Klivaløkshagi - production, noise and shadow

Summary/Conclusion

The wind farm Klivaløkshagi at Sandóy, Faroe Island is analysed. This memo includes a short summary of input data used for the calculations, such as wind statistics, terrain roughness and height contours, hours of sunshine, in addition to guidelines of calculation methods. It also includes a summary of the results.

The layout consists of 7 Vestas V117-4.2MW turbines. A previous layout with 5 turbines in a row has been provided in 2021 and has been extended with additional 2 turbines – one at each end of the row. Noise and shadow receptors are delivered by the customer.

Shadow flicker and noise calculations use updated guidelines from Denmark, from 2022 and 2019/2021 respectively. Calculations are made for both outdoor and indoor shadow flicker, and noise levels at normal and low frequencies.

The analysis shows that none of the buildings included get noise levels or number of hours with shadow flicker above the recommended limits.

WindPRO printout for PARK, DECIBEL and SHADOW calculations are added as appendix, and a overview of production and losses are given in the results chapter.

Version	Date	Description	Prepared by	Checked by	Approved by
J02	2023-12-11	Update of production losses.	Maria Enger Hoem	Marte Sofie Buraas	
J01	2023-11-16	For external use. Summarizing memo for update on previous analyses at Klivaløkshagi.	Maria Enger Hoem, Bendik Alvestad	Hanna Sabelström	

1 Energy, Noise and Shadow calculations

The following calculations are performed in WindPRO for this analysis.

1. PARK
2. DECIBEL normal frequency
3. DECIBEL low frequency
4. SHADOW indoor
5. SHADOW outdoor

1.1 Guidelines for shadow and noise calculations

Guidelines for calculating real case shadow flicker was updated January 2022 and is used for these calculations (Bolig- og Planstyrelsen, 2022). The following methodology is used:

- The recommended maximum time with real case shadow flicker is 10 hours per year.
- Shadow flicker is calculated for outdoor planar areas of 15 m x 15 m at 1 m above the ground. Area defined as “Greenhouse”. If receptors get more then recommended time of shadow flicker, indoor shadow flicker should be calculated as well. *In this analysis indoor shadow flicker has been calculated even though outdoor shadow flicker is far from limit values.*
- For indoor shadow flicker, calculations should be calculated for specific windows according to the guidelines. In early-stage calculations such as this analysis, generic 2 m x 2 m windows placed 1.5 m above the ground is used at the location of nearby buildings. Area defined as “Greenhouse”.
- Topographic height contours should be maximum 5 m equidistant, and topographic shadow is included to reduce shadow flicker from the turbines. These line-of-sight calculations is performed at 1.5 m above ground with a horizontal resolution of minimum 10 m. Obstacles such as other buildings and forest should not be included.
- When the sun is less than 3 degrees above the horizon shadow flicker is not calculated.
- Shadow flicker should be calculated for a distance corresponding to the turbine blade covering minimum 20 % of the sun. This is usually about 2000 m. *In this analysis 2500 m is used as a set distance.*
- Worst case calculations assume that the sun is always shining, turbine always running, and rotor is always oriented perpendicular to receptor. Real case uses local wind and sun statistics.

Calculations of noise from wind turbines are defined in The Windmill Executive Order BEK no. 135 of 7. February 2019 (Miljø- og Fødevareministeriet, 2019), and described further in corresponding guidelines (Miljøstyrelsen, 2021). The following methodology is used:

- Outdoor in noise sensitive area: Maximum noise level at 6 m/s at 10 m height at a receptor is a sound pressure of 37 dB(A), and for 8 m/s at 10 m height it is 39 dB(A).
- Outdoor in open land: Maximum noise level at 6 m/s at 10 m height at a receptor is a sound pressure of 42 dB(A), and for 8 m/s at 10 m height it is 44 dB(A).
- Indoor in noise sensitive area: Maximum low frequency noise level at both 6 m/s and 8 m/s at 10 m height at a receptor is a sound pressure of 20 dB(A).
- The Danish 2019 noise calculation model (corresponding to BEK 135) has been used in the calculations for both normal and low frequencies. The model uses three variable factors:
    - Source noise levels from turbines, either as octave or 1/3 octave data.
    - Hub height of the turbines.
    - Distance between turbine and receptor.
- Noise receptors at 1.5 m above ground.

2 Input data

This chapter presents a short summary of the data used in the calculations of Klivaløkshagi wind farm at Sandóy. Calculations of energy production (park), noise and shadow are performed using the software WindPRO[1].

Power curve, thrust curve and blade data for the turbines are gathered from documentation from turbine manufacturer Vestas in document number 0067-7063 V00. The power curve and thrust curve used is for mode PO1/PO1-0S. Noise data, 1/3 octave data, is gathered from Vestas document number 0067-7587 V02. Noise data used is for mode PO1 and with serrated trailing edge blades (TES).

2.1 Layout and receptors

Energy (park), noise and shadow calculations are performed. Coordinates for the turbine layout and a list of receptors are provided by the Customer. A summary of the layout is presented in Table 1 and its coordinates are given in Table 2. Overview map of measurement mast, turbines and receptors are shown in Figure 2-1.

Table 1: Summary of layout provided by the Customer.

Wind farm	WTGs	Hub height
Klivaløkshagi	7 x V117-4.2MW	91.5 m

Table 2: Coordinates of turbines. Coordinate system WGS 84 UTM Zone 29.

Turbine number	Easting	Northing
1	611989	6859561
2	612188	6859278
3	612386	6858996
4	612584	6858713
5	612782	6858430
6	611791	6859843
7	612981	6858148

Coordinates of the included receptors are given in Table 3. All receptors are assumed to be in noise sensitive areas, with regular dwellings for low frequency noise calculations.

Table 3: Coordinates of receptors for noise and shadow. Coordinate system WGS 84 UTM Zone 29.

Receptor name	Easting	Northing	Comment
A	613979	6857844	Cottage
B	613827	6858343	Cottage
C	613820	6858427	Cottage
D	614296	6857947	Regular
E	614457	6857878	Regular
F	614633	6858383	Regular
G	614101	6860212	Cottage
H	610778	6859169	Cottage

[1] https://www.emd-international.com/windpro/

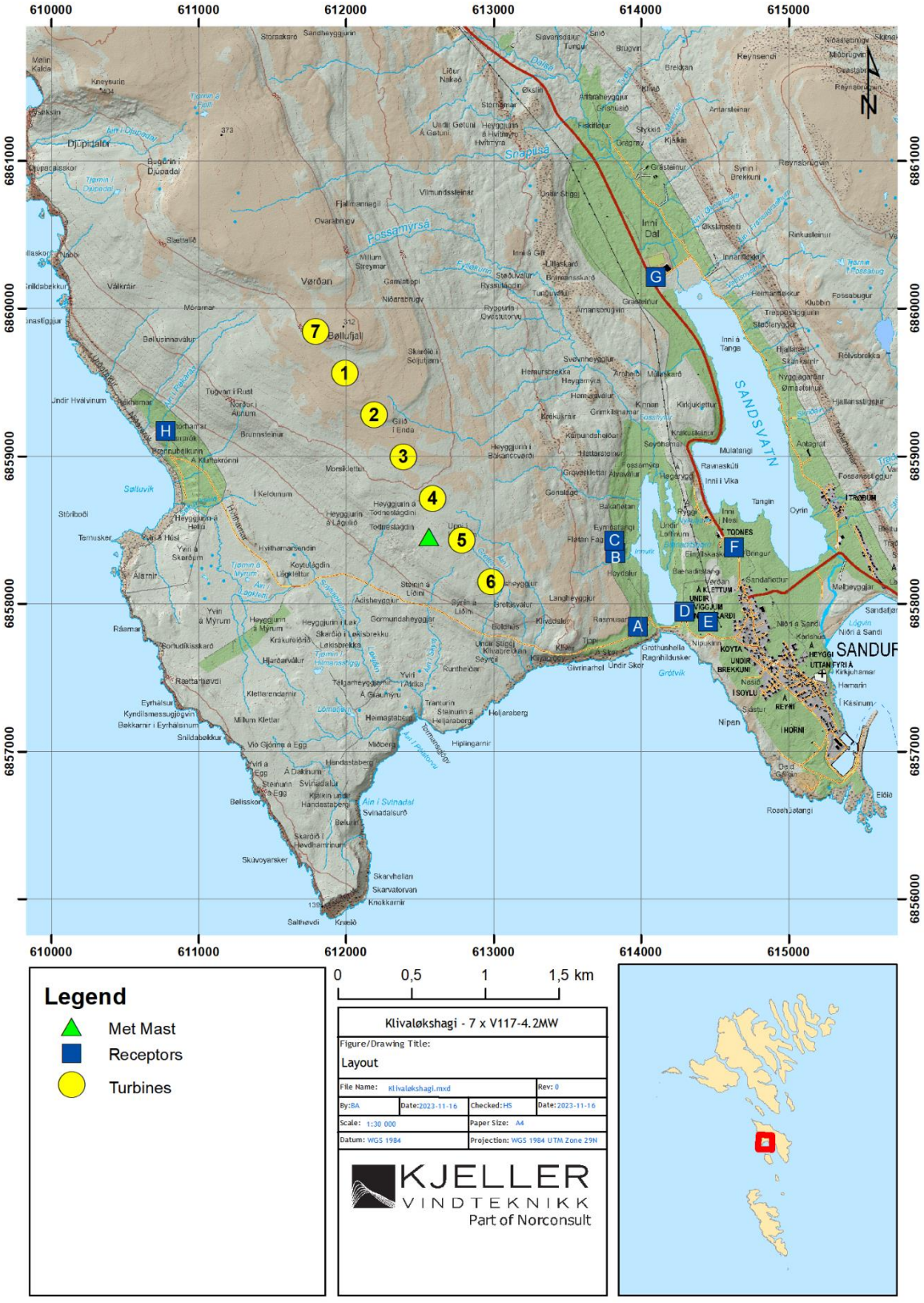

Figure 2-1: Layout with V117-4.2MW turbines for Klivaløkshagi. Receptors are marked with dark blue squares and met mast location as green triangle.

2.2 Wind data

The wind statistics is based on measurements at a KVT met mast at Klivaløkshagi (18009), which was installed in September 2019 and is continuously collecting data. The measurement height is 85.1 m above ground. The previous analysis which this analysis is an update to, was performed in December 2021, thus the measurements included is dated from 05.09.2019 to 31.08.2021.

Long term model data is extracted from the WRF dataset (KVTMeso9km) which cover a period from January 2000 to September 2021. The measurements are long term corrected by the modelled dataset of 9 km x 9 km with data from 2000 to 2021. Method is described in (Liléo, Berge, Undheim, Klinkert, & Bredesen, 2013). WAsP[2] is used to extrapolate the wind to 91.5 m hub height. Figure 2-2 shows long term wind rose (the wind direction distribution) and Table 4 shows long term corrected mean wind speed, both at hub height.

Table 4: Long-term corrected mean wind speed at the mast location at hub height.

	Klivaløkshagi
Mean wind speed at 91.5 m AGL	10.3 m/s

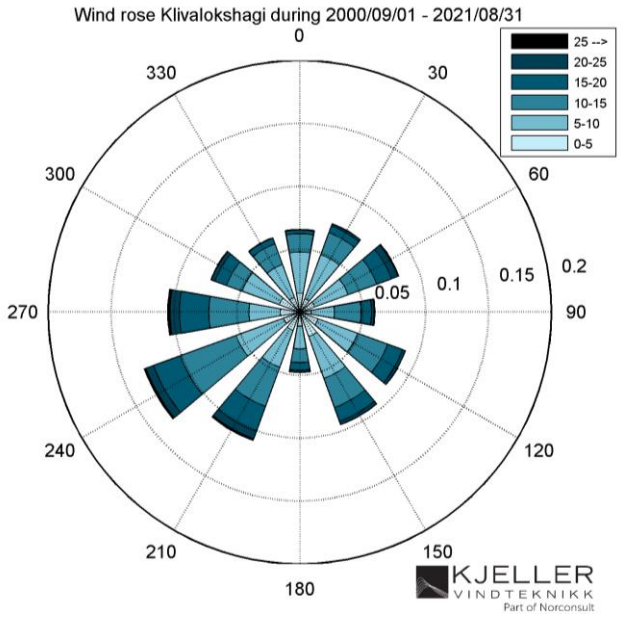

Figure 2-2: Long-term wind rose at 91.5 m above ground.

2.3 Sun probability data

Average sunshine hours per month at Faroe Islands, based on calculations for Tórshavn, is presented by DMI for the normal period of 1991 – 2020 (Cappelen & Drost Jensen, 2021). Dividing by the average number of days per month yields the average number of sunshine hours per day used in the shadow calculations for "real case".

Table 5: Average number of sunshine hours per month at Tórshavn from DMI, average days per month, and resulting average hours per day with sunshine per month. Values for Tórshavn are used for Klivaløkshagi directly.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sunshine hours per month	29.8	53.0	91.5	116.2	157.8	135.4	106.9	101.6	88.9	59.7	38.6	22.7
Days per month	31	28	31	30	31	30	30	31	31	30	31	30
Sunshine hours per day	0.96	1.89	2.95	3.87	5.09	4.51	3.45	3.28	2.96	1.93	1.29	0.73

[2] https://www.wasp.dk/wasp

2.4 Terrain data

Digital surface model of 10 m x 10 m resolution is downloaded from Føroyakort[3] as tif-files. Contours are then extracted with 5 m equidistance and 2 m equidistance close to turbines and receptors.

Roughness map of the area is created with roughness corresponding to land (class 1.0) and water (class 0.0002). The areas with water are drawn from OpenTopoMap available through WindPRO.

3 Results

For detailed results see WindPRO printouts from PARK calculations, SHADOW calculations and DECIBEL calculations in the appendix. Table 6 shows a summary of production calculations performed in the PARK module with production, and a summary of the expected losses. For the wake losses a wake decay constant of TI*0.8 = 0.067 is used based on turbulence intensity (TI) from the measurements and a factor of 0.8 for the N.O. Jensen wake model.

Table 6: Overview of park energy production calculation with expected losses.

Results	
Turbine type	Vestas V117-4.2 MW
Number of turbines	7
Hub height [m asl.]	91.5
Rated power of each turbine [MW]	4.2
Rated power of the wind farm [MW]	29.4
Mean wind speed at turbine locations [m/s]	10.5
Gross annual energy production (AEP) [GWh/y]	148.1
Production losses:	
Wake losses	4.2 %
General losses*	6.7 %
Icing** and blade degradation	1.5 %
Wind turbine performance	3.0 %
Total combined losses	**14.6 %**
Net annual energy production (P50) [GWh/y]	**126.4**

* Blockage losses, electrical losses, high wind hysteresis and unavailability losses.
** Simplified evaluation of icing. Anti icing systems are assumed not in use.

Results of noise (normal and low frequencies) and shadow (outdoor and indoor) are summarized below. More details in the appendix.

Noise: No receptors are above the sound pressure limits of 37 dB(A) for 6 m/s or 39 dB(A) for 8 m/s. However, receptor B and C are very close to the limits. There are no receptors defined as open land receptors. Note, the that the source noise data for the turbines at 6 m/s and 8 m/s are separated by 2 dB(A), and since the limits for the two wind speeds also are separated by 2 dB the two noise maps in Figure 3-1 and Figure 3-2 looks identical when calculated using the method of BEK. 135 from 2019 and showing the different noise limits.

Low frequency noise: No receptors are above sound pressure limit of 20 dB(A), neither for cottage nor regular dwellings. No map is given.

Shadow outdoor, expected: hours with expected shadow flicker is below 10 hours/year at all receptors.

Shadow indoor, expected: hours with expected shadow flicker is below 10 hours/year at all receptors.

Figure 3-3 shows number of hours with expected shadow flicker from the turbines at Klivaløkshagi using local sun probability data.

[3] https://www.foroyakort.fo/tak-datur-nidur/dsm-haeddarmodell/

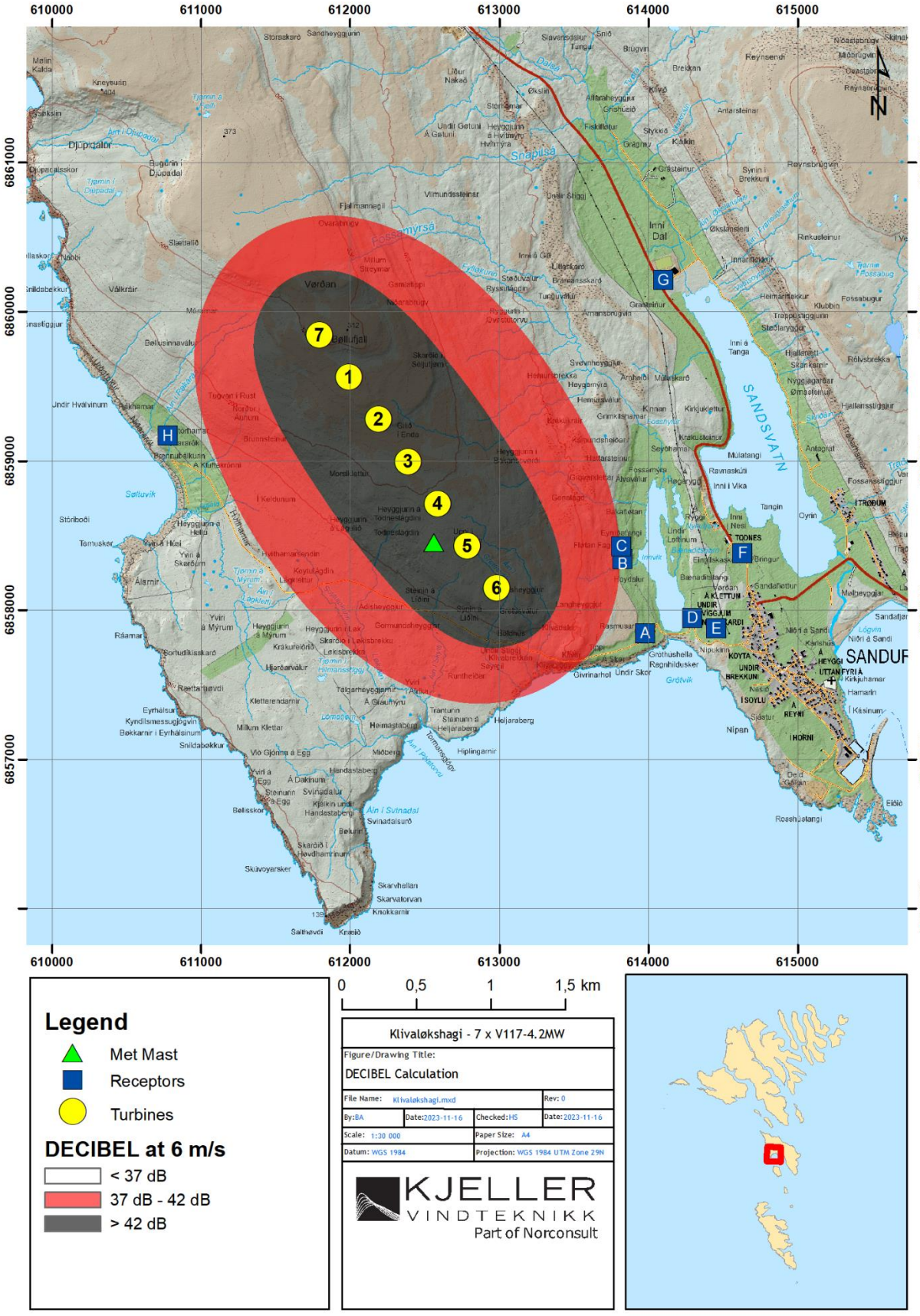

Figure 3-1: Calculated noise map at wind speed 6 m/s for Klivaløkshagi using the Danish 2019 method (BEK. 135).

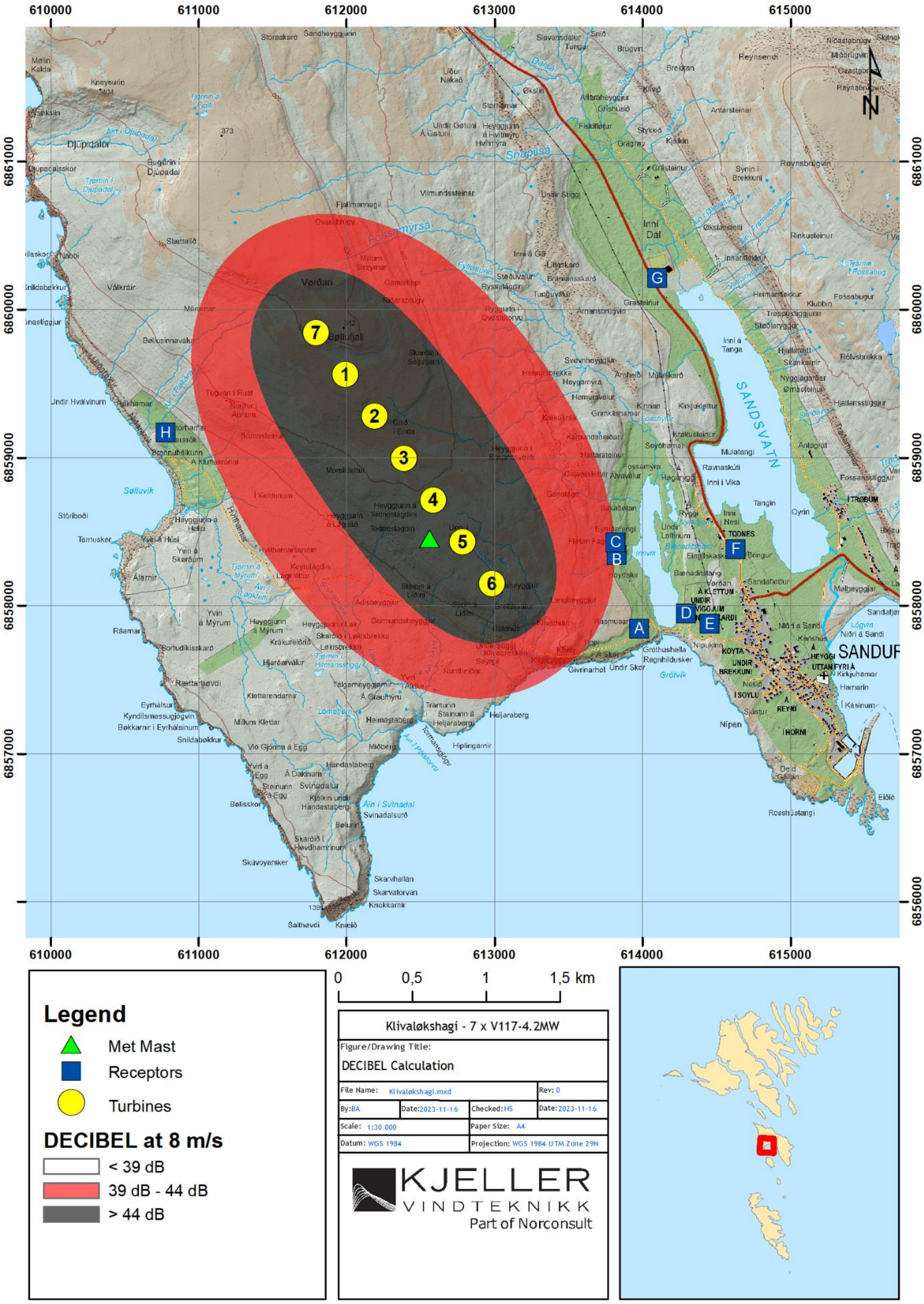

Figure 3-2: Calculated noise map at wind speed 8 m/s for Klivaløkshagi using the Danish 2019 method (BEK. 135).

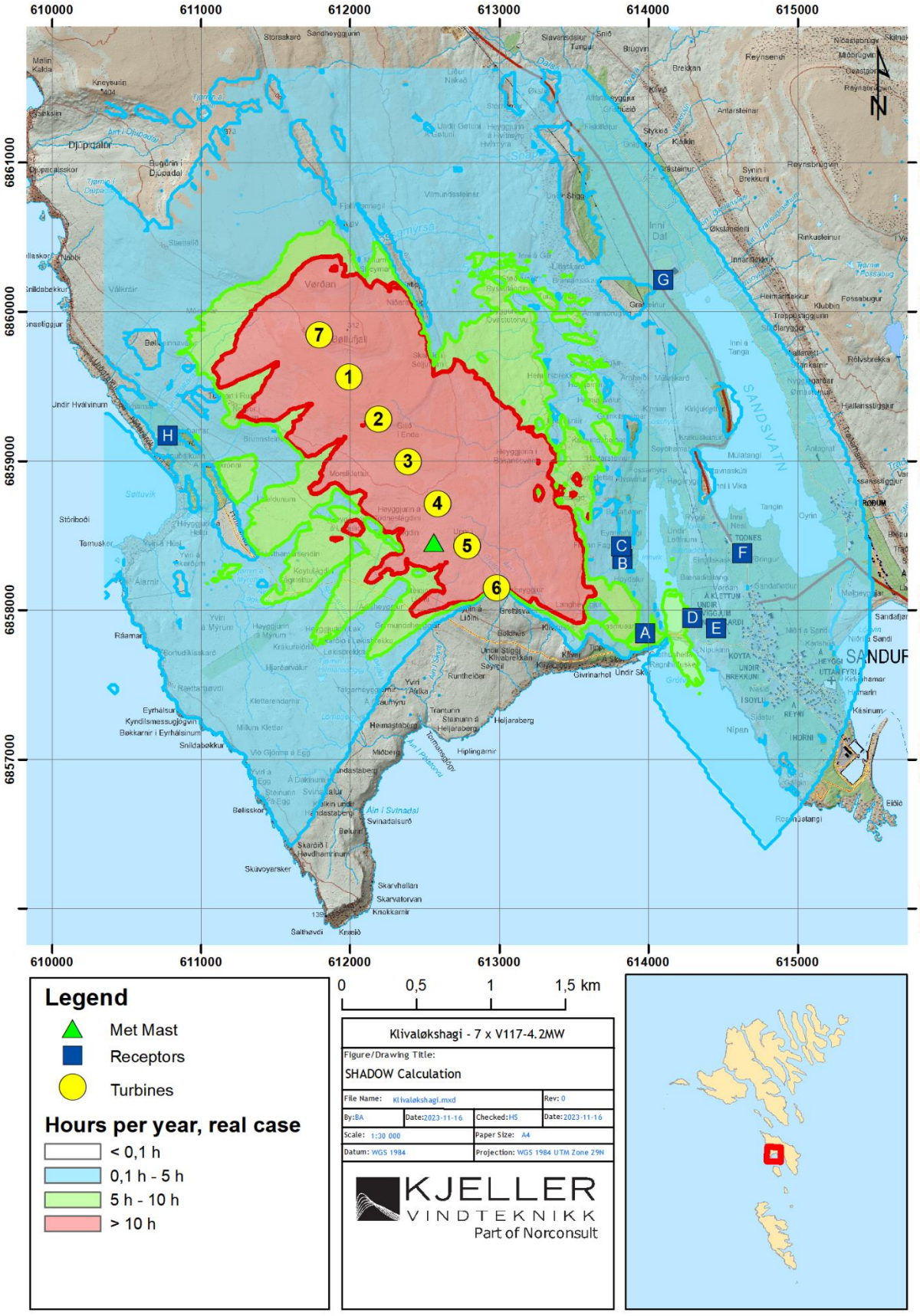

Figure 3-3: Calculated real case shadow flicker map for Klivaløkshagi.

4 References

Bolig- og Planstyrelsen. (2022). *Vejledning om planlægning for og tilladelse til opstilling af vindmøller.* Copenhagen: Bolig- og Planstyrelsen.

Cappelen, J., & Drost Jensen, C. (2021). *Climatological Standars Normals 1991-2020 - Faroe Islands.* The Danish Meteorological Institute.

Liléo, S., Berge, E., Undheim, O., Klinkert, R., & Bredesen, R. E. (2013). *Long-term corection of wind measurements. State-of-the-art, guidelines and future work.* Elforsk 13:18.

Miljø- og Fødevareministeriet. (2019, 02 07). *Bekjendtgørelse om støj fra vindmøller.* Retrieved from Retsinformation: https://www.retsinformation.dk/eli/lta/2019/135

Miljøstyrelsen. (2021). *Støj fra vindmøller - Vejledning nr 51 fra Miljøstyrelsen.* Odense: Miljøministeriet.

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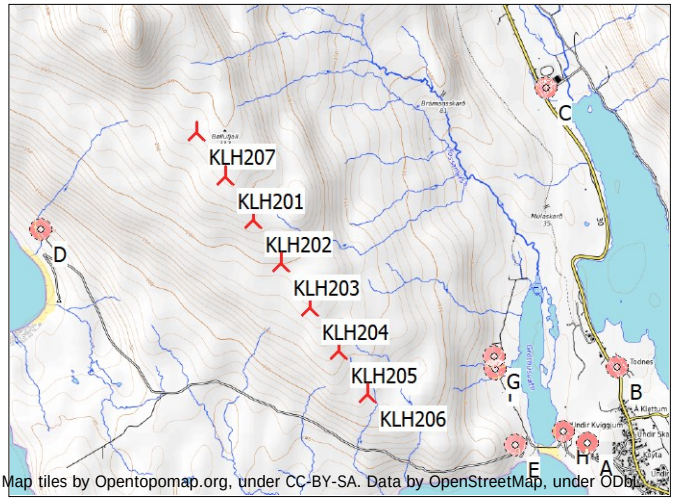
Calculated:
2023-11-16 14:51/3.5.587

DECIBEL - Main Result

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency

Noise calculation model:
Danish low frequency 2019
The calculation is based on "BEK nr 135 af 07/02/2019" from the Danish Environmental Agency.

All coordinates are in
UTM (north)-WGS84 Zone: 29



Scale 1:50 000
New WTG
Noise sensitive area

WTGs

	Easting	Northing	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Noise data Creator	Name	First wind speed	LwaRef	Last wind speed	LwaRef
			[m]					[kW]	[m]	[m]			[m/s]	[dB(A)]	[m/s]	[dB(A)]
1	611 989	6 859 561	276,6	KLH201	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
2	612 188	6 859 278	258,3	KLH202	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
3	612 386	6 858 996	218,1	KLH203	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
4	612 584	6 858 713	194,2	KLH204	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
5	612 782	6 858 430	167,8	KLH205	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
6	611 791	6 859 843	303,5	KLH207	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3
7	612 981	6 858 148	143,3	KLH206	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	92,2	8,0	94,3

Calculation Results

Sound level

Noise sensitive area							Demands	Sound level		Demands fulfilled ?
No.	Name	Easting	Northing	Z	Immission height	Wind speed	Noise	From WTGs	Distance to noise demand	Noise
				[m]	[m]	[m/s]	[dB(A)]	[dB(A)]	[m]	
A	NSA5	614 457	6 857 878	27,2	1,5	6,0	20,0	6,0	1 335	Yes
A						8,0	20,0	8,3	1 262	Yes
B	NSA6	614 633	6 858 383	10,0	1,5	6,0	20,0	5,6	1 501	Yes
B						8,0	20,0	8,0	1 420	Yes
C	NSA7	614 101	6 860 212	8,8	1,5	6,0	20,0	5,6	1 889	Yes
C						8,0	20,0	8,0	1 761	Yes
D	NSA8	610 778	6 859 169	52,4	1,5	6,0	20,0	8,6	1 046	Yes
D						8,0	20,0	11,0	947	Yes
E	NSA1	613 979	6 857 844	30,3	1,5	6,0	20,0	8,2	879	Yes
E						8,0	20,0	10,6	805	Yes
F	NSA2	613 827	6 858 343	23,1	1,5	6,0	20,0	10,0	700	Yes
F						8,0	20,0	12,3	617	Yes
G	NSA3	613 820	6 858 427	30,2	1,5	6,0	20,0	10,1	715	Yes
G						8,0	20,0	12,4	628	Yes
H	NSA4	614 296	6 857 947	14,0	1,5	6,0	20,0	6,8	1 165	Yes
H						8,0	20,0	9,1	1 091	Yes

Distances (m)

	WTG						
NSA	1	2	3	4	5	6	7
A	2988	2667	2354	2051	1764	3313	1501
B	2894	2604	2329	2075	1851	3195	1669
C	2210	2130	2103	2133	2217	2340	2349
D	1273	1413	1617	1862	2136	1217	2427
E	2628	2295	1966	1644	1333	2964	1044
F	2204	1887	1582	1296	1048	2529	868
G	2153	1841	1542	1268	1037	2474	885
H	2816	2494	2179	1876	1589	3142	1331

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DECIBEL - Assumptions for noise calculation

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency

Noise calculation model:
Danish low frequency 2019
Wind speed (in 10 m height):
6,0 m/s - 8,0 m/s, step 2,0 m/s
Terrain reduction:
-1.5 dB(A) Onshore
-3 dB(A) Offshore
Meteorological coefficient, C0:
0,0 dB
Type of demand in calculation:
1: WTG noise is compared to demand (DK, DE, SE, NL etc.)
Noise values in calculation:
All noise values are mean values (Lwa) (Normal)
Pure tones:
Pure tones penalty is added to total noise impact at receptors
Noise sensitive area
Height above ground level, when no value in NSA object:
1,5 m; Don't allow override of model height with height from NSA object
Uncertainty margin:
0,0 dB; Uncertainty margin in NSA has priority
Deviation from "official" noise demands. Negative is more restrictive, positive is less restrictive.:
0,0 dB(A)
Low frequency calculation

All coordinates are in
UTM (north)-WGS84 Zone: 29

WTG: VESTAS V117-4.2 4200 117.0 !O!
Noise: Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018

Source	Source/Date	Creator	Edited
Manufacturer	2017-12-03	USER	2021-01-22 13:45

Blades with serrated trailing edge.
Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

				Low frequency data												
Status	Hub height [m]	Wind speed [m/s]	LwA,ref [dB(A)]	10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
From Windcat	91,5	6,0	92,2	45,1	50,1	55,4	59,9	64,1	68,2	72,1	75,4	78,6	81,6	84,1	86,3	88,4
From Windcat	91,5	8,0	94,3	48,1	53,1	58,3	62,7	66,7	70,7	74,5	77,8	80,9	83,8	86,3	88,4	90,5

Noise sensitive area: A NSA5

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: B NSA6

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

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DECIBEL - Assumptions for noise calculation

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: C NSA7

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: D NSA8

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: E NSA1

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: F NSA2

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

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DECIBEL - Assumptions for noise calculation

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: G NSA3

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

Noise sensitive area: H NSA4

Predefined calculation standard: Regular dwellings
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
20,0 dB(A)	20,0 dB(A)

No distance demand
dLsigma

10,0 Hz [dB]	12,5 Hz [dB]	16,0 Hz [dB]	20,0 Hz [dB]	25,0 Hz [dB]	31,5 Hz [dB]	40,0 Hz [dB]	50,0 Hz [dB]	63,0 Hz [dB]	80,0 Hz [dB]	100,0 Hz [dB]	125,0 Hz [dB]	160,0 Hz [dB]
4,9	5,9	4,6	6,6	8,4	10,8	11,4	13,0	16,6	19,7	21,2	20,2	21,2

Pure tone penalty: 0 dB

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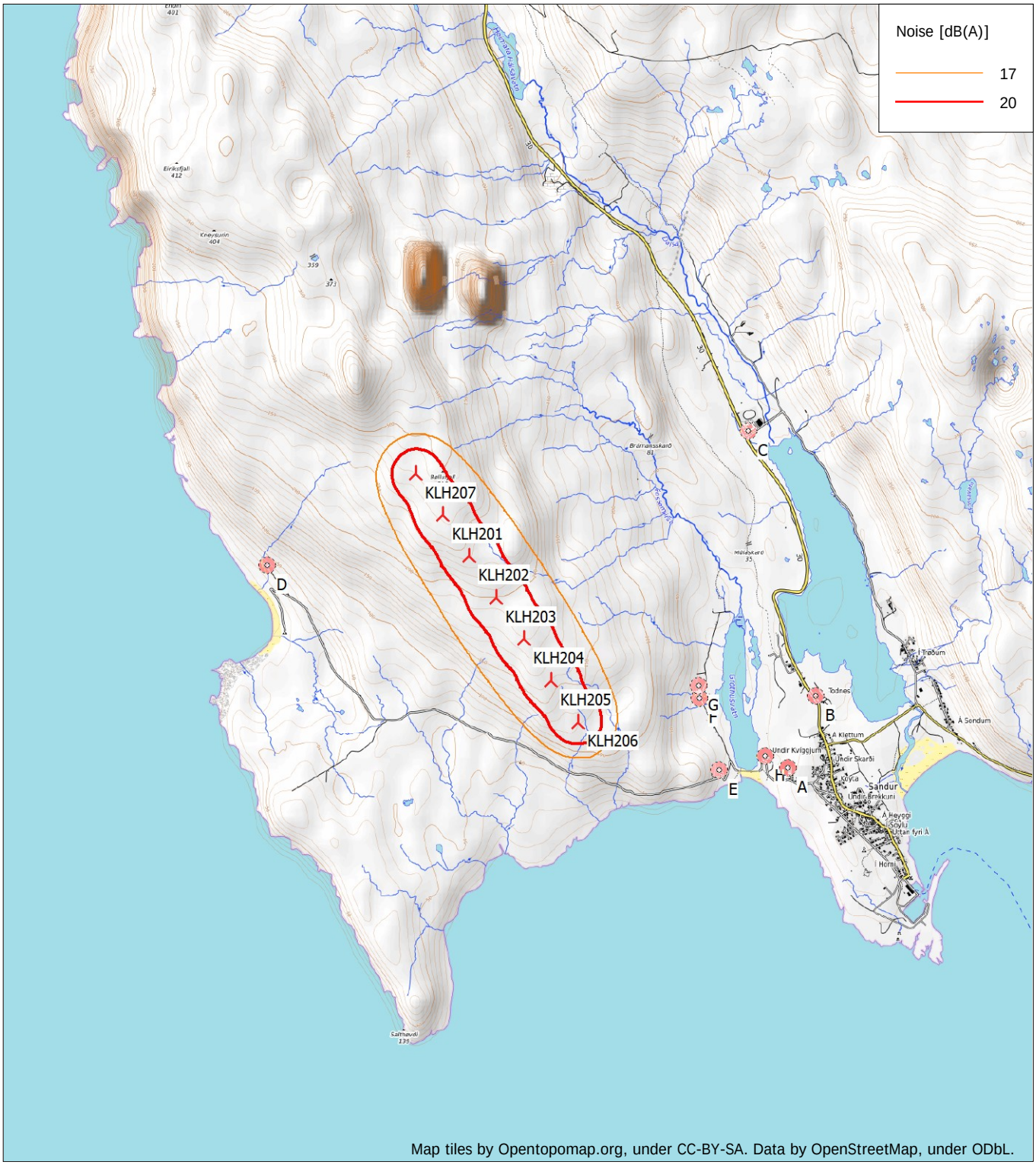
Calculated:
2023-11-16 14:51/3.5.587

DECIBEL - Map 6,0 m/s Regular dwellings

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish low frequency 2019. Wind speed: 6,0 m/s Regular dwellings
Height above sea level from active line object

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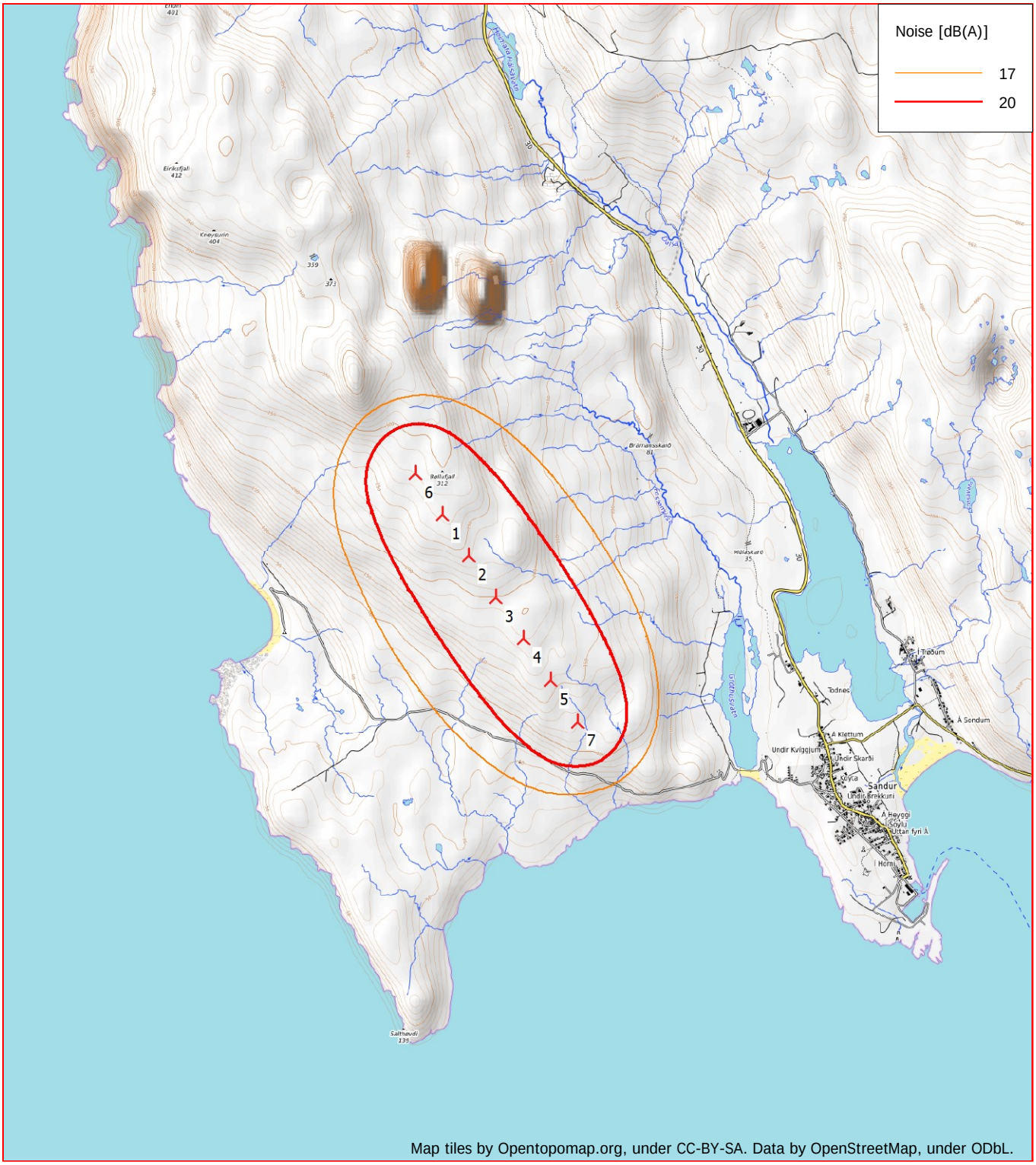
Calculated:
2023-11-16 14:51/3.5.587

DECIBEL - Map 6,0 m/s Cottage zones

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish low frequency 2019. Wind speed: 6,0 m/s Cottage zones
Height above sea level from active line object

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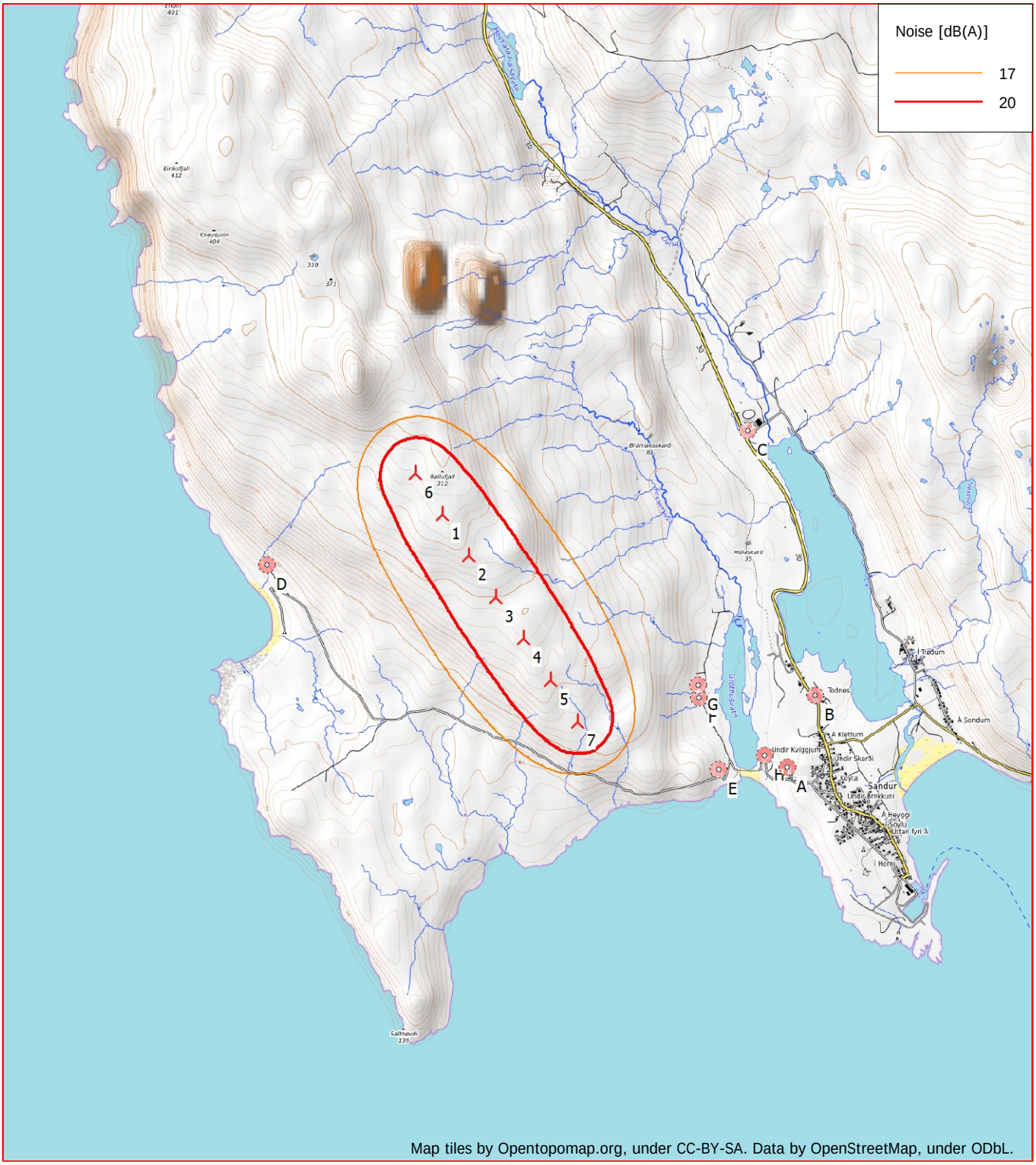
Calculated:
2023-11-16 14:51/3.5.587

DECIBEL - Map 8,0 m/s Regular dwellings

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish low frequency 2019. Wind speed: 8,0 m/s Regular dwellings
Height above sea level from active line object

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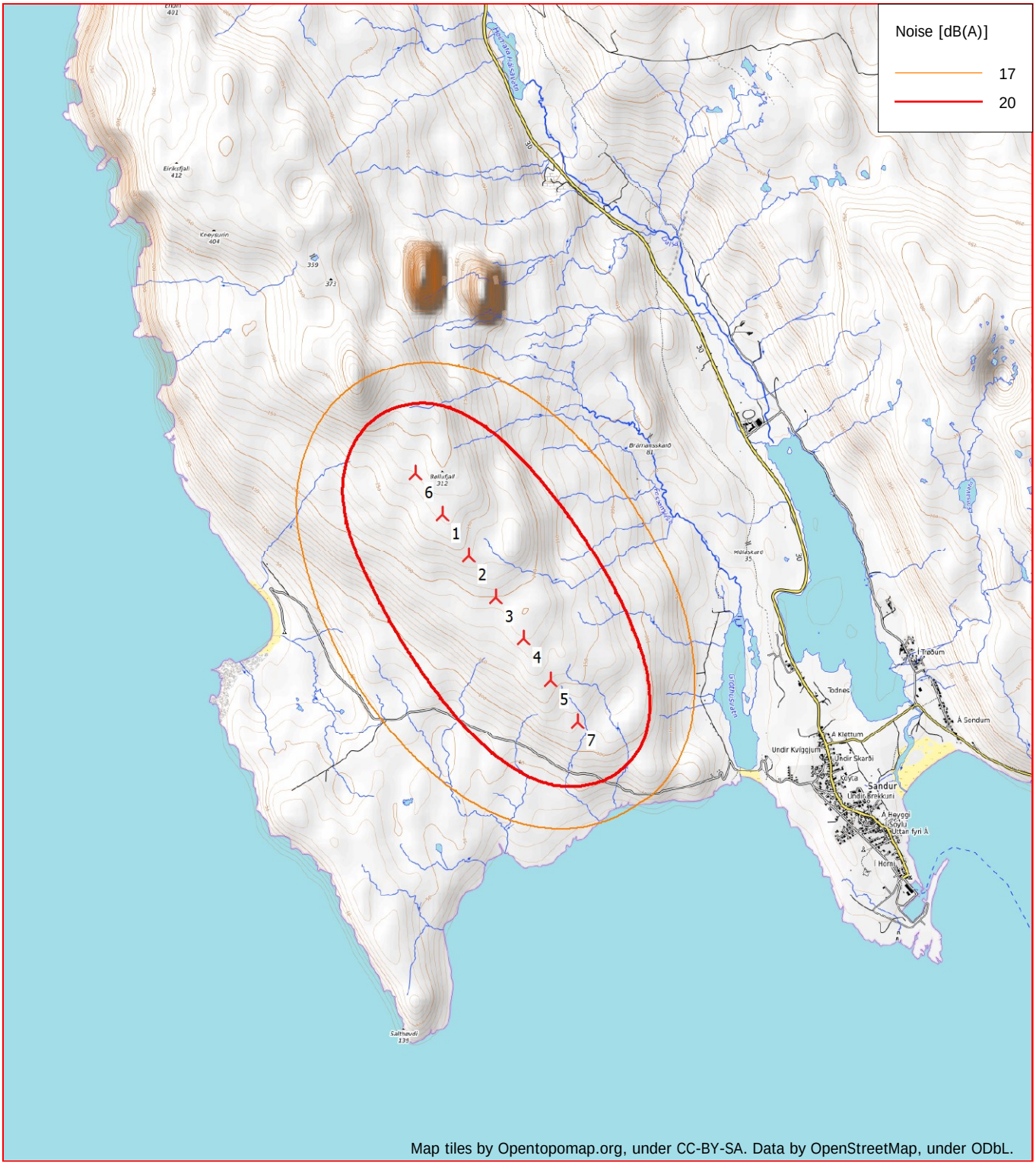
Calculated:
2023-11-16 14:51/3.5.587

DECIBEL - Map 8,0 m/s Cottage zones

Calculation: Copy of 7 x V117 4p2 MW HH 91p5 m, low frequency



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish low frequency 2019. Wind speed: 8,0 m/s Cottage zones
Height above sea level from active line object

Project:
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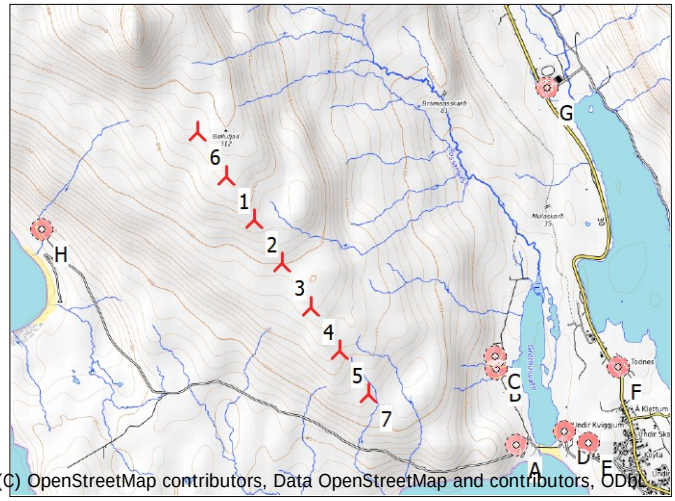
Calculated:
2023-11-16 14:53/3.5.587

DECIBEL - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range

Noise calculation model:
Danish 2019
The calculation is based on "BEK nr 135 af 07/02/2019" from the Danish Environmental Agency.

All coordinates are in
UTM (north)-WGS84 Zone: 29



Scale 1:50 000
New WTG
Noise sensitive area

WTGs

	Easting	Northing	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Noise data Creator	Name	First wind speed	LwaRef	Last wind speed	LwaRef
			[m]					[kW]	[m]	[m]			[m/s]	[dB(A)]	[m/s]	[dB(A)]
1	611 989	6 859 561	276,6	KLH201	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
2	612 188	6 859 278	258,3	KLH202	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
3	612 386	6 858 996	218,1	KLH203	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
4	612 584	6 858 713	194,2	KLH204	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
5	612 782	6 858 430	167,8	KLH205	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
6	611 791	6 859 843	303,5	KLH207	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0
7	612 981	6 858 148	143,3	KLH206	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018	6,0	104,0	8,0	106,0

Calculation Results

Sound level

Noise sensitive area							Demands	Sound level		Demands fulfilled ?
No.	Name	Easting	Northing	Z	Immission height	Wind speed	Noise	From WTGs	Distance to noise demand	Noise
				[m]	[m]	[m/s]	[dB(A)]	[dB(A)]	[m]	
A	NSA1	613 979	6 857 844	30,3	1,5	6,0	37,0	34,6	259	Yes
A						8,0	39,0	36,6	257	Yes
B	NSA2	613 827	6 858 343	23,1	1,5	6,0	37,0	36,8	19	Yes
B						8,0	39,0	38,8	16	Yes
C	NSA3	613 820	6 858 427	30,2	1,5	6,0	37,0	36,9	13	Yes
C						8,0	39,0	38,9	11	Yes
D	NSA4	614 296	6 857 947	14,0	1,5	6,0	37,0	32,6	532	Yes
D						8,0	39,0	34,6	530	Yes
E	NSA5	614 457	6 857 878	27,2	1,5	6,0	37,0	31,4	705	Yes
E						8,0	39,0	33,5	703	Yes
F	NSA6	614 633	6 858 383	10,0	1,5	6,0	37,0	31,0	825	Yes
F						8,0	39,0	33,0	823	Yes
G	NSA7	614 101	6 860 212	8,8	1,5	6,0	37,0	30,8	964	Yes
G						8,0	39,0	32,8	961	Yes
H	NSA8	610 778	6 859 169	52,4	1,5	6,0	37,0	34,9	254	Yes
H						8,0	39,0	36,9	252	Yes

Distances (m)

	WTG						
NSA	1	2	3	4	5	6	7
A	2628	2295	1966	1644	1333	2964	1044
B	2204	1887	1582	1296	1048	2529	868
C	2153	1841	1542	1268	1037	2474	885
D	2816	2494	2179	1876	1589	3142	1331
E	2988	2667	2354	2051	1764	3313	1501
F	2894	2604	2329	2075	1851	3195	1669
G	2210	2130	2103	2133	2217	2340	2349
H	1273	1413	1617	1862	2136	1217	2427

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DECIBEL - Assumptions for noise calculation

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range

Noise calculation model:
Danish 2019
Wind speed (in 10 m height):
6,0 m/s - 8,0 m/s, step 2,0 m/s
Terrain reduction:
-1.5 dB(A) Onshore
-3 dB(A) Offshore
Meteorological coefficient, C0:
0,0 dB
Type of demand in calculation:
1: WTG noise is compared to demand (DK, DE, SE, NL etc.)
Noise values in calculation:
All noise values are mean values (Lwa) (Normal)
Pure tones:
Pure tones penalty is added to total noise impact at receptors
Noise sensitive area
Height above ground level, when no value in NSA object:
1,5 m; Don't allow override of model height with height from NSA object
Uncertainty margin:
0,0 dB; Uncertainty margin in NSA has priority
Deviation from "official" noise demands. Negative is more restrictive, positive is less restrictive.:
0,0 dB(A)
Octave data required
Frequency dependent air absorption

63 [dB/km]	125 [dB/km]	250 [dB/km]	500 [dB/km]	1 000 [dB/km]	2 000 [dB/km]	4 000 [dB/km]	8 000 [dB/km]
0,11	0,38	1,02	2,00	3,60	8,80	29,00	104,50

All coordinates are in
UTM (north)-WGS84 Zone: 29

WTG: VESTAS V117-4.2 4200 117.0 !O!
Noise: Octave PO1/PO1 (HWO) - - Modes PO1 & PO1 (HWO) - 09-2018

Source	Source/Date	Creator	Edited
Manufacturer	2017-12-03	USER	2021-01-22 13:45

Blades with serrated trailing edge.
Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

Status	Hub height [m]	Wind speed [m/s]	LwA,ref [dB(A)]	Pure tones	Octave data 63 [dB]	125 [dB]	250 [dB]	500 [dB]	1000 [dB]	2000 [dB]	4000 [dB]	8000 [dB]
From Windcat	91,5	6,0	104,0	No	84,0	91,4	96,2	98,6	98,4	95,6	90,4	82,6
From Windcat	91,5	8,0	106,0	No	86,3	93,5	98,3	100,6	100,4	97,7	92,6	85,0

Noise sensitive area: A NSA1

Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: B NSA2

Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

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DECIBEL - Assumptions for noise calculation

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: C NSA3
Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: D NSA4
Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: E NSA5
Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: F NSA6
Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

Noise sensitive area: G NSA7
Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

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DECIBEL - Assumptions for noise calculation

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range

Noise sensitive area: H NSA8

Predefined calculation standard: Residential areas
Immission height(a.g.l.): Use standard value from calculation model
Uncertainty margin: Use default value from calculation model

Noise demand:

6,0 [m/s]	8,0 [m/s]
37,0 dB(A)	39,0 dB(A)

No distance demand
Pure tone penalty: 0 dB

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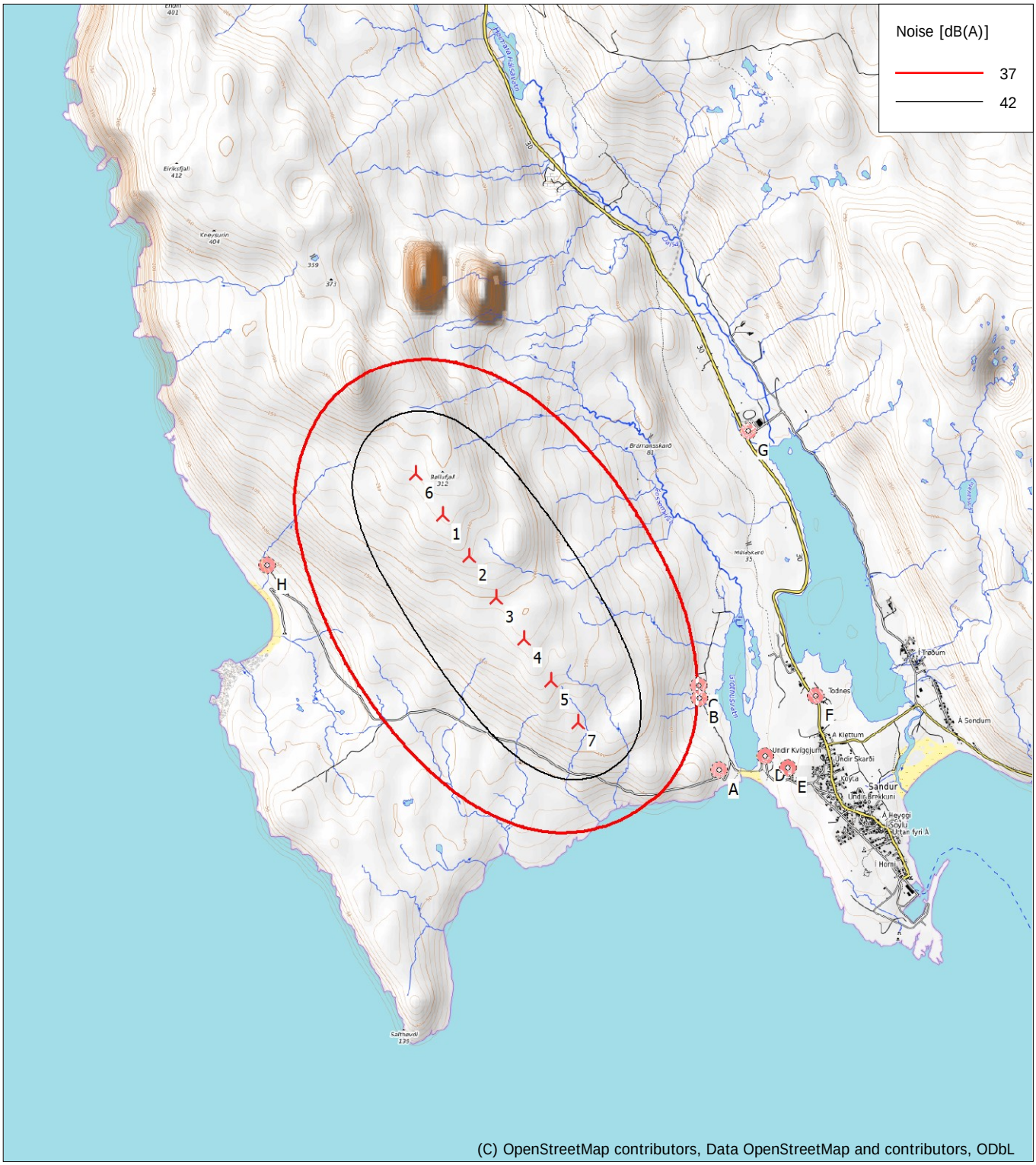
Calculated:
2023-11-16 14:53/3.5.587

DECIBEL - Map 6,0 m/s

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish 2019. Wind speed: 6,0 m/s
Height above sea level from active line object

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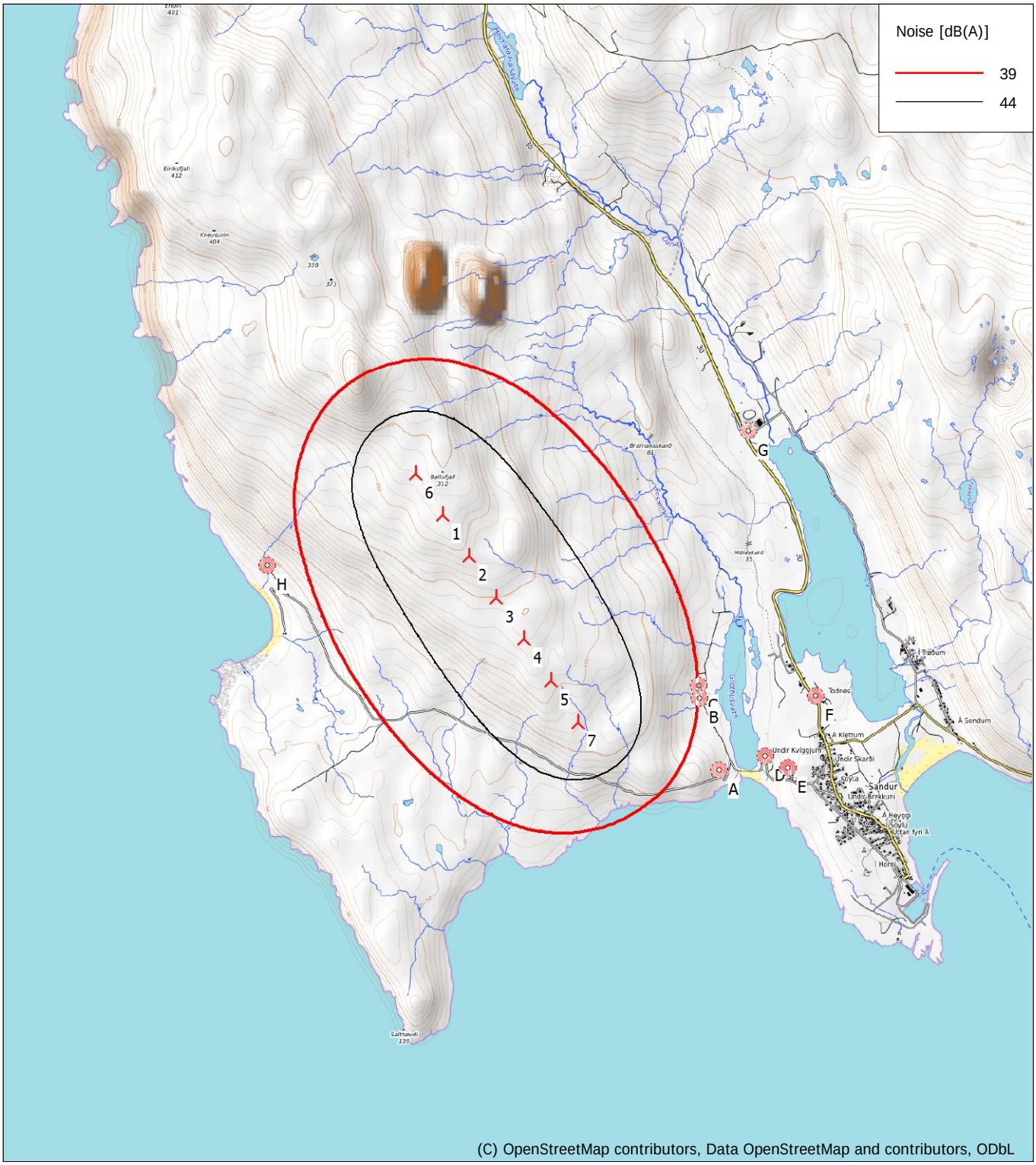
Calculated:
2023-11-16 14:53/3.5.587

DECIBEL - Map 8,0 m/s

Calculation: 7 x V117 4p2 MW HH 91p5 m, hearing range



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG Noise sensitive area

Noise calculation model: Danish 2019. Wind speed: 8,0 m/s
Height above sea level from active line object

Project:
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Calculated:
2023-11-09 09:35/3.5.587

PARK - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m

Wake Model N.O. Jensen (RISØ/EMD)

Calculation performed in UTM (north)-WGS84 Zone: 29
At the site centre the difference between grid north and true north is: 1,9°

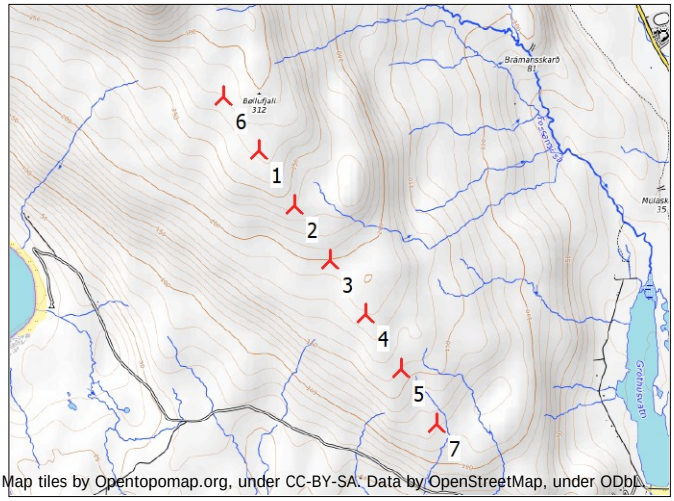
Power curve correction method
New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>
Air density calculation method
Height dependent, temperature from climate station
Station: THORSHAVN V3 2014
Base temperature: 6,0 °C at 55,0 m
Base pressure: 1013,3 hPa at 0,0 m
Air density for Site center in key hub height: 207,5 m + 92,0 m = 1,226 kg/m³ -> 100,1 % of Std
Relative humidity: 0,0 %

Wake Model Parameters
Terrain type Wake decay constant
User defined 0,067

Omnidirectional displacement height from objects

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0,5	360,0	1,0	0,5	32,0	1,0



Scale 1:40 000

New WTG

Resource file(s)

\\kvtsrv03\kvt\KUNDER\180_SEV_Vindmaalinger_Torshavn_faeroyene\017_Klivaløkshagi\Analyse\2023_11_Klivaløkshagi_update\WAsP\Klivalokshagi_HH91p5m_large_corr_1.012.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	GROSS (no loss) Free WTGs [MWh/y]	Wake loss [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	141 869,9	148 103,1	4,2	55,0	20 267,1	4 826	10,5

¤) Based on wake reduced results and any curtailments.

Calculated Annual Energy for each of 7 new WTGs with total 29,4 MW rated power

Links	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh/y]	Wake loss [%]	Free mean wind speed [m/s]
1 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 679,1	4,4	10,78
2 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	20 610,7	4,7	10,78
3 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	19 920,3	5,0	10,39
4 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	19 794,4	4,9	10,29
5 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	19 652,6	4,5	10,15
6 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	21 268,2	3,1	10,96
7 A	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	USER	PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	19 944,5	2,8	10,09

Annual Energy result includes shown losses. Additional losses and uncertainty must be considered for an investment decision.

WTG siting

	UTM (north)-WGS84 Zone: 29 Easting	Northing	Z [m]	Row data/Description
1 New	611 989	6 859 561	276,6	KLH201
2 New	612 188	6 859 278	258,3	KLH202
3 New	612 386	6 858 996	218,1	KLH203
4 New	612 584	6 858 713	194,2	KLH204
5 New	612 782	6 858 430	167,8	KLH205
6 New	611 791	6 859 843	303,5	KLH207
7 New	612 981	6 858 148	143,3	KLH206

Project:
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Calculated:
2023-11-09 09:35/3.5.587

PARK - Power Curve Analysis

Calculation: 7 x V117 4p2 MW HH 91p5 mWTG: 1 - VESTAS V117-4.2 4200 117.0 !O!, Hub height: 91,5 m

Name: PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018
Source: Manufacturer

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type	Generator type	Specific power kW/m²
2018-09-10	USER	2017-08-10	2021-12-13	32,0	Pitch	User defined	Variable	0,39

Documents no. DMS 0067-7063 V05 & DMS 0067-7064 V06.

HP curve comparison - Note: For standard air density

Vmean	[m/s]	5	6	7	8	9	10
HP value Pitch, variable speed (2013)	[MWh]	5 574	8 843	12 195	15 322	18 055	20 310
VESTAS V117-4.2 4200 117.0 !O! PO1 (HWO) - Calculated - Modes PO1 & PO1-0S (HWO) - 09-2018	[MWh]	5 548	8 808	12 161	15 301	18 087	20 475
Check value	[%]	0	0	0	0	0	-1

The table shows comparison between annual energy production calculated on basis of simplified "HP-curves" which assume that all WTGs performs quite similar - only specific power loading (kW/m^2) and single/dual speed or stall/pitch decides the calculated values. Productions are without wake losses.
For further details, ask at the Danish Energy Agency for project report J.nr. 51171/00-0016 or see the windPRO manual.
The method is refined in EMD report "20 Detailed Case Studies comparing Project Design Calculations and actual Energy Productions for Wind Energy Projects worldwide", jan 2003.
Use the table to evaluate if the given power curve is reasonable - if the check value are lower than -5%, the power curve probably is too optimistic due to uncertainty in power curve measurement.

Power curve

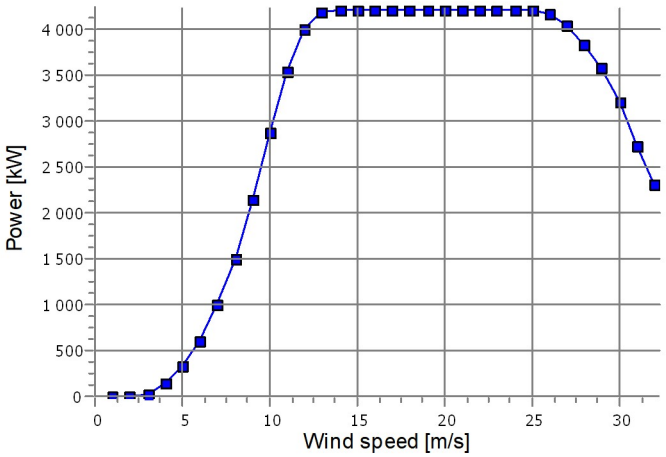
Original data, Air density: 1,225 kg/m³

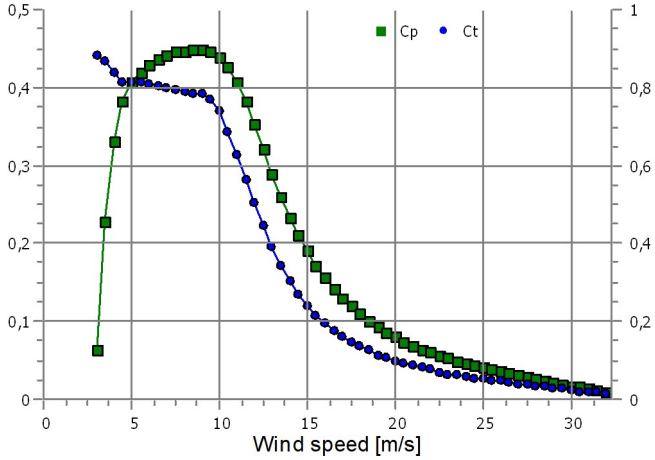
Wind speed [m/s]	Power [kW]	Cp	Wind speed [m/s]	Ct curve
3,0	12,0	0,07	3,0	0,88
3,5	65,0	0,23	3,5	0,87
4,0	140,0	0,33	4,0	0,84
4,5	230,0	0,38	4,5	0,81
5,0	336,0	0,41	5,0	0,81
5,5	460,0	0,42	5,5	0,81
6,0	610,0	0,43	6,0	0,81
6,5	788,0	0,44	6,5	0,80
7,0	996,0	0,44	7,0	0,80
7,5	1 236,0	0,44	7,5	0,79
8,0	1 507,0	0,45	8,0	0,79
8,5	1 814,0	0,45	8,5	0,79
9,0	2 155,0	0,45	9,0	0,78
9,5	2 521,0	0,45	9,5	0,77
10,0	2 892,0	0,44	10,0	0,74
10,5	3 245,0	0,43	10,5	0,69
11,0	3 556,0	0,41	11,0	0,63
11,5	3 815,0	0,38	11,5	0,57
12,0	4 008,0	0,35	12,0	0,51
12,5	4 124,0	0,32	12,5	0,45
13,0	4 178,0	0,29	13,0	0,39
13,5	4 187,0	0,26	13,5	0,35
14,0	4 196,0	0,23	14,0	0,31
14,5	4 200,0	0,21	14,5	0,27
15,0	4 200,0	0,19	15,0	0,24
15,5	4 200,0	0,17	15,5	0,22
16,0	4 200,0	0,16	16,0	0,20
16,5	4 200,0	0,14	16,5	0,18
17,0	4 200,0	0,13	17,0	0,16
17,5	4 200,0	0,12	17,5	0,15
18,0	4 200,0	0,11	18,0	0,14
18,5	4 200,0	0,10	18,5	0,13
19,0	4 200,0	0,09	19,0	0,12
19,5	4 200,0	0,09	19,5	0,11
20,0	4 200,0	0,08	20,0	0,10
20,5	4 200,0	0,07	20,5	0,09
21,0	4 200,0	0,07	21,0	0,09
21,5	4 200,0	0,06	21,5	0,08
22,0	4 200,0	0,06	22,0	0,08
22,5	4 200,0	0,06	22,5	0,07
23,0	4 200,0	0,05	23,0	0,07
23,5	4 200,0	0,05	23,5	0,06
24,0	4 200,0	0,05	24,0	0,06
24,5	4 200,0	0,04	24,5	0,06
25,0	4 200,0	0,04	25,0	0,05
25,5	4 191,0	0,04	25,5	0,05
26,0	4 165,0	0,04	26,0	0,05
26,5	4 107,0	0,03	26,5	0,04
27,0	4 039,0	0,03	27,0	0,04
27,5	3 934,0	0,03	27,5	0,04
28,0	3 834,0	0,03	28,0	0,04
28,5	3 723,0	0,02	28,5	0,03
29,0	3 586,0	0,02	29,0	0,03
29,5	3 415,0	0,02	29,5	0,03
30,0	3 212,0	0,02	30,0	0,03
30,5	2 981,0	0,02	30,5	0,02
31,0	2 729,0	0,01	31,0	0,02
31,5	2 492,0	0,01	31,5	0,02
32,0	2 315,0	0,01	32,0	0,02

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1,218 kg/m³ New windPRO method (adjusted IEC method, improved to match turbine control) <RECOMMENDED>

Wind speed [m/s]	Power [kW]	Cp	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1,0	0,0	0,00	0,50- 1,50	0,0	0,0	0,0
2,0	0,0	0,00	1,50- 2,50	0,0	0,0	0,0
3,0	11,3	0,06	2,50- 3,50	12,2	12,2	0,1
4,0	138,7	0,33	3,50- 4,50	64,7	76,9	0,4
5,0	333,8	0,41	4,50- 5,50	171,2	248,1	1,2
6,0	606,2	0,43	5,50- 6,50	338,2	586,2	2,8
7,0	989,8	0,44	6,50- 7,50	577,2	1 163,4	5,6
8,0	1 497,7	0,45	7,50- 8,50	886,4	2 049,8	9,9
9,0	2 140,7	0,45	8,50- 9,50	1 248,3	3 298,1	15,9
10,0	2 871,9	0,44	9,50-10,50	1 606,0	4 904,1	23,7
11,0	3 533,7	0,41	10,50-11,50	1 863,3	6 767,4	32,7
12,0	3 990,7	0,35	11,50-12,50	1 949,0	8 716,4	42,2
13,0	4 172,6	0,29	12,50-13,50	1 863,9	10 580,3	51,2
14,0	4 195,0	0,23	13,50-14,50	1 684,9	12 265,2	59,3
15,0	4 200,0	0,19	14,50-15,50	1 485,2	13 750,4	66,5
16,0	4 200,0	0,16	15,50-16,50	1 287,4	15 037,9	72,7
17,0	4 200,0	0,13	16,50-17,50	1 100,2	16 138,1	78,0
18,0	4 200,0	0,11	17,50-18,50	927,8	17 065,8	82,5
19,0	4 200,0	0,09	18,50-19,50	772,5	17 838,3	86,3
20,0	4 200,0	0,08	19,50-20,50	635,5	18 473,8	89,3
21,0	4 200,0	0,07	20,50-21,50	516,8	18 990,6	91,8
22,0	4 200,0	0,06	21,50-22,50	415,6	19 406,2	93,8
23,0	4 200,0	0,05	22,50-23,50	330,5	19 736,7	95,4
24,0	4 200,0	0,05	23,50-24,50	260,1	19 996,8	96,7
25,0	4 200,0	0,04	24,50-25,50	202,4	20 199,2	97,7
26,0	4 165,0	0,04	25,50-26,50	154,4	20 353,6	98,4
27,0	4 039,0	0,03	26,50-27,50	114,3	20 467,9	99,0
28,0	3 834,0	0,03	27,50-28,50	82,3	20 550,2	99,4
29,0	3 586,0	0,02	28,50-29,50	57,5	20 607,6	99,7
30,0	3 212,0	0,02	29,50-30,50	38,3	20 645,9	99,8
31,0	2 729,0	0,01	30,50-31,50	24,1	20 670,0	100,0
32,0	2 315,0	0,01	31,50-32,50	9,1	20 679,1	100,0





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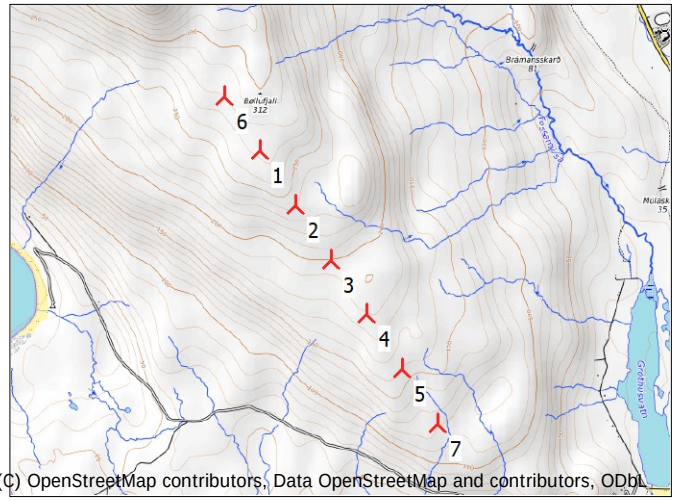
PARK - WTG distances

Calculation: 7 x V117 4p2 MW HH 91p5 m

WTG distances

	Z	Nearest WTG	Z	Horizontal distance	Distance in rotor diameters
	[m]		[m]	[m]	
1	276,6	6	303,5	345	2,9
2	258,3	1	276,6	345	3,0
3	218,1	4	194,2	345	3,0
4	194,2	5	167,8	345	3,0
5	167,8	7	143,3	345	2,9
6	303,5	1	276,6	345	2,9
7	143,3	5	167,8	345	2,9
Min	143,3		143,3	345	2,9
Max	303,5		303,5	345	3,0



Scale 1:40 000

New WTG

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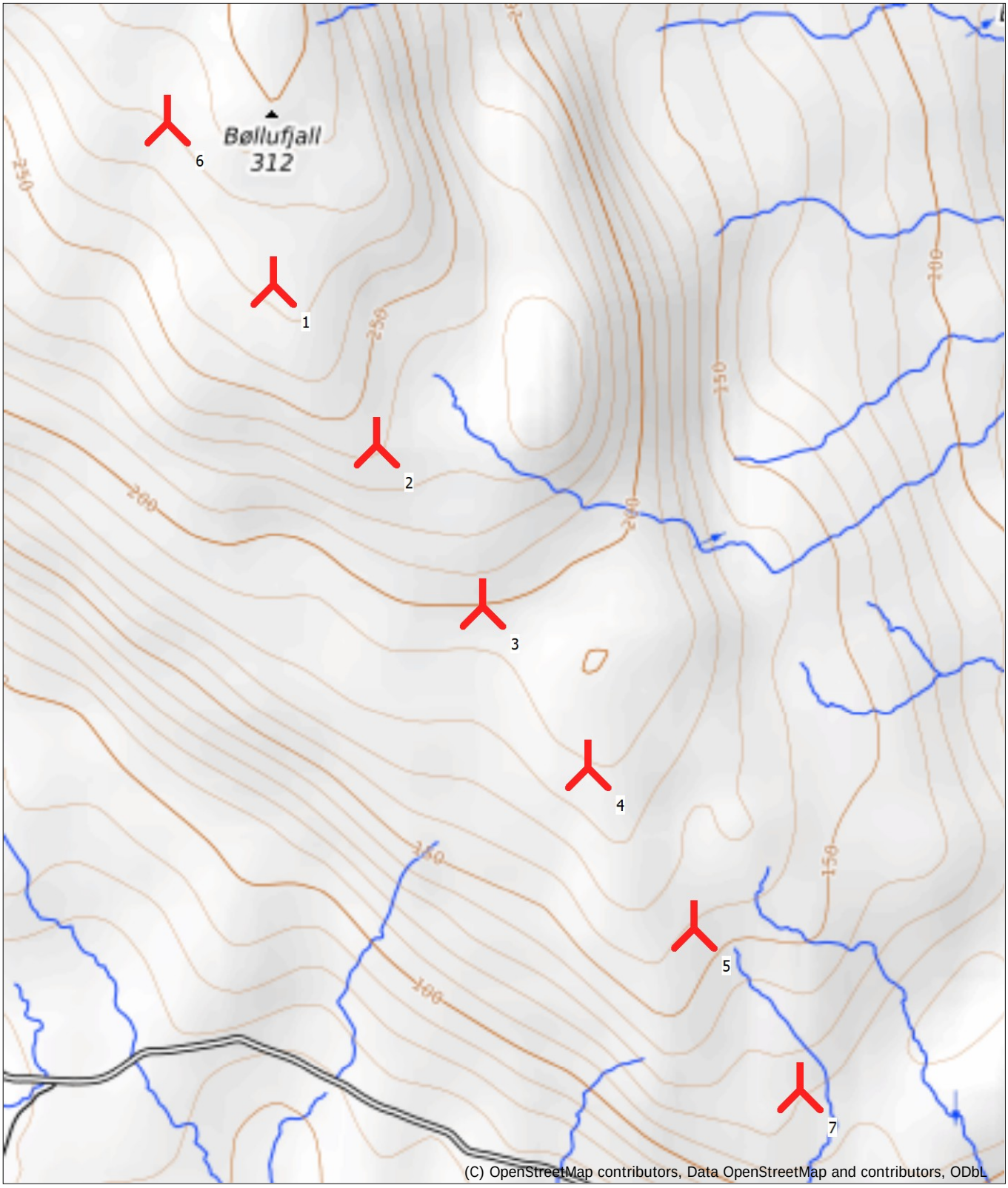
Calculated:
2023-11-09 09:35/3.5.587

PARK - Map

Calculation: 7 x V117 4p2 MW HH 91p5 m



0 100 200 300 400 m

Map: OpenTopoMap , Print scale 1:10 000, Map center UTM (north)-WGS84 Zone: 29 East: 612 386 North: 6 858 996

New WTG

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Calculated:
2023-11-09 17:12/3.5.587

SHADOW - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m, indoors

Assumptions for shadow calculations

Maximum distance for influence	2 500	m
Minimum sun height over horizon for influence	3	°
Day step for calculation	1	days
Time step for calculation	1	minutes

Sunshine probability S (Average daily sunshine hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0,96	1,89	2,95	3,87	5,09	4,51	3,45	3,28	2,87	1,90	1,24	0,70

Operational hours are calculated from WTGs in calculation and wind distribution:
Site data: WAsP (1)

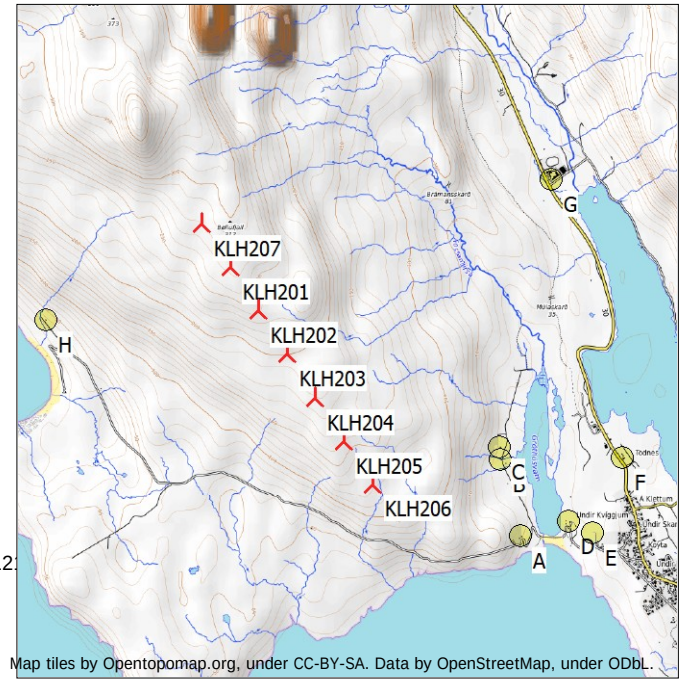
Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
601	754	807	584	588	626	510	796	1 023	897	734	520	8 440

Idle start wind speed: Cut in wind speed from power curve

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Height Contours: CONTOURLINE_Sandoy_uV_2018112
Obstacles used in calculation
Receptor grid resolution: 1,0 m
Topographic shadow included in calculation

All coordinates are in
UTM (north)-WGS84 Zone: 29



Scale 1:50 000

New WTG Shadow receptor

WTGs

	Easting	Northing	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	611 989	6 859 561	276,6	KLH201	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
2	612 188	6 859 278	258,3	KLH202	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
3	612 386	6 858 996	218,1	KLH203	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
4	612 584	6 858 713	194,2	KLH204	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
5	612 782	6 858 430	167,8	KLH205	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
6	611 791	6 859 843	303,5	KLH207	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
7	612 981	6 858 148	143,3	KLH206	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6

Shadow receptor-Input

No.	Name	Easting	Northing	Z	Width	Height	Elevation a.g.l.	Slope of window	Direction mode	Eye height (ZVI) a.g.l.
				[m]	[m]	[m]	[m]	[°]		[m]
A	NSA1	613 979	6 857 844	30,3	2,0	2,0	1,5	90,0	"Green house mode"	3,5
B	NSA2	613 827	6 858 343	23,1	2,0	2,0	1,5	90,0	"Green house mode"	3,5
C	NSA3	613 820	6 858 427	30,2	2,0	2,0	1,5	90,0	"Green house mode"	3,5
D	NSA4	614 296	6 857 947	14,0	2,0	2,0	1,5	90,0	"Green house mode"	3,5
E	NSA5	614 457	6 857 878	27,2	2,0	2,0	1,5	90,0	"Green house mode"	3,5
F	NSA6	614 633	6 858 383	10,0	2,0	2,0	1,5	90,0	"Green house mode"	3,5
G	NSA7	614 101	6 860 212	8,8	2,0	2,0	1,5	90,0	"Green house mode"	3,5
H	NSA8	610 778	6 859 169	52,4	2,0	2,0	1,5	90,0	"Green house mode"	3,5

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values Shadow hours per year [h/year]
A	NSA1	55:09	102	0:45	7:21
B	NSA2	3:53	33	0:14	0:35
C	NSA3	9:48	56	0:24	1:29

To be continued on next page...

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SHADOW - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m, indoors

...continued from previous page

No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values Shadow hours per year [h/year]
D	NSA4	36:49	130	0:26	5:03
E	NSA5	21:40	82	0:24	3:02
F	NSA6	14:42	76	0:17	2:08
G	NSA7	11:17	76	0:13	1:38
H	NSA8	17:52	128	0:14	2:32

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	KLH201	7:59	1:12
2	KLH202	13:58	1:54
3	KLH203	19:09	2:37
4	KLH204	28:43	3:50
5	KLH205	39:21	5:23
6	KLH207	2:10	0:19
7	KLH206	46:33	6:40

Total times in Receptor wise and WTG wise tables can differ, as a WTG can lead to flicker at 2 or more receptors simultaneously and/or receptors may receive flicker from 2 or more WTGs simultaneously.

The calculation of the total expected values for a given receptor assumes a weighted average directional reduction for all WTGs contributing to shadow flicker within the same day. In the case where shadow flicker from different WTGs is not concurrent within the day, the total expected time at a given receptor may deviate marginally from the individual flicker time caused by each turbine separately.

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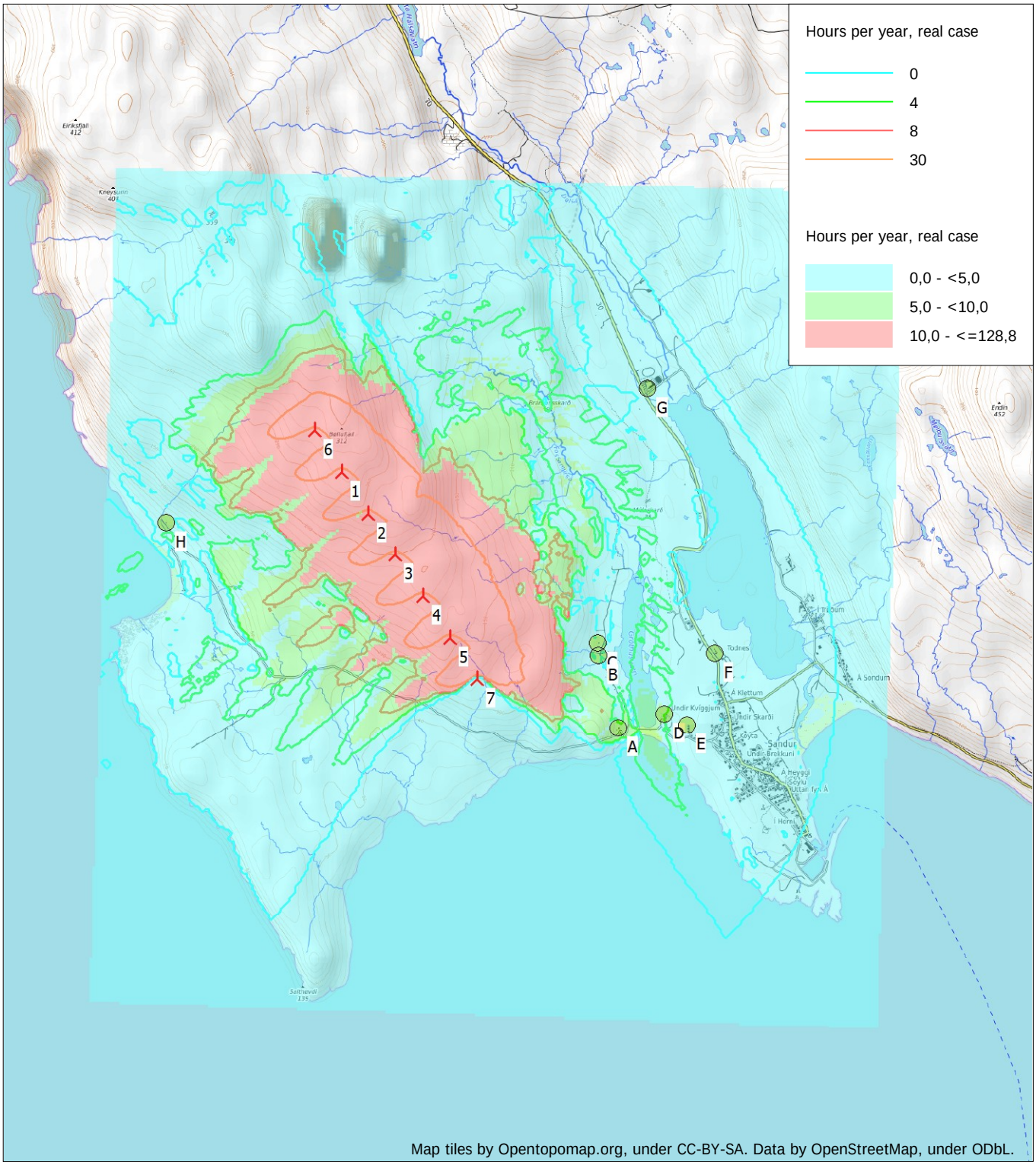
2023-11-09 17:12/3.5.587

SHADOW - Map

Calculation: 7 x V117 4p2 MW HH 91p5 m, indoors



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 613 100 North: 6 858 720

New WTG Shadow receptor

Flicker map level: Height Contours: CONTOURLINE_Sandoy_uV_20181121_0.wpo (1)

Time step: 3 minutes, Day step: 7 days, Map resolution: 20 m, Visibility resolution: 10 m, Eye height: 1,5 m

Project:
Sandoy_uV_20181121

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Calculated:
2023-11-09 15:02/3.5.587

SHADOW - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m, outdoors

Assumptions for shadow calculations

Maximum distance for influence	2 500	m
Minimum sun height over horizon for influence	3	°
Day step for calculation	1	days
Time step for calculation	1	minutes

Sunshine probability S (Average daily sunshine hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0,96	1,89	2,95	3,87	5,09	4,51	3,45	3,28	2,87	1,90	1,24	0,70

Operational hours are calculated from WTGs in calculation and wind distribution:
Site data: WAsP (1)

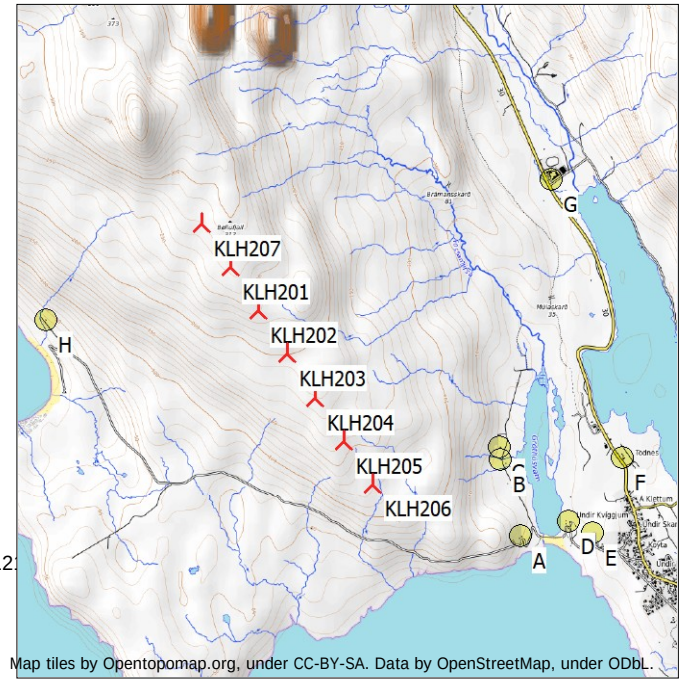
Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
601	754	807	584	588	626	510	796	1 023	897	734	520	8 440

Idle start wind speed: Cut in wind speed from power curve

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Height Contours: CONTOURLINE_Sandoy_uV_2018112
Obstacles used in calculation
Receptor grid resolution: 1,0 m
Topographic shadow included in calculation

All coordinates are in
UTM (north)-WGS84 Zone: 29



Scale 1:50 000

New WTG Shadow receptor

WTGs

	Easting	Northing	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	611 989	6 859 561	276,6	KLH201	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
2	612 188	6 859 278	258,3	KLH202	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
3	612 386	6 858 996	218,1	KLH203	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
4	612 584	6 858 713	194,2	KLH204	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
5	612 782	6 858 430	167,8	KLH205	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
6	611 791	6 859 843	303,5	KLH207	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6
7	612 981	6 858 148	143,3	KLH206	Yes	VESTAS	V117-4.2-4 200	4 200	117,0	91,5	2 500	13,6

Shadow receptor-Input

No.	Name	Easting	Northing	Z	Width	Height	Elevation a.g.l.	Slope of window	Direction mode	Eye height (ZVI) a.g.l.
				[m]	[m]	[m]	[m]	[°]		[m]
A	NSA1	613 979	6 857 844	30,3	15,0	15,0	1,0	0,0	"Green house mode"	1,0
B	NSA2	613 827	6 858 343	23,1	15,0	15,0	1,0	0,0	"Green house mode"	1,0
C	NSA3	613 820	6 858 427	30,2	15,0	15,0	1,0	0,0	"Green house mode"	1,0
D	NSA4	614 296	6 857 947	14,0	15,0	15,0	1,0	0,0	"Green house mode"	1,0
E	NSA5	614 457	6 857 878	27,2	15,0	15,0	1,0	0,0	"Green house mode"	1,0
F	NSA6	614 633	6 858 383	10,0	15,0	15,0	1,0	0,0	"Green house mode"	1,0
G	NSA7	614 101	6 860 212	8,8	15,0	15,0	1,0	0,0	"Green house mode"	1,0
H	NSA8	610 778	6 859 169	52,4	15,0	15,0	1,0	0,0	"Green house mode"	1,0

Calculation Results

Shadow receptor

		Shadow, worst case			Shadow, expected values
No.	Name	Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow hours per year [h/year]
A	NSA1	61:29	102	0:49	8:11
B	NSA2	3:09	22	0:14	0:28
C	NSA3	12:07	67	0:26	1:50

To be continued on next page...

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SHADOW - Main Result

Calculation: 7 x V117 4p2 MW HH 91p5 m, outdoors

...continued from previous page

No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values Shadow hours per year [h/year]
D	NSA4	42:02	130	0:30	5:46
E	NSA5	24:36	83	0:26	3:27
F	NSA6	16:44	80	0:18	2:26
G	NSA7	12:14	83	0:14	1:47
H	NSA8	22:24	141	0:16	3:11

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	KLH201	10:15	1:32
2	KLH202	16:27	2:15
3	KLH203	21:21	2:55
4	KLH204	32:20	4:20
5	KLH205	43:22	5:55
6	KLH207	2:32	0:23
7	KLH206	53:10	7:37

Total times in Receptor wise and WTG wise tables can differ, as a WTG can lead to flicker at 2 or more receptors simultaneously and/or receptors may receive flicker from 2 or more WTGs simultaneously.

The calculation of the total expected values for a given receptor assumes a weighted average directional reduction for all WTGs contributing to shadow flicker within the same day. In the case where shadow flicker from different WTGs is not concurrent within the day, the total expected time at a given receptor may deviate marginally from the individual flicker time caused by each turbine separately.

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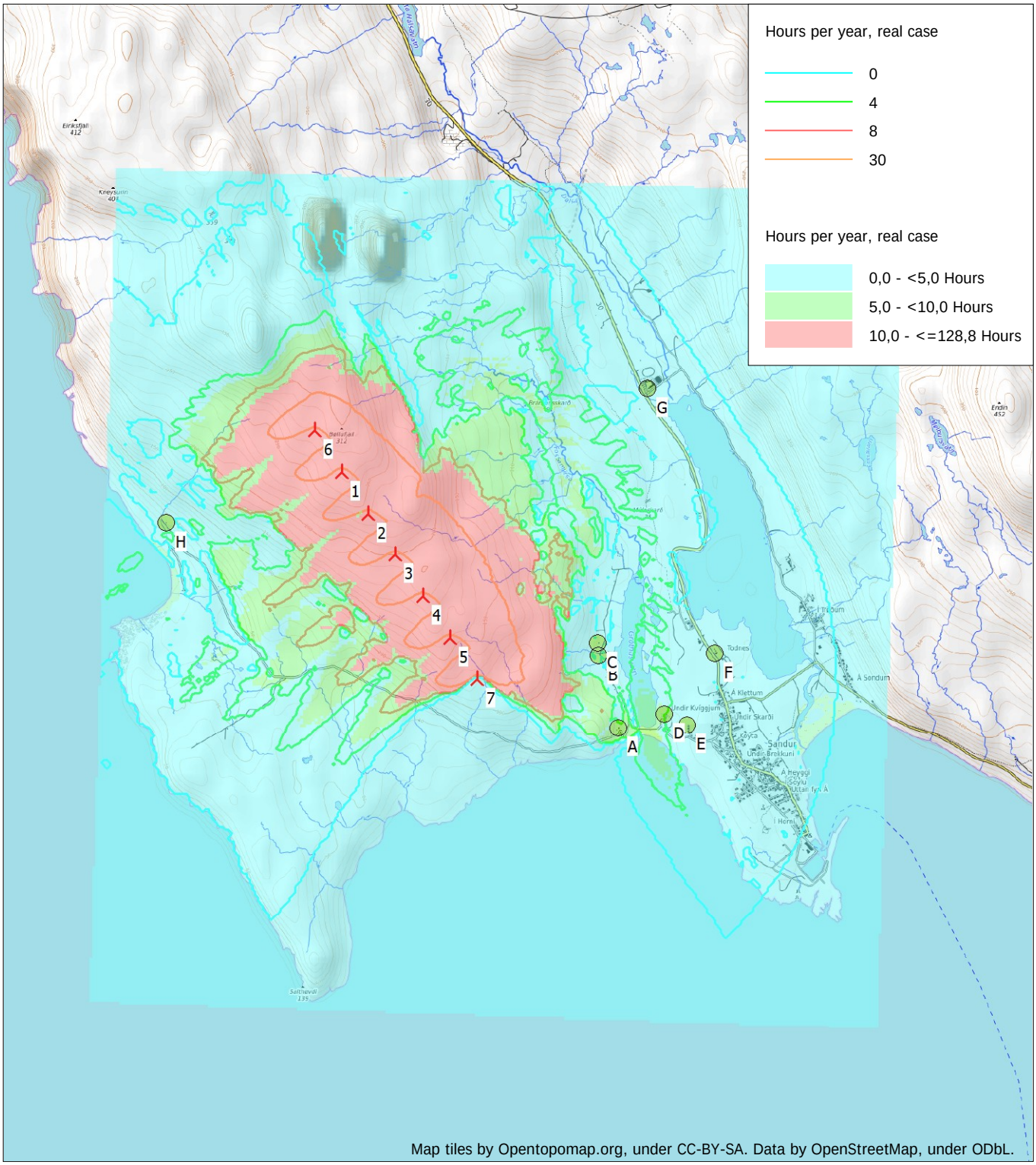
Calculated:
2023-11-09 15:02/3.5.587

SHADOW - Map

Calculation: 7 x V117 4p2 MW HH 91p5 m, outdoors



0 500 1000 1500 2000 m

Map: OpenTopoMap , Print scale 1:40 000, Map center UTM (north)-WGS84 Zone: 29 East: 613 100 North: 6 858 720

New WTG Shadow receptor

Flicker map level: Height Contours: CONTOURLINE_Sandoy_uV_20181121_0.wpo (1)

Time step: 3 minutes, Day step: 7 days, Map resolution: 20 m, Visibility resolution: 10 m, Eye height: 1,5 m