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Appendix D11:
Wake Impact Assessment Report

FE De Rust WEF

Wake Impact Assessment Report

April 2023

Requested by:	Energy Team (Pty) Ltd
Prepared by:	EnergieTEAM
Verified by:	Energy Team (Pty) Ltd

Table of Content

Executive summary

The purpose of this wake impact report is to provide an indication of the expected wake impact of the proposed De Rust Wind Energy facility (WEF) on seven surrounding WEFs. This assessment is based on work conducted by EnergieTEAM towards an energy production assessment based on:

- Data provided by two meteorological mast specifically erected for the De Rust WEF project. The wind campaigns started in October 2021 and they still in operation.
- A long-term correlation done between 12 months of the met mast data (February 2022-February 2023) and 20 years of data from ERA5 source (April 2003-April 2023).
- One preliminary layout on Pofadder project with 97 Nordex N163 5700 with 118 m hub height.
- The layouts communicated by developers of the neighbouring WEF projects.
- For these reasons the research of this wake effect study can't be considerate as a final energy production assessment, or a final wake effect calculation. This report indicates the wish to collaborate with EnergyTEAM on the matter of the wake effect between wind farms and must be updated once the wind campaign finishes and the final layout decided.

Project description

The De Rust project is located on the Remaining Extent of the Farm, Houmoed 206, Portion 1 of the farm Houmoed 206, Portion 1 of the farm Samoep 147, Portion 9 of the farm Nouzees 148, approximately 20 kilometers of West of the proposed Korana substation in the Northern Cape province.

The site is situated in the Khai-Ma local municipality near Pofadder within the Namakwa subregion of the Northern Cape. De Rust turbine base elevations range between 950 m to 1060 m above sea level.

A map showing the site is presented below, including the proposed turbines and the surrounding wind farms.

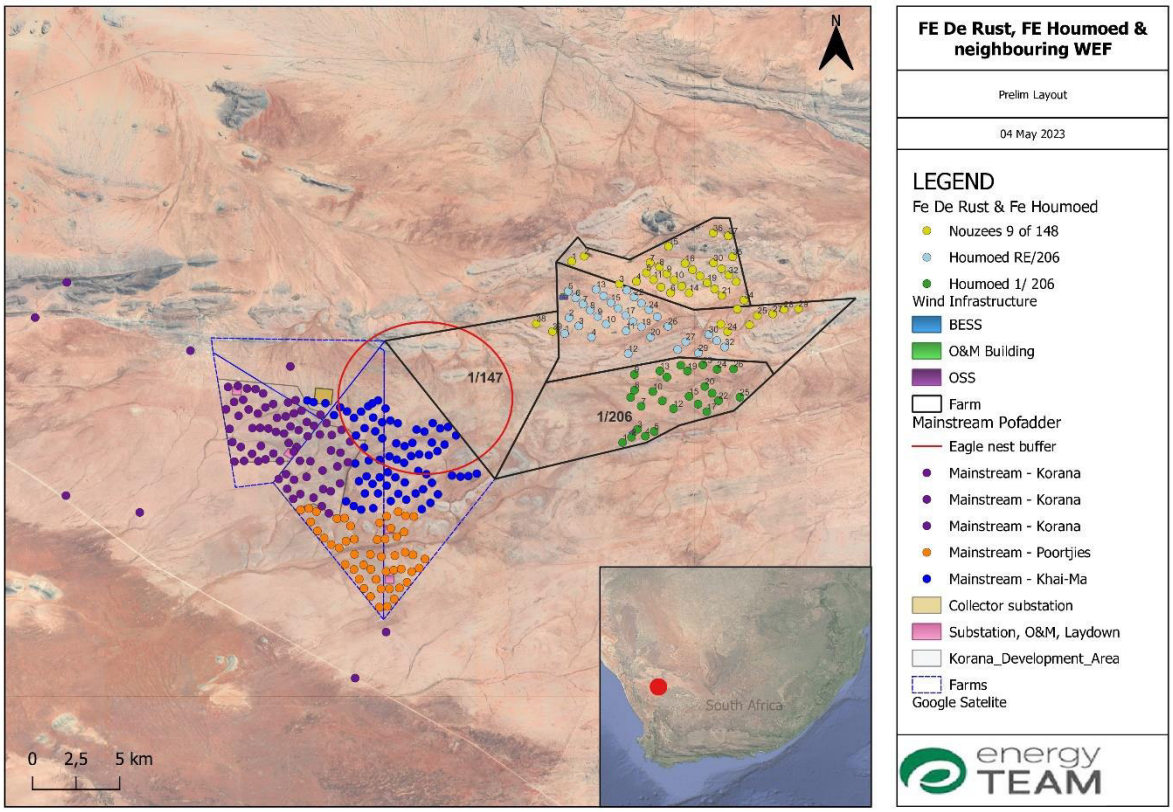


Figure 1. Location FE De Rust & FE Houmoed

The coordinates of the proposed turbines are as follows:

Preliminary De Rust layout for 97 turbines

NAME	POINT_X (Geo – WGS 84)	POINT_Y (Geo – WGS 84)	NAME	POINT_X (Geo – WGS 84)	POINT_Y (Geo – WGS 84)	NAME	POINT_X (Geo – WGS 84)	POINT_Y (Geo – WGS 84)
P1 - 1	19,433290° E	-29,249941° N	**P1 - 35**	19,528506° E	29,247229° N	**P2 - 30**	19,514402° E	-29,293261° N
P1 - 2	19,440745° E	-29,246972° N	**P1 - 36**	19,517012° E	-29,233302° N	**P2 - 31**	19,519142° E	-29,296886° N
P1 - 3	19,461503° E	-29,263402° N	**P1 - 37**	19,525961° E	-29,234948° N	**P2 - 32**	19,523805° E	-29,300655° N
P1 - 4	19,471615° E	-29,261833° N	**P1 - 38**	19,412397° E	-29,286801° N	**P3 -1**	19,463383° E	-29,357139° N
P1 - 5	19,477549° E	-29,256789° N	**P1 - 39**	19,421992° E	-29,291500° N	**P3 -2**	19,468662° E	-29,353973° N
P1 - 6	19,491794° E	-29,268613° N	**P2 - 1**	19,429152° E	-29,292716° N	**P3 -3**	19,472216° E	-29,349335° N
P1 - 7	19,479702° E	-29,250882° N	**P2 - 2**	19,431752° E	-29,283325° N	**P3 -4**	19,476862° E	-29,353421° N
P1 - 8	19,485214° E	-29,253375° N	**P2 - 3**	19,437578° E	-29,288157° N	**P3 -5**	19,482129° E	-29,350534° N
P1 - 9	19,489555° E	-29,257415° N	**P2 - 4**	19,445015° E	-29,294839° N	**P3 -6**	19,468165° E	-29,330461° N
P1 - 10	19,494003° E	-29,260964° N	**P2 - 5**	19,431218° E	-29,267682° N	**P3 -7**	19,474419° E	-29,335698° N
P1 - 11	19,481717° E	-29,260862° N	**P2 - 6**	19,435665° E	-29,271579° N	**P3 -8**	19,470508° E	-29,326175° N
P1 - 12	19,486122° E	-29,265273° N	**P2 - 7**	19,440016° E	-29,275226° N	**P3 -9**	19,470362° E	-29,316921° N
P1 - 13	19,498362° E	-29,264798° N	**P2 - 8**	19,444235° E	-29,278970° N	**P3 -10**	19,481317° E	-29,327053° N
P1 - 14	19,502790° E	-29,268673° N	**P2 - 9**	19,448658° E	-29,282679° N	**P3 -11**	19,486860° E	-29,332529° N
P1 - 15	19,490601° E	-29,241185° N	**P2 - 10**	19,453701° E	-29,287182° N	**P3 -12**	19,493519° E	-29,337123° N
P1 - 16	19,500386° E	-29,251184° N	**P2 - 11**	19,465499° E	-29,291130° N	**P3 -13**	19,485478° E	-29,314834° N
P1 - 17	19,504744° E	-29,254990° N	**P2 - 12**	19,466739° E	-29,304557° N	**P3 -14**	19,489653° E	-29,318476° N
P1 - 18	19,509155° E	-29,258779° N	**P2 - 13**	19,447797° E	-29,266617° N	**P3 -15**	19,502721° E	-29,329844° N
P1 - 19	19,513403° E	-29,262661° N	**P2 - 14**	19,452188° E	-29,270450° N	**P3 -16**	19,508011° E	-29,334438° N
P1 - 20	19,517830° E	-29,266422° N	**P2 - 15**	19,456518° E	-29,274387° N	**P3 -17**	19,513230° E	-29,338947° N
P1 - 21	19,522148° E	-29,270187° N	**P2 - 16**	19,460877° E	-29,277909° N	**P3 -18**	19,497791° E	-29,311516° N
P1 - 22	19,531265° E	-29,278192° N	**P2 - 17**	19,465229° E	-29,282030° N	**P3 -19**	19,501805° E	-29,314877° N
P1 - 23	19,521510° E	-29,287213° N	**P2 - 18**	19,469626° E	-29,285639° N	**P3 -20**	19,512030° E	-29,323969° N
P1 - 24	19,525516° E	-29,291547° N	**P2 - 19**	19,474547° E	-29,288732° N	**P3 -21**	19,516361° E	-29,327990° N
P1 - 25	19,543149° E	-29,282114° N	**P2 - 20**	19,479990° E	-29,294707° N	**P3 -22**	19,520221° E	-29,332353° N
P1 - 26	19,538504° E	-29,287614° N	**P2 - 21**	19,465973° E	-29,267084° N	**P3 -23**	19,510803° E	-29,311278° N
P1 - 27	19,552249° E	-29,281097° N	**P2 - 22**	19,470220° E	-29,271070° N	**P3 -24**	19,519326° E	-29,313831° N
P1 - 28	19,558835° E	-29,278396° N	**P2 - 23**	19,474597° E	-29,274774° N	**P3 -25**	19,532789° E	-29,330338° N
P1 - 29	19,567462° E	-29,278046° N	**P2 - 24**	19,478940° E	-29,278601° N	**P3 -26**	19,529077° E	-29,313628° N
P1 - 30	19,517196° E	-29,250891° N	**P2 - 25**	19,483914° E	-29,282843° N			
P1 - 31	19,521876° E	-29,254438° N	**P2 - 26**	19,490248° E	-29,288435° N			
P1 - 32	19,526175° E	-29,258212° N	**P2 - 27**	19,500753° E	-29,297584° N			
P1 - 33	19,530627° E	-29,261970° N	**P2 - 28**	19,496005° E	-29,302159° N			
P1 - 34	19,535236° E	-29,272946° N	**P2 - 29**	19,508301° E	-29,304131° N			

Table 1. Turbines coordinates FE De Rust WEF

The configuration of three wind farms considered in the wake assessments are:

- **Khai-Ma** (proposed) - Turbine locations and turbine model are provided by Mainstream consisting of 71 Nordex N163 5700, with a hub height of 118 m.
- **Korana** (proposed) - Turbine locations and turbine model are provided by Mainstream consisting of 69 Nordex N163 5700, with a hub height of 118m.
- **Poortjies** (proposed) - Turbine locations and turbine model are provided by Mainstream consisting of 50 Nordex N163 5700, with a hub height of 118 m.

Moreover, a second scenario has been studied, in which it has been considered that Khai-Ma would only have 37 turbines because of the eagle nest.

The coordinates for the above mentioned turbines are indicated in Appendix 1.

Wake Analysis

Modelled wake losses

Wind turbine extract energy from the wind and downstream there is a wake from the wind turbine where the wind speed is reduced. As the flow proceeds downstream, there is a spreading of the wake and the wake recovers towards free stream conditions. The wake effect loss is the aggregated influence on the energy production of the wind farm which results from changes in wind speed caused by the impact of the turbines on each other. These effects are calculated using the WindPro computational model. The wind flow modelling is calculated after processing of site data.

Conventional Eddy Viscosity wake calculation

The Eddy Viscosity wake model is a CFD calculation representing the development to the velocity deficit field using a finite-difference solution of the thin shear layer equation of the Navier-Stokes equation in axi-symmetric co-ordinates.

The Eddy Viscosity model automatically observes the conservation of mass and momentum in the wake.

An Eddy Viscosity, averaged across each downstream wake section, is used to relate the shear stress to gradient of velocity deficit.

The mean filed can be obtained by a linear superposition of the wake deficit field and the incident wind flow.

The Eddy Viscosity model with WindPro is employed in a scheme which, taking each wind speed and direction in turn calculates the wake loss and power production of a project. The important parameters used in the process are:

- Turbine layout and inter-turbine spacing;
- Adjusted wind speed rom site wind flow calculations;
- Ambien turbulence profile;
- Wind turbine thrust characteristic;
- Wind turbine power characteristic; and
- Rotor speed characteristic.

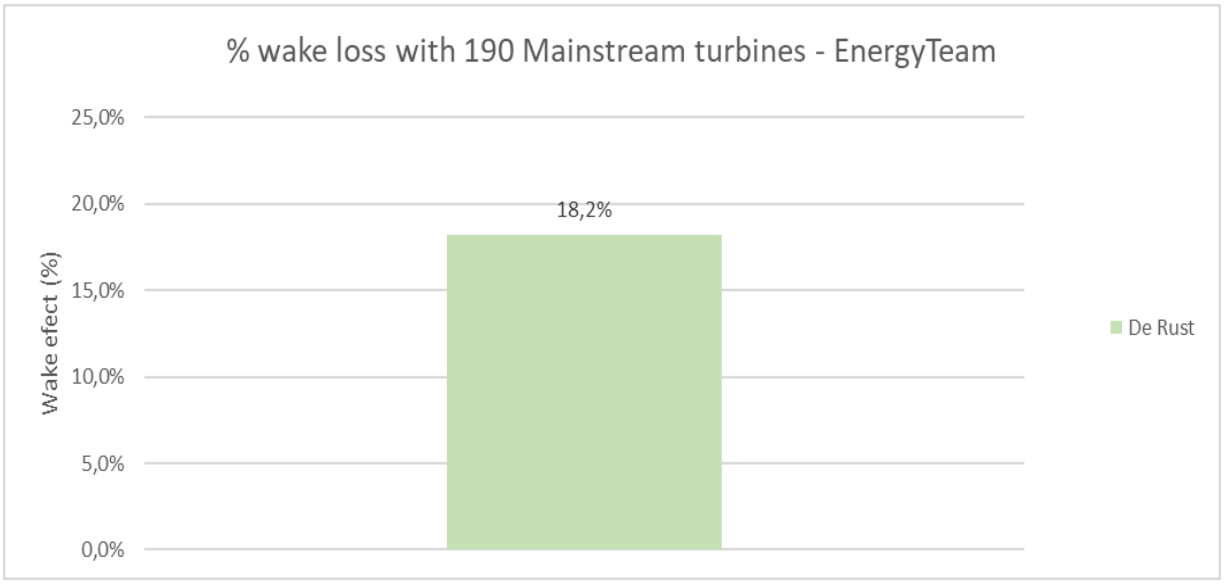
Any air density adjustments required due to differences between the hub-height air density at the turbine locations and at the reference mast location is applied and included in the array effect.

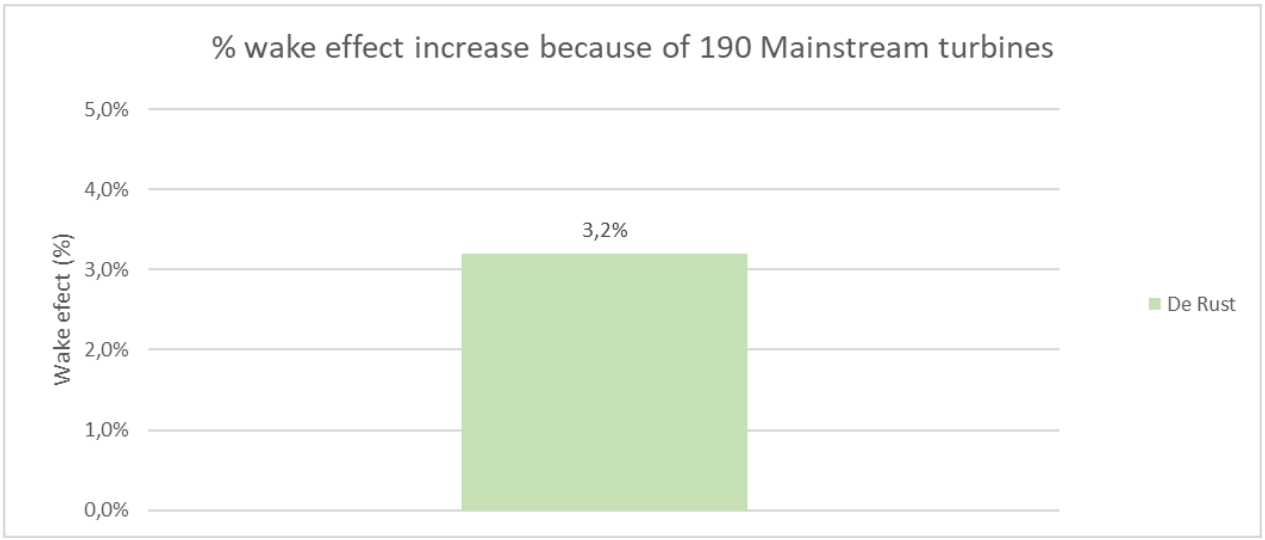
The Large Wind Farm (LWF) had no effect on the wake effect. For this reason, it wasn't considered in the calculation.

External wake estimates

To assess the magnitude of the effect of neighbouring wind farms on the energy production of De Rust Wind Farms the methodology described above has been applied and the results are shown in the tables and graphs below:

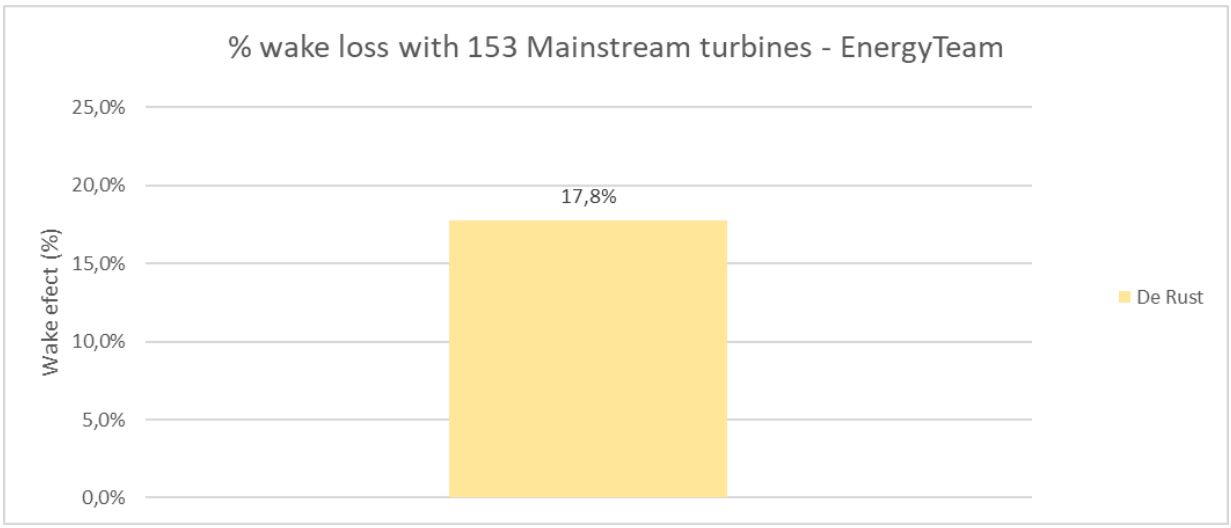
FE De Rust	% wake loss
FE De Rust with Mainstream wind farms (190xN163 5.7 MW – 200 mbp)	18,2%
FE De Rust without any Mainstream wind farms	15,0%
Impact of Mainstream wind farms on FE de Rust 97xN163 5.7 MW	3,2%

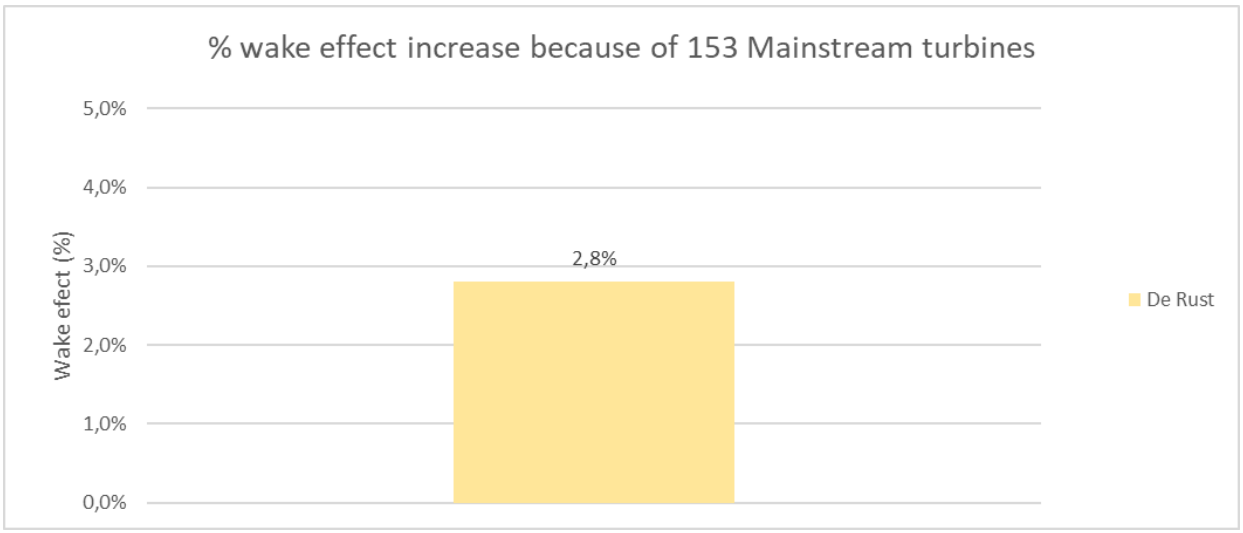




If Khai-Ma turbines are reduce to 31 because of the eagle nest, the wake effect assessment would be as follow:

FE De Rust	% wake loss
FE De Rust with Mainstream wind farms (153xN163 5.7 MW – 200 mbp)	17,8%
FE De Rust without any Mainstream wind farms	15,0%
Impact of Mainstream wind farms on FE de Rust 97xN163 5.7 MW	2,8%





To assess the magnitude of the effect of De Rust Wind Farms on the energy production of neighbouring wind farms, the methodology described above has been applied and the results are shown in the tables and graphs below:

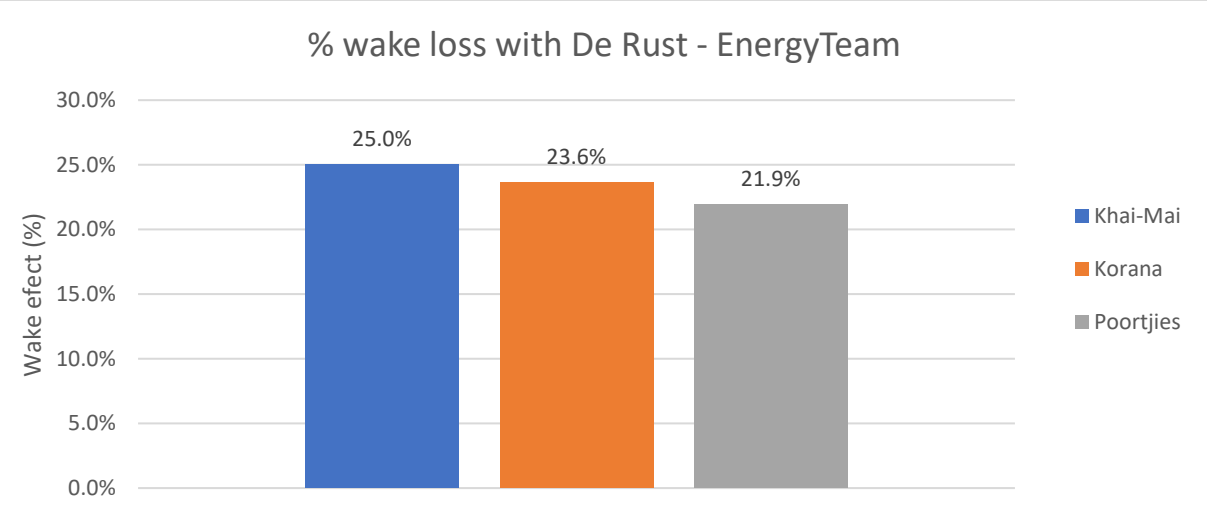
Khai-Ma	% wake loss
Khai-Ma with all wind farms except FE de Rust	24,2%
Khai-Ma with all wind farms (including FE de Rust 97xN163 5.7 MW)	25,0%
Impact of FE de Rust 97xN163 5.7 MW	0,8%

Korana	% wake loss
Korana with all wind farms except FE de Rust	23,0%
Korana with all wind farms (including FE de Rust 97xN163 5.7 MW)	23,6%
Impact of FE de Rust 97xN163 5.7 MW	0,6%

Poortjies	% wake loss
Poortjies with all wind farms except FE de Rust	21,1%
Poortjies with all wind farms (including FE de Rust 97xN163 5.7 MW)	21,9%
Impact of FE de Rust 97xN163 5.7 MW	0,8%

Figure 2. Predicted external wake loss of De Rust on neighbouring wind farms

In conclusion the proposed De Rust WEF will be affected by Khai-Ma, Korana and Poortjies in terms of wake effect as it has a **3,20%** wake loss. Meanwhile, Khai-Ma, Korana and Poortjies will be affected by De Rust WEF in terms of wake effect as it has a **0,80%** wake loss



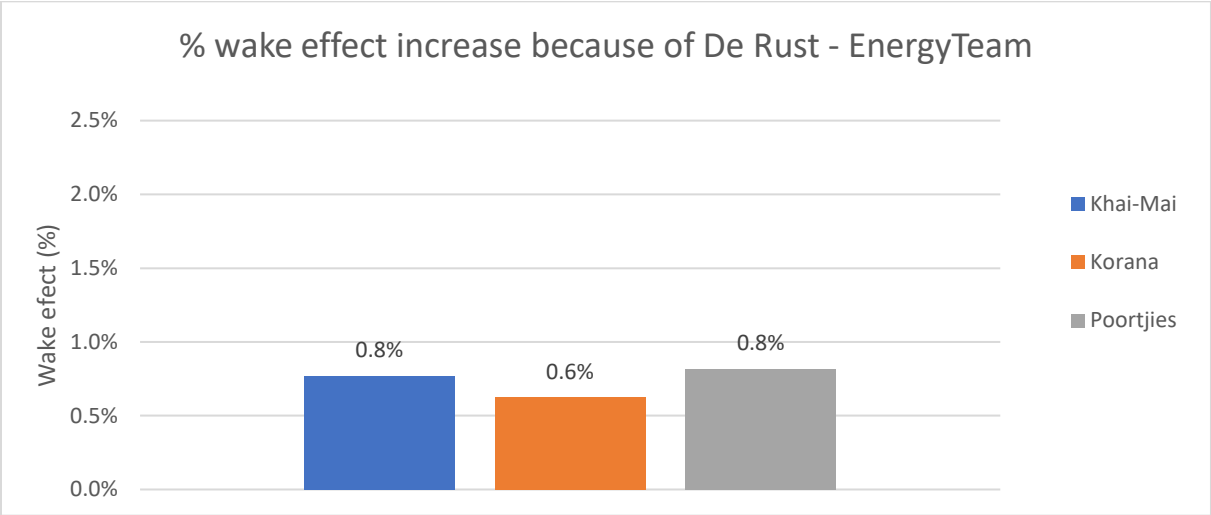


Figure 3. Summary predicted external wake loss of De Rust on neighbouring wind farms

Appendix 1: turbines' coordinates

Khai-Ma turbines coordinates	Longitude (Geo - WGS84)	Latitude (Geo - WGS84)
KM - 1	19,276923°	-29,332272°
KM - 2	19,280701°	-29,333320°
KM - 3	19,287670°	-29,333910°
KM - 4	19,292734°	-29,340946°
KM - 5	19,296342°	-29,336319°
KM - 6	19,300456°	-29,338791°
KM - 7	19,304536°	-29,342530°
KM - 8	19,308769°	-29,338904°
KM - 9	19,312958°	-29,335669°
KM - 10	19,305742°	-29,352943°
KM - 11	19,310825°	-29,348653°
KM - 12	19,315416°	-29,333995°
KM - 13	19,318808°	-29,332252°
KM - 14	19,315918°	-29,342409°
KM - 15	19,317143°	-29,350556°
KM - 16	19,321210°	-29,345179°
KM - 17	19,323214°	-29,336992°
KM - 18	19,326037°	-29,344153°
KM - 19	19,330452°	-29,345763°
KM - 20	19,321259°	-29,354728°
KM - 21	19,329545°	-29,357601°
KM - 22	19,334484°	-29,359302°
KM - 23	19,339107°	-29,357375°
KM - 24	19,341525°	-29,349448°
KM - 25	19,346197°	-29,350700°
KM - 26	19,351116°	-29,345696°
KM - 27	19,355525°	-29,348777°
KM - 28	19,360170°	-29,347931°
KM - 29	19,310472°	-29,360148°
KM - 30	19,325471°	-29,365341°
KM - 31	19,329834°	-29,367243°
KM - 32	19,334191°	-29,369141°
KM - 33	19,338319°	-29,365150°
KM - 34	19,343118°	-29,364106°
KM - 35	19,348809°	-29,364632°
KM - 36	19,350618°	-29,357176°

KM - 37	19,353903°	-29,362281°
KM - 38	19,358103°	-29,358359°
KM - 39	19,364909°	-29,352942°
KM - 40	19,313261°	-29,367761°
KM - 41	19,319748°	-29,367370°
KM - 42	19,305293°	-29,369515°
KM - 43	19,307472°	-29,380024°
KM - 44	19,312001°	-29,377134°
KM - 45	19,311011°	-29,387256°
KM - 46	19,315540°	-29,381599°
KM - 47	19,319757°	-29,377725°
KM - 48	19,324642°	-29,374710°
KM - 49	19,329004°	-29,377724°
KM - 50	19,323897°	-29,382645°
KM - 51	19,318779°	-29,387247°
KM - 52	19,299877°	-29,391952°
KM - 53	19,304402°	-29,394700°
KM - 54	19,308813°	-29,396804°
KM - 55	19,315952°	-29,395983°
KM - 56	19,344639°	-29,396567°
KM - 57	19,349754°	-29,392819°
KM - 58	19,354177°	-29,387751°
KM - 59	19,335461°	-29,390925°
KM - 60	19,341012°	-29,387277°
KM - 61	19,345445°	-29,384780°
KM - 62	19,350658°	-29,380948°
KM - 63	19,326285°	-29,391766°
KM - 64	19,330743°	-29,387481°
KM - 65	19,334605°	-29,380762°
KM - 66	19,342568°	-29,373924°
KM - 67	19,347379°	-29,375881°
KM - 68	19,362528°	-29,376698°
KM - 69	19,367539°	-29,377343°
KM - 70	19,372208°	-29,376995°
KM - 71	19,377193°	-29,375543°

Korana turbines coordinates	Longitude (Geo - WGS84)	Latitude (Geo - WGS84)
K1	19,230053°	-29,324323°
K2	19,235881°	-29,323635°
K3	19,241302°	-29,325212°
K4	19,246310°	-29,325551°
K5	19,250817°	-29,328114°
K6	19,228857°	-29,337498°
K7	19,233645°	-29,333150°
K8	19,239001°	-29,331862°
K9	19,230989°	-29,349081°
K10	19,236336°	-29,341330°
K11	19,242249°	-29,337593°
K12	19,247692°	-29,339990°
K13	19,252132°	-29,336401°
K14	19,256743°	-29,334402°
K15	19,265575°	-29,333428°
K16	19,273486°	-29,338346°
K17	19,284731°	-29,340740°
K18	19,270048°	-29,332138°
K19	19,244473°	-29,348633°
K20	19,249042°	-29,348477°
K21	19,253880°	-29,348877°
K22	19,259078°	-29,342526°
K23	19,264179°	-29,341737°
K24	19,269004°	-29,339914°
K25	19,280910°	-29,347301°
K26	19,270648°	-29,359761°
K27	19,265911°	-29,357377°
K28	19,268918°	-29,362538°
K29	19,256884°	-29,363649°
K30	19,260803°	-29,368020°
K31	19,232656°	-29,356875°
K32	19,237597°	-29,359744°
K33	19,244278°	-29,363806°
K34	19,249490°	-29,359196°
K35	19,233840°	-29,368420°
K36	19,239522°	-29,368021°
K37	19,247931°	-29,368180°
K38	19,276632°	-29,345006°

K39	19,277192°	-29,353405°
K40	19,271823°	-29,349836°
K41	19,267001°	-29,347614°
K42	19,258441°	-29,350865°
K43	19,263177°	-29,351818°
K44	19,252259°	-29,367082°
K45	19,272554°	-29,367944°
K46	19,278741°	-29,368224°
K47	19,288289°	-29,345747°
K48	19,297180°	-29,349653°
K49	19,291413°	-29,352721°
K50	19,284357°	-29,352367°
K51	19,290933°	-29,361871°
K52	19,296547°	-29,363198°
K53	19,302240°	-29,356557°
K54	19,300998°	-29,368821°
K55	19,294738°	-29,371278°
K56	19,296258°	-29,381274°
K57	19,285977°	-29,373717°
K58	19,286290°	-29,384707°
K59	19,290793°	-29,385967°
K60	19,289736°	-29,399007°
K61	19,285554°	-29,394800°
K62	19,280606°	-29,389761°
K63	19,276504°	-29,377430°
K64	19,264358°	-29,375883°
K65	19,269096°	-29,379171°
K66	19,260013°	-29,378756°
K67	19,264987°	-29,384498°
K68	19,268609°	-29,390462°
K69	19,272800°	-29,387658°

Poortjies turbines coordinates	Longitude (Geo - WGS84)	Latitude (Geo - WGS84)
P1	19,272956°	-29,397001°
P2	19,277843°	-29,396128°
P3	19,282323°	-29,398044°
P4	19,294457°	-29,402141°
P5	19,298966°	-29,401904°
P6	19,302548°	-29,406514°
P7	19,304715°	-29,414316°
P8	19,299851°	-29,415474°
P9	19,295749°	-29,419454°
P10	19,291012°	-29,417463°
P11	19,286823°	-29,413672°
P12	19,282913°	-29,409409°
P13	19,278908°	-29,404138°
P14	19,318251°	-29,414493°
P15	19,319785°	-29,404592°
P16	19,323878°	-29,400719°
P17	19,330688°	-29,398114°
P18	19,326344°	-29,407862°
P19	19,334972°	-29,400427°
P20	19,339920°	-29,400883°
P21	19,334199°	-29,410034°
P22	19,329976°	-29,412808°
P23	19,322972°	-29,414199°
P24	19,304849°	-29,423185°
P25	19,314281°	-29,423299°
P26	19,320734°	-29,424704°
P27	19,299284°	-29,429261°
P28	19,328725°	-29,423974°
P29	19,334835°	-29,422067°
P30	19,339445°	-29,423581°
P31	19,346530°	-29,426045°
P32	19,304535°	-29,432236°
P33	19,310220°	-29,429535°
P34	19,314547°	-29,432113°
P35	19,307593°	-29,437999°
P36	19,317580°	-29,438051°
P37	19,310440°	-29,443431°
P38	19,320546°	-29,443650°

P39	19,323500°	-29,433396°
P40	19,328007°	-29,432613°
P41	19,332509°	-29,431943°
P42	19,343109°	-29,431388°
P43	19,338673°	-29,433517°
P44	19,325495°	-29,443650°
P45	19,331473°	-29,443146°
P46	19,335904°	-29,439843°
P47	19,314380°	-29,448236°
P48	19,328387°	-29,449693°
P49	19,324210°	-29,454070°
P50	19,319576°	-29,454526°

Appendix 2: ULs' March 2023 Monthly Summary Report

MARCH 2023 MONTHLY SUMMARY REPORT

UL's Data Management Dashboards

PREPARED FOR:
ENERGY TEAM

SAF.00008-POFADDER 1

ISSUE DATE
31-MAR-2023

UL Services Group LLC, 463 New Karner Rd | Albany, NY 12205 | USA
www.ul.com/renewables

EXECUTIVE SUMMARY

This report summarizes the March 2023 wind resource of the proposed SAF.00008-Pofadder 1 Wind Project. Site information, monthly statistics, and a map of the project area with the location of each mast are presented below. The following pages provide a more in-depth summary of the campaign.

Automatic quality controls have excluded invalid data (i.e. icing, or unphysical values). Statistics presented in this report are informative only. Data is fully reviewed and properly cleaned by a wind engineer prior to a resource or energy assessment.

1. PROJECT CHARACTERISTICS

Table 1.1: Site Information

Mast Name	Site Coordinates		Elevation (m)	Period of Record
	Latitude	Longitude		
SAF.00008-Pofadder 1	-29.274	19.461	1075	13-Oct-2021 - 31-Mar-2023

Table 1.2: March 2023 Summary Statistics

Mast Name	Wind Resource				Environmental Parameters	
	Monitoring Height (m)	Average Wind Speed (m/s)	Average Wind Shear Exponent* (Heights)	Prevailing Wind Direction	Temperature** (°C)	Air Density (kg/m^3)
SAF.00008-Pofadder 1	119	7.27	0.15 (119 m / 60 m)	SSE	21.2	1.061

* Only Speeds > 4 m/s in calculation

** Monthly average temperature taken from highest valid sensor

2. MARCH 2023 OBSERVED WIND RESOURCE

Figure 2.1: Daily Mean Wind Speeds

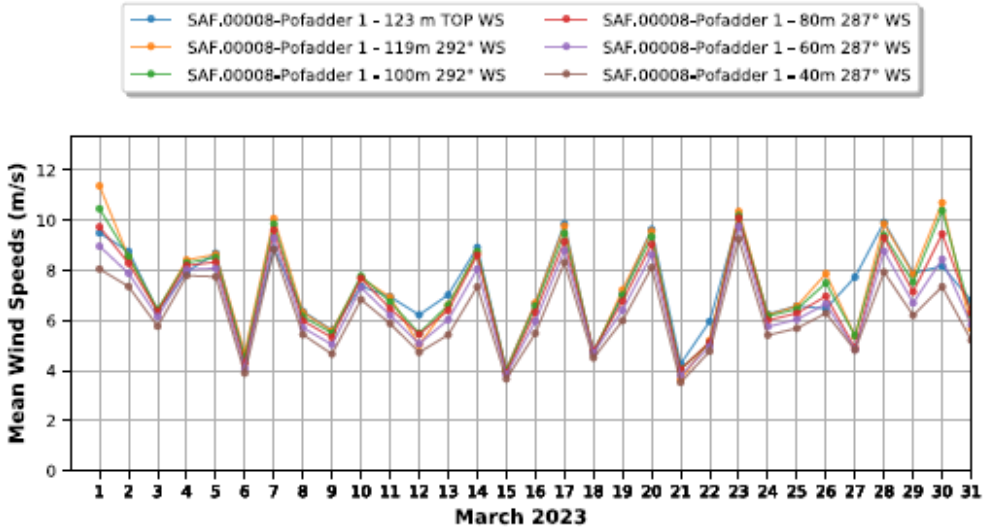


Figure 2.2: Daily Mean Wind Directions

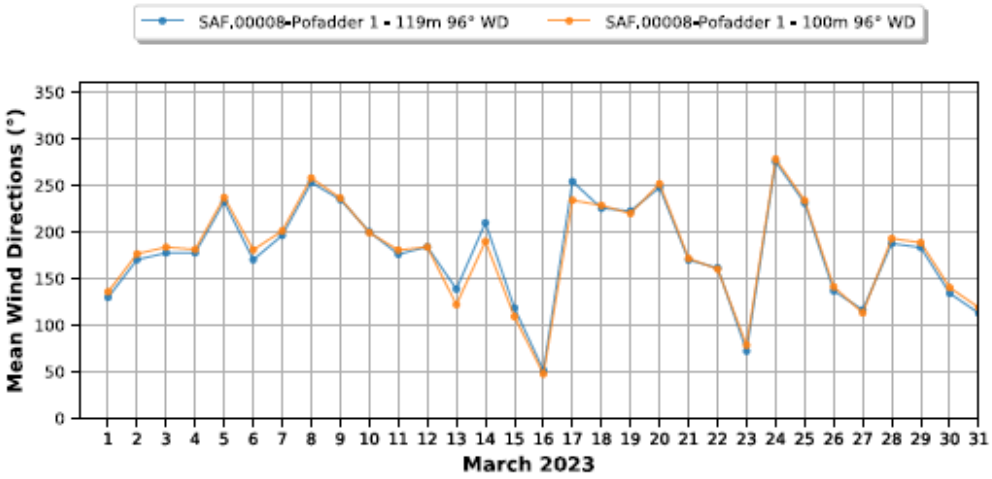


Figure 2.3: Daily Temperature Profile

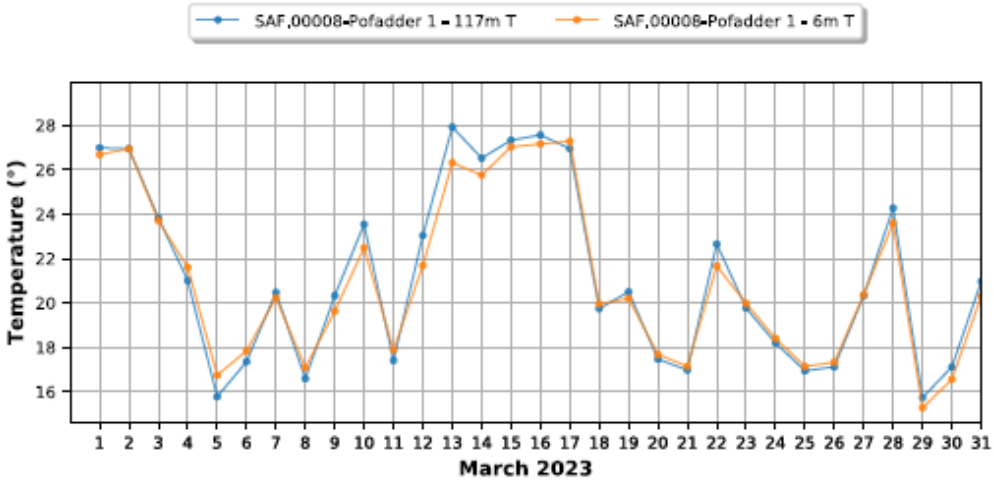


Figure 2.4: Diurnal Profile

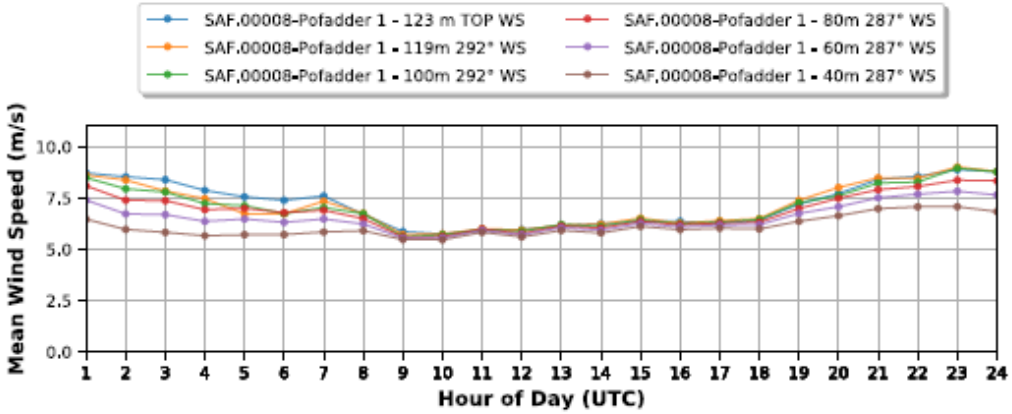


Figure 2.5: Shear Profile

Figure 2.6: SAF.00008-Pofadder 1 Observed Monthly Wind Frequency Distribution at 119m

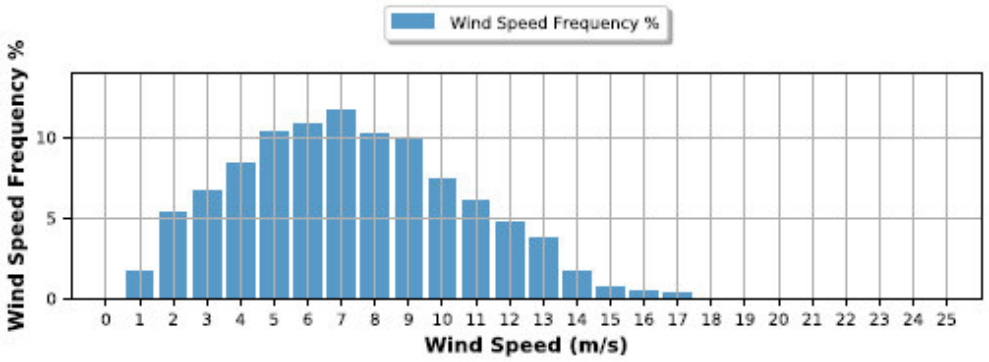
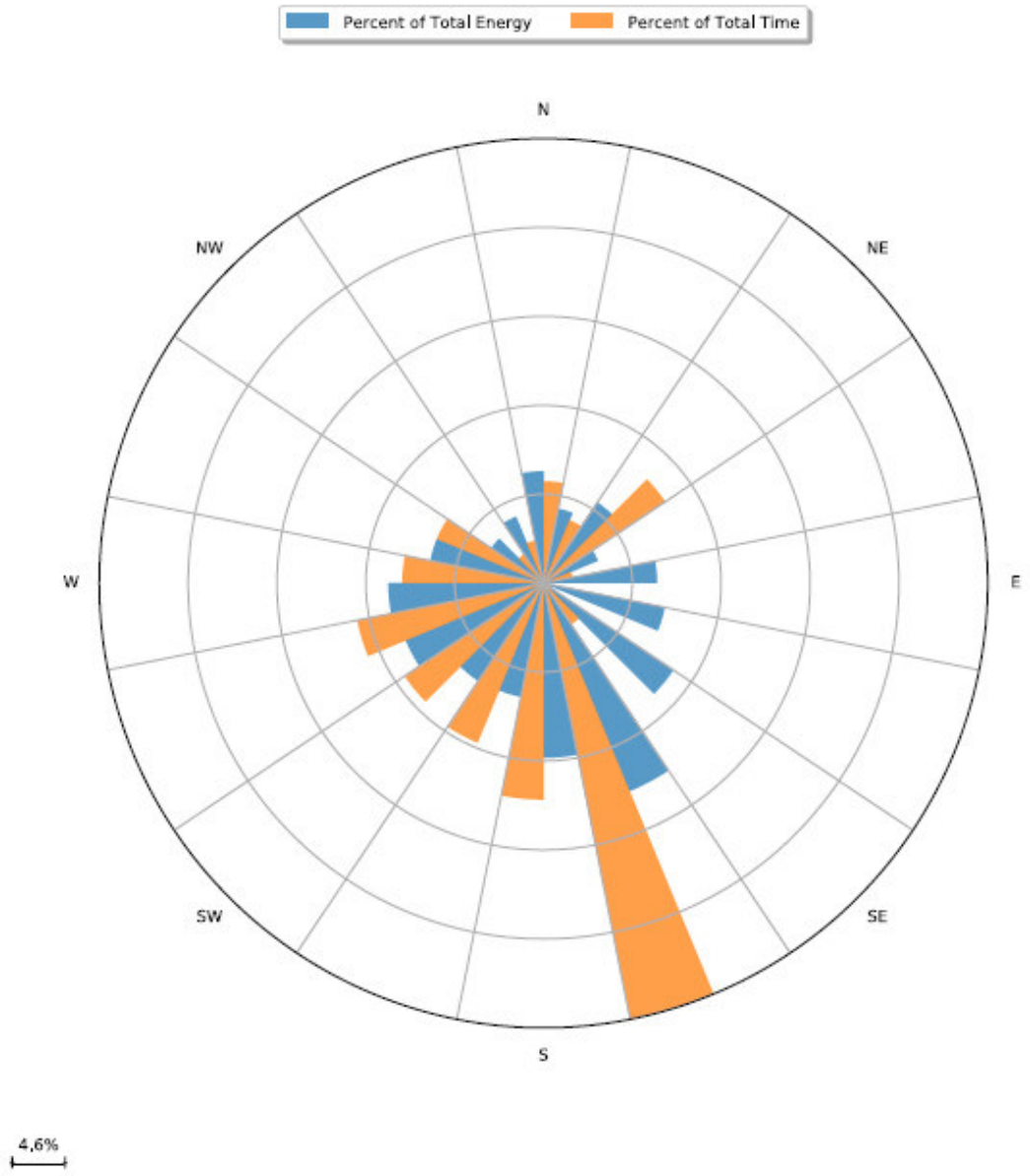


Figure 2.7: Wind Frequency and Energy Rose
SAF.00008-Pofadder 1 at 119m



3. MARCH 2023 SENSOR SUMMARY

Table 3.1: SAF.00008-Pofadder 1 Sensor Summary

Sensor Type	Stream Name	Height (m)	Operation Status	Monthly Average			Data Recovery (%)	Sensor Manufacturer	Installation Date
				Value	Std. Dev	Unit			
Anemometer	123 m TOP WS	123.0	✔	7.25	0.66	m/s	98.1	Thies	10-Sep-2021
	119m 292° WS	119.0	✔	7.27	0.68	m/s	80.7	Thies	10-Sep-2021
	100m 292° WS	100.0	✔	7.2	0.7	m/s	81.2	Thies	10-Sep-2021
	80m 287° WS	80.0	✔	7	0.71	m/s	82.5	Thies	10-Sep-2021
	60m 287° WS	60.0	✔	6.66	0.74	m/s	82.6	Thies	10-Sep-2021
	40m 287° WS	40.0	✔	6.24	0.77	m/s	83	Thies	10-Sep-2021
Wind Vane	119m 96° WD	119.0	✔	179	8	°	98.3	Thies	10-Sep-2021
	100m 96° WD	100.0	✔	180	8	°	98.6	Thies	10-Sep-2021
Temperature	117m T	117.0	✔	21.2	0.0	°C	100	Default TEMP	10-Sep-2021
	6m T	8.0	✔	21.0	0.0	°C	100	Default TEMP	10-Sep-2021
Relative Humidity	117m H	117.0	✔	42.4	0.0	%	100	Default RH	10-Sep-2021
	6m H	8.0	✔	43.4	0.0	%	100	Default RH	10-Sep-2021
Barometer	117m P	117.0	✔	883.4	0.1	mbar	100	Vaisala	10-Sep-2021
Auxiliary	6m Rain	8.0	✔	0	0		100	Rain gauge	10-Sep-2021