T4 Wind Farm

ZVI Analysis

Report Prepared For:
Ventus Energy
M338 Private Bag 300987
Albany
Auckland
New Zealand

By:
Energy3 Services Limited
P.O. Box 17563
Sumner
Christchurch, 8830
New Zealand

Document Control Record

Document prepared by:

Energy3 Services Limited
PO Box 17563
Christchurch, New Zealand

Telephone **+64 3 376 5539**
Email info@energy3.co.nz
WWW www.energy3.co.nz

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Summary

Ventus Energy contracted Energy3 Services Limited to undertake a revised ZVI analysis using larger turbines than originally consented on the T4 wind farm project. Since the original Resource Consent for the project was granted, average turbine size offered my manufacturers has grown considerably, such that it is now difficult if not impossible to procure reputable machines of the size originally consented.

The T4 site is 30 km to the west of Te Kuiti. The site is characterised by grassed pasture with some remnant scrub pockets and a number exotic plantings, the elevation is approximately 260-330 m above sea level. The topography is suitable for a wind farm development and has been extensively studied for this purpose.

The revised T4 project now consists of 11 proposed wind turbine locations, a reduction from the original 22 consented locations. The locations are spatially suitable for large scale wind turbines.

The following tables summarises the originally consented turbine dimensions relative to the new turbine proposal.

Parameter	Hub Height (m)	Rotor Diameter (m)	Tip Height (m)
Originally Consented Turbine Specifications	95	155	172.5
Revised Proposal Turbine Specifications	60	100	110.0

Table 1: Wind turbine sizing

The software programme WindFarm was used to process the supplied contour data and perform the ZVI analysis. The software package QGIS has been used to manipulate the files drived from WindFarm analysis for presentation and further analysis.

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1. ZONE OF VISUAL INFLUENCE SOFTWARE AND KEY INPUTS

The Zone of Visual Influence (ZVI) for the proposed Kaimai Wind Farm has been calculated using the software package "WindFarm" (Release 4.2.2.1). WindFarm is written by ReSoft, a specialist wind farm software development company (http://www.resoft.co.uk/English/).

WindFarm is an integrated software package, which combines the ability to create turbine site layouts, assess wind farm energy yields, and possess the ability to analyse various turbine layouts for both acoustic emissions and visual impacts.

To accurately position general turbine layouts and specific turbine locations, and subsequently assess the ZVI, topographical contour information is required.

Topographical data has been obtained through a variety of sources. The LINZ Data Service has been accessed to provide background raster maps. Ventus Energy has provided contour data of the site and surrounding area, which was originally prepared by New Zeland Aerial Mapping. Contour resolution is 5m for an area of 5km X 7km centred on the proposed wind farm; contour resolution reduces to 20m outside of this area. The data is provided as a WaSP vector "map" file, containing both the 5m and 20m contours relevant to the analysis in a single vector file.

A surveyed layout of the proposed turbine locations is also entered as a key input parameter to the assessment. In addition, turbine size and geometry must be entered as a key input to assess the visibility level.

The following table presents the 22 turbine positions that were originally consented for the smaller scale machines proposed at the time.

Turbine ID	Easting	Northing	Turbine ID	Easting	Northing
1	2664832	6331426	12	2667475	6328881
2	2664936	6331211	13	2667510	6328650
3	2665059	6330955	14	2667714	6328528
4	2665164	6330776	15	2667530	6328229
5	2665329	6330557	16	2667633	6327900
6	2665428	6330343	17	2667804	6327686
7	2665862	6329857	18	2667816	6327415
8	2666396	6329701	19	2667920	6327156
9	2666553	6329502	20	2668045	6326891
10	2666635	6329261	21	2668150	6326646
11	2667307	6329057	22	2668263	6326402

Table 2: Original turbine locations (NZMG)

The following table presents the revised surveyed turbine positions, on which larger scale turbines are sought to be installed.

Turbine ID	Easting	Northing
1	2664860	6331362
2	2664939	6331125
3	2665062	6330939
4	2665150	6330768
5	2665299	6330589
6	2665416	6330349
7	2665864	6329839
8	2666407	6329752
9	2666591	6329544
10	2666689	6329292
11	2667330	6329048

Table 3: Revised turbine locations

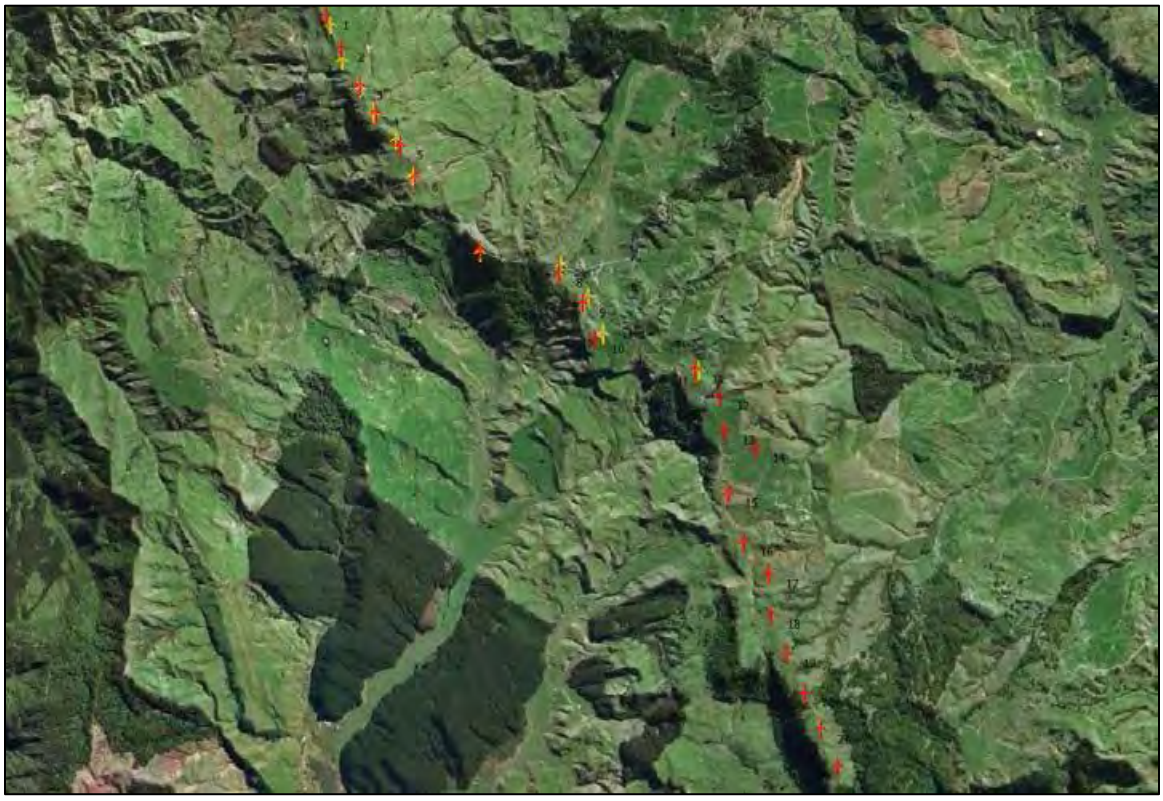

Figure 1: Comparative Turbine Locations, 11 revised positions shown in yellow icons, the original 22 positions shown in red icons

WindFarm uses the topographical contour, turbine layout information, and turbine geometry to perform the ZVI calculations and create the wireframe image for Photomontage formation if required.

2. ZVI CALCULATION PROCESS

The ZVI module of WindFarm creates maps of the "zone-of-visual-influence" of a wind farm, and in addition the cumulative visual impacts of a number of wind farms should there be more than one wind farm in the immediate area to be assessed.

There are a number of different ways of counting visibility. The most common way is to count the number of turbines visible from certain points within a specified radius of the wind farm, with the point of visibility being either a blade tip, nacelle, or a point on the tower. The blade tip counting option was used as the basis of the T4 Wind Farm analysis, this being the most conservative option. Using the blade tip counting method, a count of no more than one is ascribed to any turbine with a potentially visible blade tip; thus if all turbines had tips that were visible from a location within the calculation zone, the location would have a ZVI count of 11.

Alternatively, a visibility count can be made, which sums blade tips, nacelles, and reference points on the tower that can be seen. Therefore if a whole turbine can be seen, the count for that turbine would be 3. The maximum count for a wind farm using this method is three times the number of turbines if no weighting is used for any particular component. This method does, however, have the disadvantage that a count of 6 could be either 6 blade tips or 2 whole turbines, which are visually very different.

The ZVI calculations use the input contour files, and the applicable turbine dimensions to calculate where, and how many turbines can be seen from any particular vantage point. The accuracy of the ZVI calculation is dependent on the resolution of the contour data. With only 20m contour data available for the wider area, the results will not be as accurate as using 2m contour data for the entire ZVI calculation area, for example.

Various options are available to the software operator when conducting the ZVI analysis process. Key input variables include:

- Topographical dataset(s)
- Centre point of calculation area (usually notional wind farm centre)
- Calculation area
- Calculation shape (circular or square)
- Counting methodology (nacelle, blade, tower, or all components)
- Observer height relative to ground level
- Resolution of each visibility point
- Atmospheric refraction
- Earths curvature
- Inclusion of features which obscure visibility

It should be recognised that only the topography file is used in the ZVI calculation (sometimes called a "bald earth" ZVI), ignoring the effects of trees, buildings or other structures, and therefore representing the theoretical maximum visibility of turbines that may be seen from a given point. However; WindFarm does permit the specification of exclusion zones where

features other than the landscape obscure the visibility of the wind farm. For example, a forest area may be defined and given a nominal height of 20m. The turbines' visibility is automatically set to zero inside the exclusion zone, and in addition, the wind farm visibility will be modified at the edges of the forest because of its height.

No exclusion zones have currently been entered into the ZVI analysis in order to present a conservative scenario, however; shelterbelts, exotic forests, bush, and other structures in the immediate vicinity of the proposed wind farm can be defined as exclusion zones, thus reducing actual overall visibility.

The graphical output of the ZVI analysis is a shaded circular or square region (depending on the calculation shape selection), with various colours identifying the number of visible turbine points from a particular vantage point. The output then has a topographical map of the area overlaid to give spatial context to the viewer.

The following screenshots illustrate the graphical ZVI output as part of the modelling process:

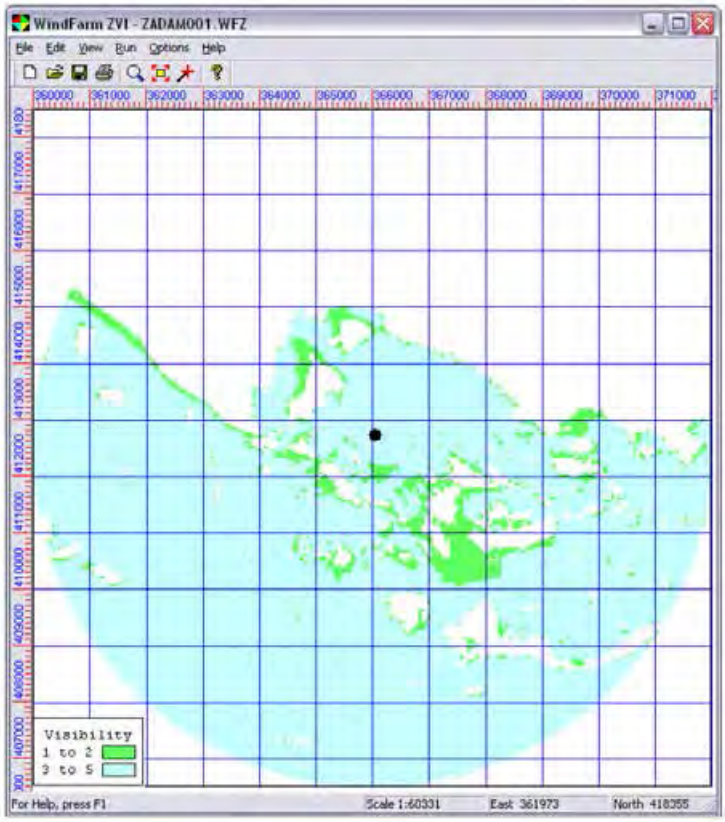

Figure 2 - ZVI Output

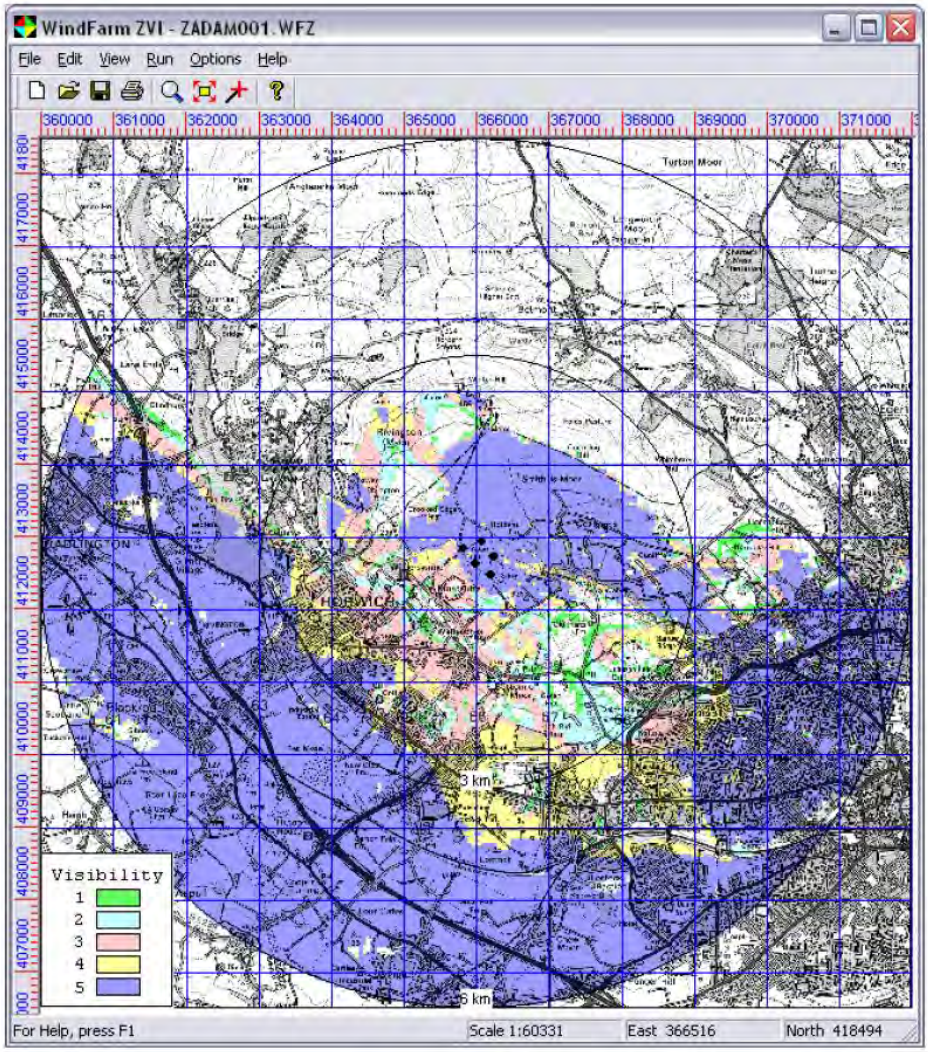

Figure 3 - ZVI output overlaying topographical map

Run Data and Statistics are available from each calculation run, and describe critical parameters of the run data, and also a list of visibility statistics. The number of visibility points, percentage of total points, and the area is given for each of the groups. The information can be printed or exported as required.

3. ZVI RUN INPUTS

The following table presents the key run inputs for the prior consented layout and the new proposed layout with the larger turbines. The run output file for each scenario is presented in Appendix A.

Parameter	22 Turbine Layout	11 Turbine Layout
Counting Method	1 for each turbine	1 for each turbine
Visibility Point	Blade Tip	Blade Tip
ZVI Centre (NZMG)	2665782, 6330237	2665782, 6330237
ZVI Radius (m)	8,000	8,000
ZVI Resolution (m)	20	20
Receptor Height (m)	2	2
Zone	Circular	Circular
Hub Height (m)	60	95
Rotor Diameter (m)	100	155

Figure 4 - ZVI model input parameter summary

The ZVI calculation centre has been kept consistent between the two calculation runs to enable accurate comparison analysis. Likewise, the calculation radius of 8,000m is identical between the two runs and mirrors the calculation radius used in the original Resource Consent application.

4. ZVI RESULTS

The following table presents the key run outputs for the consnted layout and the new proposed layout with the larger scale turbines. The run output file for each scenario is presented in Appendix A and is included with the run input in the WindFarm RUZ files as per section 3.

Visibility	Points	Percentage	Area (sq/km)
1 to 3	33,423	6.63	13.37
4 to 6	65,533	13.00	26.21
7 to 9	46,800	9.29	18.72
10 to 12	33,738	6.69	13.50
13 to 15	22,574	4.48	9.03
16 to 18	24,516	4.86	9.81
19 to 22	54,107	10.74	21.64
0 not counted	223,282	44.30	89.31
Total	503,973	100.00	201.59

Figure 5 – 22 position layout ZVI summary

Visibility	Points	Percentage	Area (sq/km)
1 to 3	37,934	7.53	15.17
4 to 6	55,376	10.99	22.15
7 to 9	51,986	10.32	20.79
10 to 12	119,599	23.73	47.84
0 not counted	239,078	47.44	95.63
Total	503,973	100.00	201.59

Figure 6 – 11 position layout ZVI summary

Visibility	Points	Percentage	Area (sq/km)
1 to 3	13%	14%	13%
4 to 6	-15%	-15%	-15%
7 to 9	11%	11%	11%
10 to 12	254%	255%	254%
13 to 15	-100%	-100%	-100%
16 to 18	-100%	-100%	-100%
19 to 22	-100%	-100%	-100%

Figure 7 –ZVI variance summary relative to the original proposal

The results show that the change to 11 turbine positions from the original 22, even in conjunction with a larger turbine size reduces the overall visibility within the 8,000m radius from 56% to 53%, an overall reduction in visibility of 3%. The percentage of the number of the turbines visible from any vantage point is also logically reduced.

Appendix B presents the maps showing the ZVI difference between the two layouts, and the extent of the ZVI for each respective layout and turbine size.

Of particular interest is the impact of the proposed layout and size changes in relation to potential viewers located on Coutts and Marokopa Roads, these 19 original locations are presented in the following table in the NZMG CRS.

Vantage Point	East NZMG	North NZMG)
1	2664096	6331881
2	2664189	6331709
3	2665004	6329881
4	2664901	6329850
5	2664787	6329811
6	2666736	6329780
7	2666932	6329985
8	2667445	6331124
11	2664685	6326648
12	2664691	6326315
13	2665096	6326065
14	2665443	6325682
15	2665655	6324897
16	2665557	6324645
17	2665667	6324334
18	2666814	6324867
19	2667541	6324563
20	2667533	6324740
21	2667997	6325423

Figure 8 – Selected vantage locations of interest

Using the QGIS raster sampling tool, the proposed turbine changes were assessed in regards to visibility for each point of interest. The results are presented in the table below, and describe the level of visibility for each layout and turbine size.

Vantage Point	Visibility (11 turbines)	Visibility (22 turbines)	Relative Change
1	7 to 9	7 to 9	No Change
2	7 to 9	7 to 9	No Change
3	10 to 11	19 to 22	Reduction
4	4 to 6	4 to 6	No Change
5	7 to 9	7 to 9	No Change
6	10 to 11	4 to 6	Increase
7	4 to 6	7 to 9	Reduction
8	10 to 11	19 to 22	Reduction
11	10 to 11	16 to 18	Reduction
12	10 to 11	19 to 22	Reduction
13	1 to 3	10 to 12	Reduction
14	10 to 11	19 to 22	Reduction
15	10 to 11	19 to 22	Reduction
16	7 to 9	19 to 22	Reduction
17	10 to 11	19 to 22	Reduction
18	4 to 6	7 to 9	Reduction
19	4 to 6	4 to 6	No Change
20	0	4 to 6	Reduction
21	0	4 to 6	Reduction

Figure 9 – Change in visibility for the selected vantage locations of interest

6. METHODOLOGY RELATIVE TO NZILA BPG 10.2

In August 2008 the New Zealand Institute of Landscape Architects hosted a Landscape Planning Initiative, from which arose a directive that a series of Best Practice Guide (BPG) documents be prepared. The Technical Guide for Photomontage Simulations was the first of such documents to be published, and as such, has relevance to the formation of the ZVI analysis and the photomontages for the proposed Kaimai Wind Farm.

The analysis does accurately follow the general principals set out in the NZILA BPG, namely:

- The analysis is as accurate as possible with the supplied data in order to assist in making well-informed judgments.
- The analysis by the WindFarm software package is based on a structured and replicable procedure so that others may test and confirm the accuracy and credibility of the simulations.
- The analysis is carried out by specialist wind farm software, and therefore uses techniques that represent the project in its true environmental context, and in a fair and reasonable manner.
- The report provides a clear representation of the ZVI and conveys important information in regards to the analysis for each ZVI analysis.

7. APPENDIX A – WINDFARM ZVI RUN FILE

Consented Layout

Project name : TAUMATA
ZVI run file : ZTAUMATA010.WFZ

Created : 16:46:33 08-Jun-2020
Revised : 10:58:34 09-Jun-2020
Revision : 11
Title : 65m HH 90m Rotor original 22 position layout 20200605
Author :
Comment :

GENERAL
Calculation : Single wind farm
Counting method : 1 for each turbine visible (1 point per turbine)
Visible point : Blade tip
Tower point : Half of hub height
View height : 2.0

ZVI REGION
ZVI centre - east : 2665782
ZVI centre - north : 6330237
ZVI radius : 8000
ZVI resolution : 20

EARTH'S RADIUS
Using Earth's radius : 6370
Not using atmospheric refraction.

DISPLAY REGION
Display shape : Circular, radius 8000
West : 2657782
South : 6322237
East : 2673782
North : 6338237

WIND FARM LAYOUTS
Number of wind farms : 1

Hub Height	Diameter	Wind Farm Layout File
60.00	100.00	LTAUMATA013_B.WFL

GROUPING
Number of groups : 7

Group	First	Last	Intensity	Red	Green	Blue
1	1	3	100	255	0	0
2	4	6	100	255	255	0
3	7	9	100	255	128	0
4	10	12	100	128	64	0

5	13	15	100	64	0	64
6	16	18	100	128	255	0
7	19	22	100	0	64	0

VISIBILITY

Visibility	Points	Percentage	Area (sq/km)
1 to 3	33423	6.63	13.37
4 to 6	65533	13.00	26.21
7 to 9	46800	9.29	18.72
10 to 12	33738	6.69	13.50
13 to 15	22574	4.48	9.03
16 to 18	24516	4.86	9.81
19 to 22	54107	10.74	21.64
0 not counted	223282	44.30	89.31
Not displayed	0	0.00	0.00
Total	503973	100.00	201.59

Project name : TAUMATA

ZVI run file : ZTAUMATA009.WFZ

Created :	16:41:44 08-Jun-2020
Revised :	10:57:37 09-Jun-2020
Revision :	10
Title :	Revised 11 turbine positions - 95m HH 155m Rotor - 20m resolution 20200605
Author :	
Comment :	

GENERAL

Calculation :	Single wind farm
Counting method :	1 for each turbine visible (1 point per turbine)
Visible point :	Blade tip
Tower point :	Half of hub height
View height :	2.0

ZVI REGION

ZVI centre - east :	2665782
ZVI centre - north :	6330237
ZVI radius :	8000
ZVI resolution :	20

EARTH'S RADIUS

Using Earth's radius : 6370

Not using atmospheric refraction.

DISPLAY REGION

Display shape :	Circular, radius 8000
West :	2657782
South :	6322237
East :	2673782

North : 6338237

WIND FARM LAYOUTS

Number of wind farms : 1

Hub Height	Diameter	Wind Farm Layout File
95.00	155.00	LTAUMATA013_A.WFL

GROUPING

Number of groups : 4

Group	First	Last	Intensity	Red	Green	Blue
1	1	3	100	255	0	0
2	4	6	100	255	255	0
3	7	9	100	255	128	0
4	10	12	100	128	64	0

VISIBILITY

Visibility	Points	Percentage	Area (sq/km)
1 to 3	37934	7.53	15.17
4 to 6	55376	10.99	22.15
7 to 9	51986	10.32	20.79
10 to 12	119599	23.73	47.84
0 not counted	239078	47.44	95.63
Not displayed	0	0.00	0.00
Total	503973	100.00	201.59

8. APPENDIX B – ZVI ANALYSIS MAPS

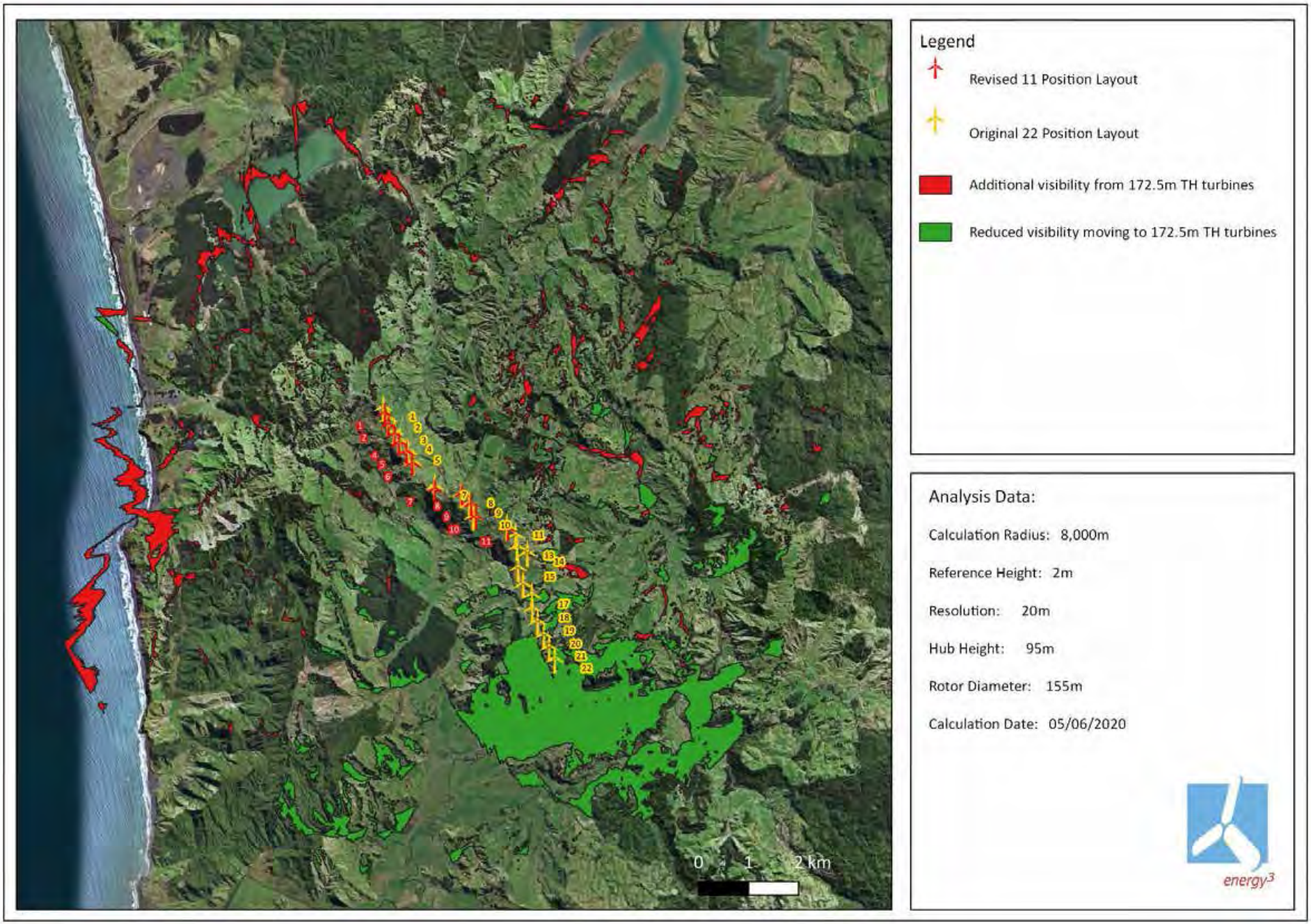

Figure 10: Visibility variance

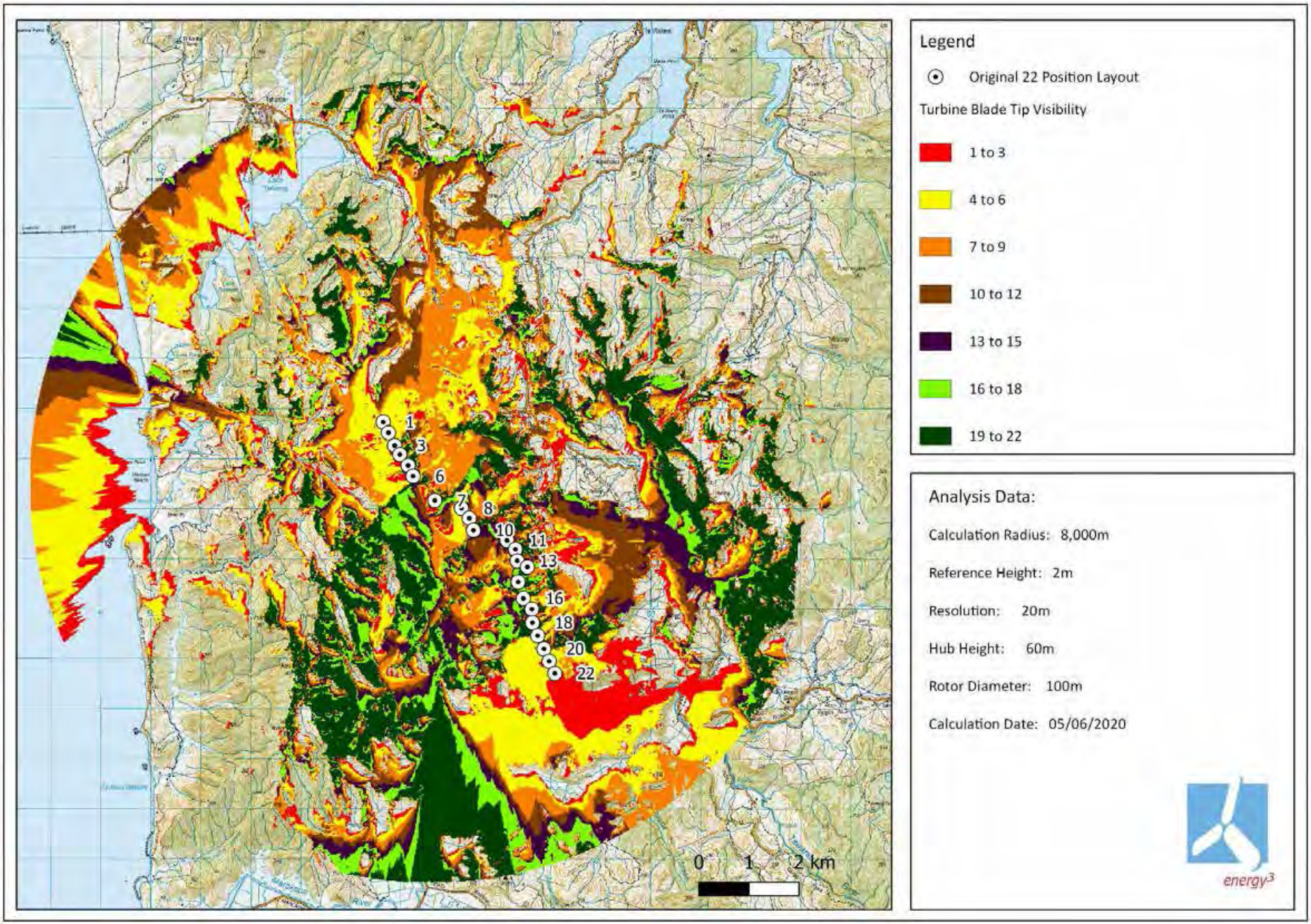

Figure 11: Original 22 turbine ZVI

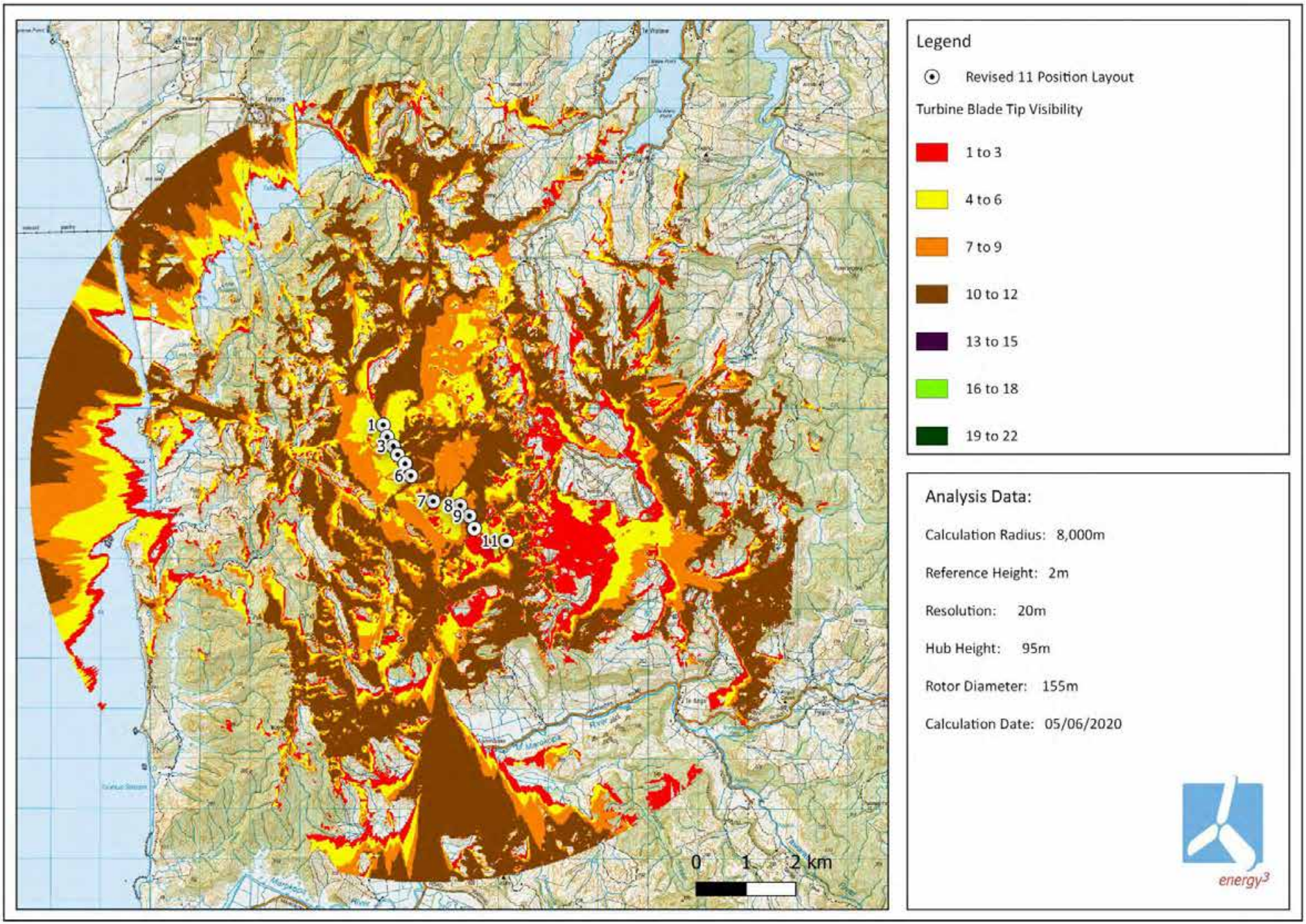

Figure 12: Revised 11 turbine ZVI

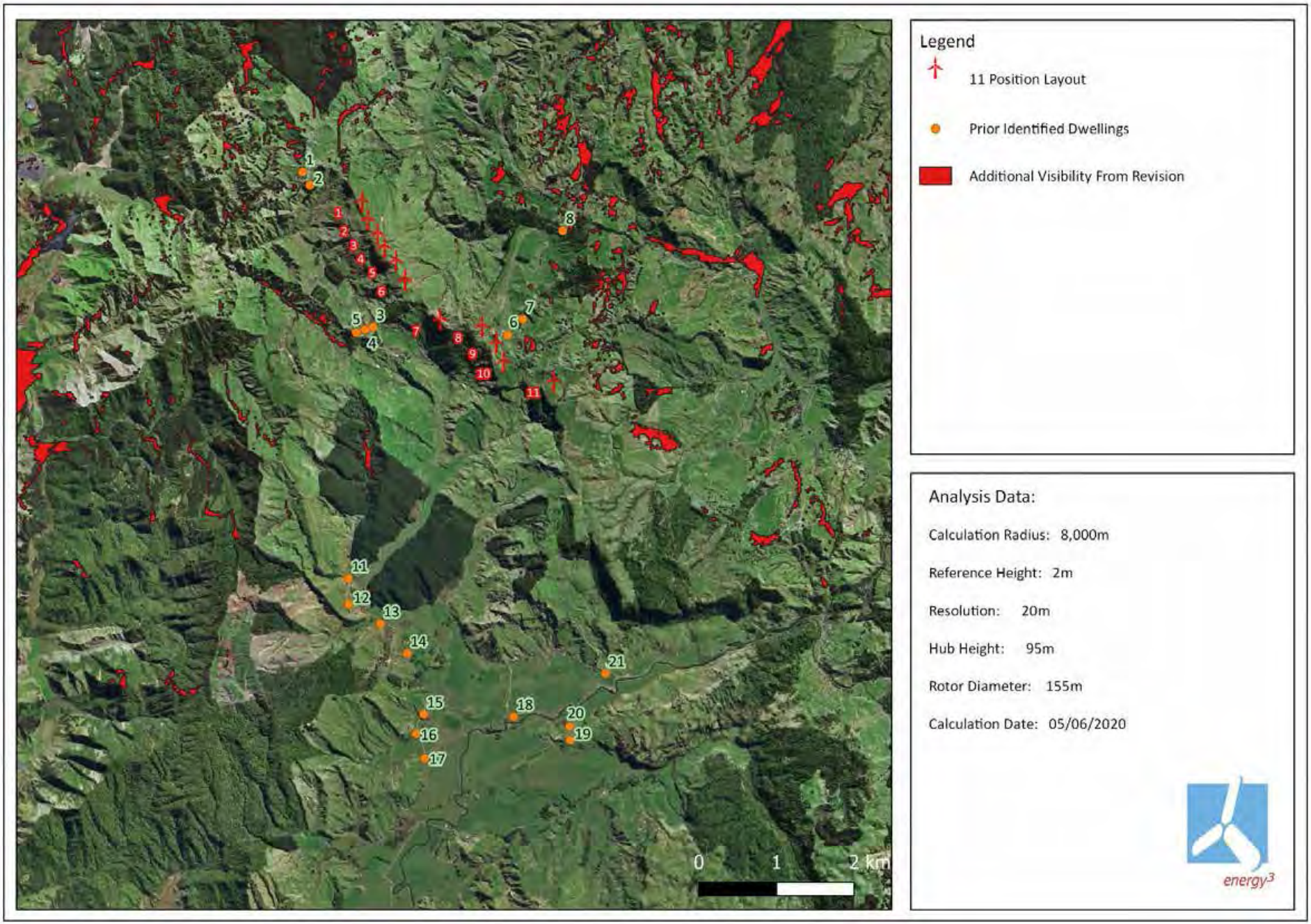

Figure 13: Dwellings identified in prior visibility study relative to new visibility variance