WAsP topographic amplification validation

00010-003-R

Version 2

7 January 2014

prevailing
wind farm analysis

Report details	
Report title	WAsP topographic amplification validation
Document no	00010-003-R
Confidentiality	Commercial in confidence

Signatures		
	Name	**Signature**
Author	Joel Manning	
Checked by	Andrew Hay	
Approved by	Matthew Colls	

Disclaimer
Prevailing accepts no liability for any issues arising as a result of use of this document. It is provided for information only.

Release history		
Version	**Date**	**Notes**
2	7 January 2014	Original release

Contents

Figures

1 Introduction

WAsP is currently the industry standard wind flow model for wind energy applications. Prevailing commonly applies WAsP within energy production assessments.

It is widely acknowledged within the wind industry that there are significant limitations to WAsP's ability to accurately predict wind speeds, particularly in areas of complex terrain.

Experienced users frequently note that WAsP has a tendency to over-predict wind speeds at lower turbine locations when the mast is located at the top of the hill. Conversely, an under-prediction is observed for turbines higher up the hill. This concern can be generalised to the statement that WAsP tends to under-predict the difference in wind speed between locations of differing elevation. To correct for this observed bias, Prevailing applies a topographic amplification to the raw WAsP results, in specific situations. This amplification is applied to horizontal variation in wind speed, and does not affect shear extrapolation.

Despite widespread recognition of this issue, Prevailing is not aware of the publication of any formal evidence or validation studies.

Prevailing has therefore commenced a study using mast pairs in complex terrain in the UK and Ireland. This study is not complete, however early results are presented here. Actual and predicted wind speed differences between locations are compared.

It is acknowledged that the number of datasets currently considered is small. Efforts are under way to increase the number of datasets as suitable measurements become available, and the Prevailing analysis archive is considered in more detail. It is anticipated that this study will be updated regularly.

2 WAsP topographic effect amplification technique

It has been observed that WAsP commonly over-predicts wind speeds for turbine locations when the mast is located at the top of the hill and the opposite for the converse situation. Within WAsP the effect of changes in elevation on the predicted wind speed is represented by the topographic effect. By amplifying this topographic effect Prevailing considers that wind speed predictions more closely reflect real wind speed variations between different locations at different elevations.

The currently applied amplification is equal to 33 % of the topographic effect predicted by WAsP and is applied on a turbine by turbine basis.

As an example, where the turbine is predicted by WAsP to be 6 % less windy than the mast, Prevailing apply an adjustment of 33 % * 6 % = 2 %, hence a total adjustment of 8 % would apply between the mast and the turbine, rather than the original 6 %.

Where the mast location(s) are representative of the turbines on average, the total adjustment is zero, since any adjustments at more or less windy turbines cancel out. In cases where the mast location is biased, however, material adjustments to average wind speeds can result. Where this adjustment is significant, it is included in Prevailing analysis reports.

2.1 Heavy forest

For locations where a displacement height is applied due to forestry, an additional WAsP simulation is carried out in order to derive the topographic effect predicted by WAsP without the inclusion of forest. This enables the non-tree-displaced topographic effect to be observed and the 33 % amplification adjustment can be derived.

For completely forested sites, the non-tree-displaced topographic effect may be amplified by 50 %, however use of this factor is rare and generally indicates a requirement to consider flow modelling in more detail.

2.2 Definitions

For the purposes of this technical note, the wind speed ratio between two locations is defined as:

$$R = \frac{U_2}{U_1}$$

Where R is the ratio, U is long-term average wind speed, and locations 1 and 2 are the less windy and more windy measured locations respectively.

The raw topographic effect is the difference between locations rather than the ratio itself.

$$T_{raw} = R_{raw} - 1$$

Where T_{raw} is the raw topographic effect.

It is this difference that is amplified:

$$T_{amp} = T_{raw} \times F$$

Therefore for an amplification factor F, the amplified wind speed ratio is as follows:

$$R_{amp} = (R_{raw} - 1)F + 1 = \left(\left(\frac{U_2}{U_1}\right) - 1\right)\mathrm{F} + 1$$

As noted elsewhere, current Prevailing policy for partially forested complex sites is F = 1.33, or an amplification of +33%. As mentioned above F = 1.5, or an amplification of +50% is applied for heavily forested sites.

3 Validation

3.1 Validation technique

In order to validate the WAsP predictions, the topographic effect (T) predicted between two measurement locations was compared to the observed topographic effect for the same locations. In both cases, this effect was derived from the long-term average all directional wind speed ratio.

In all cases, standard WAsP configuration, including default stability settings and Davenport roughness values was applied.

3.2 Data Considerations

For measurements for a site to be applicable to this study they must fulfil the following criteria:

- Good quality data from two concurrent measurement locations.
- Measurement locations which lie a significant distance and elevation from one another.
- To ensure that the validation presented is directly relevant to the UK and Ireland, only data measured in these countries has been included in the validation.
- Only partially forested sites have been considered at this stage.

Each dataset has been subject to standard rigorous Prevailing analysis techniques to produce a long-term wind speed prediction at a single height, typically turbine hub height, for each measurement location.

All sites considered at this stage can be described as partially forested, and located in moderately complex, or complex terrain.

4 Results

Figures presented below show topographic effect, as defined in Section 2.2. As such the origin represents locations that are the same wind speed, either raw prediction by WAsP (X axis), or in reality (Y axis).

The dotted line lies along Y = X. Data points on this line show correct prediction of the wind speed ratio by WAsP. Points above the line indicate the observed wind speed ratio is larger than the predicted one (WAsP under-prediction of wind speed difference).

Figure 4.1 shows a correlation of speed-ups derived from measurements and from WAsP, with no topographic adjustment applied.

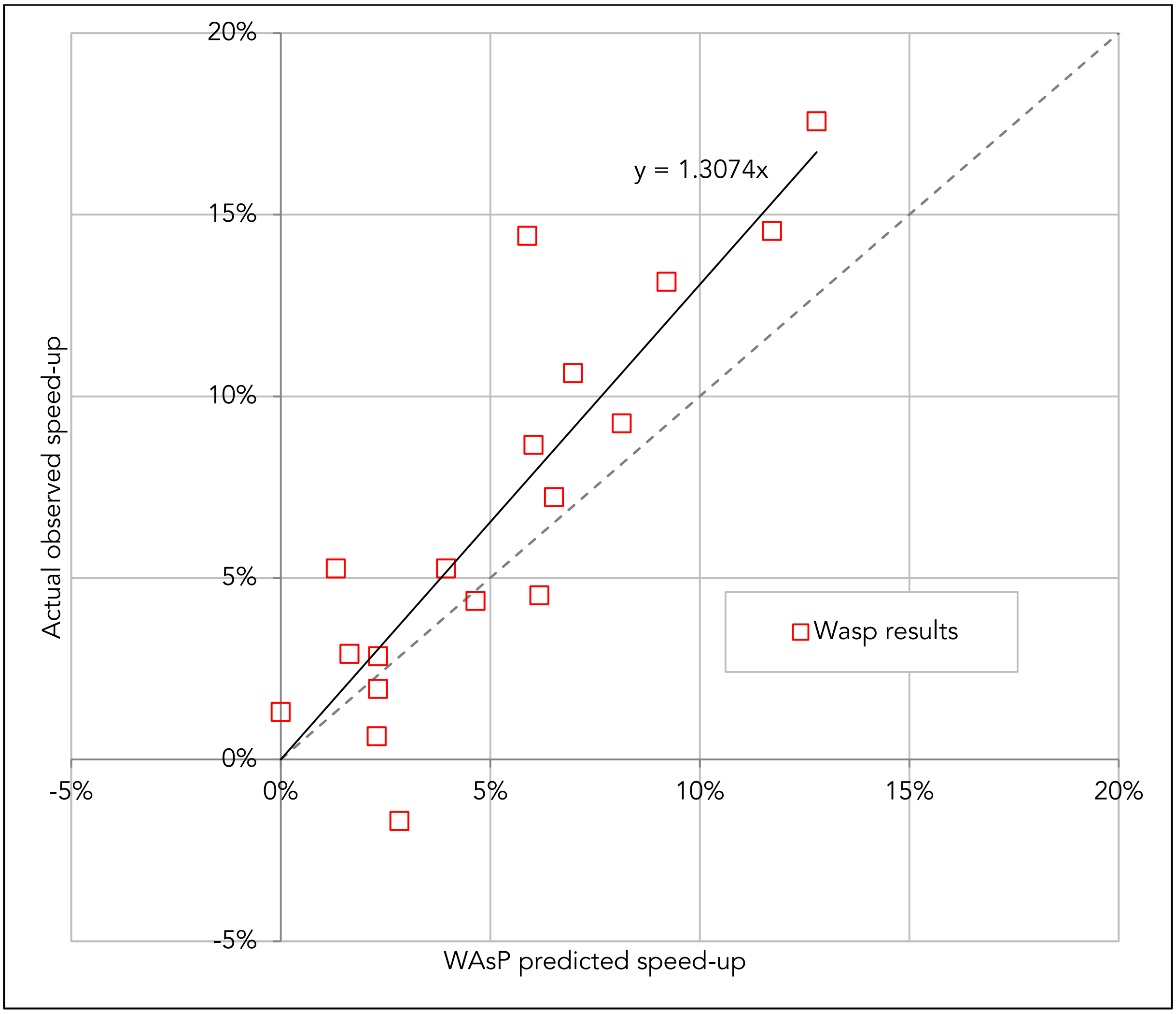

Figure 4.1 Correlation of actual observed speed-up ratios against WAsP - no topographic amplification

As the majority of the points in Figure 4.1 lie above the Y = X line it is clear that there is a bias in the WAsP predictions which can be characterised as an under-prediction of the topographic effect.

The value of the topographic amplification to be applied here can be inferred from the gradient of the trendline. However, this relationship is not exact as some of the measurements were made at forested sites; so a portion of the observed speed-up is due to differing exposure to forestry rather than topographic effects alone.

In order to appraise the methodology currently applied by Prevailing, Figure 4.2 shows the same data as Figure 4.1, with the addition of the wind speed predictions after topographic amplification has been applied. The trendline is now applied to the adjusted data.

The topographic amplification is applied as described in Section 2.

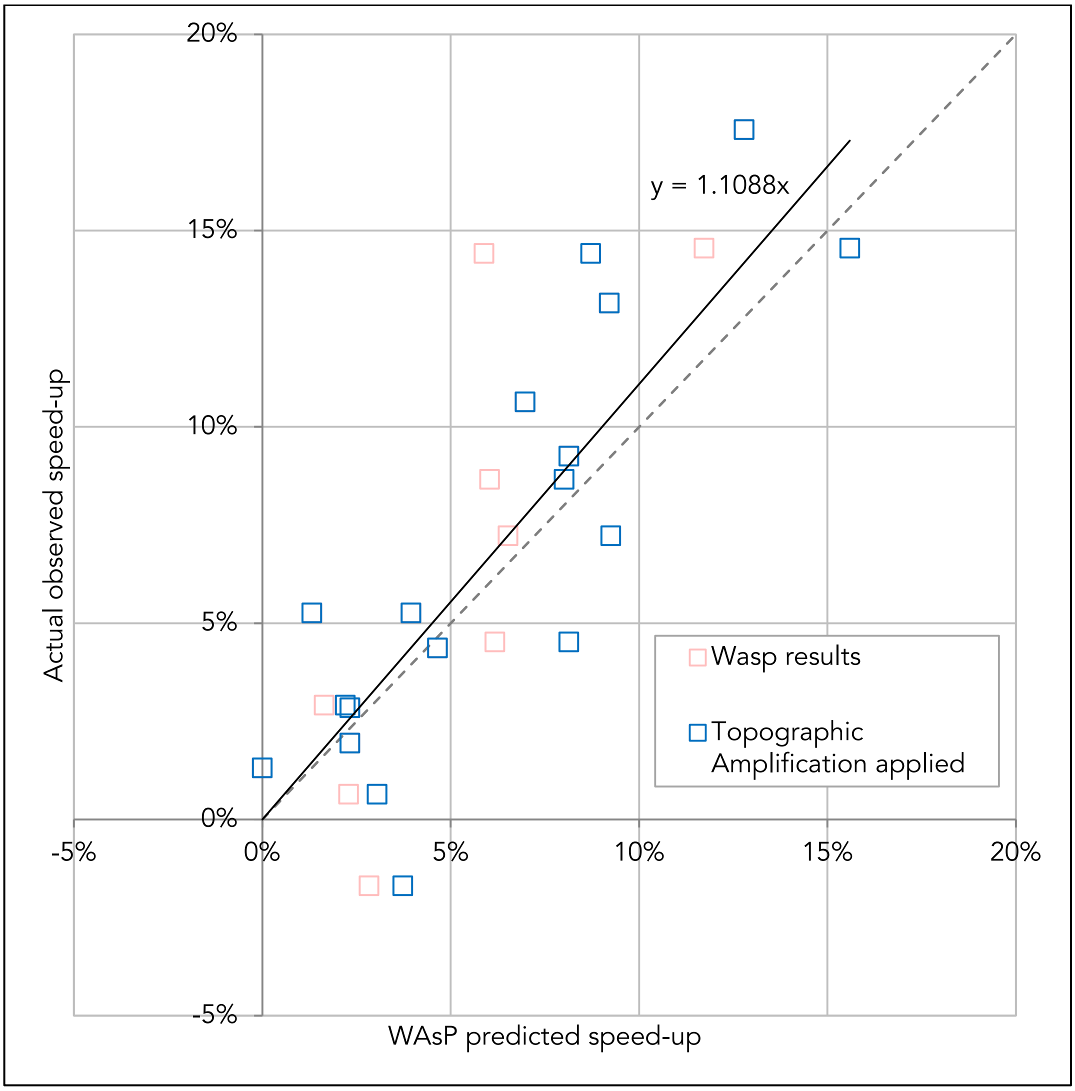

Figure 4.2 Correlation of actual observed speed-up ratios against WAsP both with and without topographic amplification

Although significant deviations from the observed speed-up ratios remain after the topographic amplification has been applied, the adjustment represents a clear improvement in agreement, with a slope value considerably closer to unity.

Due to the small dataset applied here Prevailing does not consider that changes to the current methodology are yet warranted. However it is clear that further data may allow refinements to the level of topographic amplification. Prevailing is continually working to increase the data included in this validation and it is expected that this document will be updated regularly.

5 Summary and conclusions

5.1 Summary of findings

Prevailing has commenced an investigation of WAsP predictions against measured data in order to support adjustments made to predicted topographic effect. Currently the number of datasets is small. However due to the lack of publication in this area this begins to represent a useful body of evidence. The following conclusions are drawn:

1. There is a clear bias in the topographic effect predicted by WAsP when compared to measurements, for the sites considered here.
2. This bias is in line with anecdotal evidence from discussions with a range of experienced analysts.
3. The bias can be reduced through topographic amplification, improving WAsP wind speed predictions.
4. It is noted that although the bias can be improved, significant uncertainty remains in the WAsP predictions.
5. The dataset applied here is too small to draw precise conclusions about the magnitude of the adjustment required.
6. Where masts are located appropriately, the effect of amplification tends to zero.

5.2 Conclusions

Prevailing will carry out the following based on the findings presented here:

1. The current topographic amplification, described in section 2, will continue to be applied for energy production assessment work in appropriate circumstances, using an amplification factor of 33%.
2. Prevailing will continue to add datasets to this validation study.
3. Prevailing will continually assess the validity of the topographic amplification in light of the growing body of evidence, leading to refinements as necessary.
4. When requested, Prevailing will advise on appropriate monitoring strategies, in order to reduce the potential for bias in WAsP predictions, and hence reduce the magnitude of any required bias correction.
5. Prevailing is also continually working to validate more advanced, CFD-based modelling techniques. It is anticipated that such techniques will provide additional validation of WAsP bias correction factors, as well as eventual replacement of WAsP, particularly for complex forested sites.