828992°. Eye alt. 4.62 km. Maxar Technologies 2022. http://www.earth.google.com (August 2022).

Government of South Africa. 2008. National Protected Area Expansion Strategy for South Africa 2008: Priorities for expanding the protected area network for ecological sustainability and climate change adaptation. Government of South Africa, Pretoria.

Griffiths, C., Day, J. & Picker, M. 2015. Freshwater Life: A field guide to the plants and animals of southern Africa. Penguin Random House South Africa (Pty) Ltd, Cape Town.

Kleynhans, C.J. 2000. Desktop estimates of the ecological importance and sensitivity categories (EISC), default ecological management classes (DEMC), present ecological status categories (PESC), present attainable ecological management classes (present AEMC), and best attainable ecological management class (best AEMC) for quaternary catchments in South Africa. DWAF report, Institute for Water Quality Studies, Pretoria, South Africa.

Kleynhans, C.J. & Louw, M.D. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 329/08.

Kleynhans, C.J., Louw, M.D. & Graham, M. 2008. Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical Manual). Joint Water Research Commission and Department of Water Affaris and Forestry Report. WRC Report No. TT 377-08.

Le Maitre, D.C., Seyler, H., Holland, M., Smith-Adao, L., Nel, J.L., Maherry, A. and Witthüser, K. (2018) Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. Report No. TT 743/1/18, Water Research Commission, Pretoria.

Macfarlane, D.M., Ollis, D.J. & Kotze, D.C. 2020. WET-Health (Version 2.0): a refined suite of tools for assessing the present ecological state of wetland ecosystems. WRC Report No. TT 820/20.

Manning, J. 2009. Field Guide to Wild Flowers. Struik Nature, Cape Town.

Marnewecke, G. & Kotze, D. 1999. Appendix W6: Guidelines for delineation of wetland boundary and wetland zones. In: MacKay (Ed.), H. Resource directed measures for protection of water resources: wetland ecosystems. Department of Water Affairs and Forestry, Pretoria.

Moffett, R. 1997. Grasses of the Eastern Free State: Their description and uses. UNIQWA, the Qwa-Qwa campus of the University of the North, Phuthadittjhaba.

Mucina, L. & Rutherford, M.C. (eds.) 2006. The Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19.South African National Biodiversity Institute, Pretoria.

National Environmental Management: Biodiversity Act (10/2004): National list of ecosystems that are threatened and in need of protection. Government Notice 1002 of 2011, Department of Environmental Affairs.

National Environmental Management: Biodiversity Act (10/2004): Publication of lists of critically endangered, endangered, vulnerable and protected species. Government Notice 151 of 2007, Department of Environmental Affairs.

National Water Act (Act No. 36 of 1998). Republic of South Africa.

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. (2011). Technical Report for the National Freshwater Ecosystem Priority Areas project. WRC Report No. K5/1801.

Ollis, D.J., Snaddon, C.D., Job, N.M. & Mbona, N. 2013. Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems. *SANBI Biodiversity Series 22*. South African National Biodiversity Institute, Pretoria.

Pooley, E. 1998. A field guide to wild flowers: Kwazulu-Natal and the Eastern Region. Natal Flora Publications Trust, Durban.

Raymondo, D. Van Staden, L. Foden, W. Victor, J.E. Helme, N.A. Turner, R.C. Kamundi, D.A. Manyama, P.A. (eds.) 2009. Red List of South African Plants. *Strelitzia* 25. South African National Biodiversity Institute, Pretoria.

Retief, E. & Meyer, N.L. 2017. Plants of the Free State: Inventory and identification guide. *Strelitzia* 38. South African National Biodiversity Institute, Pretoria.

SANBI. 2009. Further Development of a Proposed National Wetland Classification System for South Africa. Primary Project Report. Prepared by the Freshwater Consulting Group (FCG) for the South African National Biodiversity Institute (SANBI).

Smithers, R.H.N. 1983. The mammals of the Southern African Subregion. University of Pretoria, Pretoria.

Strahler, A.N. 1952. Hyposometric (area-altitude) analysis of erosional topology. *Geological Society of American Bulletin* 63 (11): 1117-1142.

Van Deventer, H., Smith-Adao, L., Mbona, N., Petersen, C., Skowno, A., Collins, N.B., Grenfell, M., Job, N., Lötter, M., Ollis, D., Scherman, P., Sieben, E., Snaddon, K. 2018. South African Inventory of Inland Aquatic Ecosystems. South African National Biodiversity Institute, Pretoria. Report Number: CSIR report number CSIR/NRE/ECOS/IR/2018/0001/A; SANBI report number http://hdl.handle.net/20.500.12143/5847.

Van Ginkel, C.E. & Cilliers, C.J. 2020. Aquatic and wetland plants of Southern Africa. Briza Publications, Pretoria.

Van Ginkel, C.E., Glen, R.P., Gordon-Grey, K.D., Cilliers, C.J., Musaya, M. & Van Deventer, P.P. 2011. Easy Identification of some South African Wetland Plants. WRC Report No. TT 479/10.

Van Oudtshoorn, F. 2004. Gids tot Grasse van Suider-Afrika. Briza Publications, Pretoria.

Van Wyk, B. & Malan, S. 1998. Field guide to the wild flowers of the Highveld. Struik Publishers, Cape Town.

Van Wyk, B. & Van Wyk, P. 1997. Field guide to trees of Southern Africa. Struik Publishers, Cape Town.

Venter, H.J.T. & Joubert, A.M. 1985. Climbers, trees and shrubs of the Orange Free State. P.J. de Villiers Publishers, Bloemfontein.