WELLINGTON CITY COUNCIL

Proposed Plan Change 83
Kiwi Point Quarry

Annexure to s42A Report
Wind effects

Report Date
10 December 2018

Hearing Date
10-12 December 2018

1.0 REPORT INTRODUCTION & SUMMARY

Report Author

1.1 My name is Michael Donn.

(a) I am a Building Environmental Scientist at Victoria University of Wellington contracted to the Wellington City Council (the Council) to provide independent advice on building aerodynamics.

(b) I was employed at Victoria University School of Architecture approximately in 1979 to teach building aerodynamics and building environmental science to architecture and building science students. In this capacity I have taught and led research in these areas since that time.

(c) I am currently the Director of the Centre for Building Performance Research in the School.

(d) My PhD examined the issues of Quality Assurance – believability – in the field of building environmental performance simulation, including wind tunnel testing of large CBD buildings.

(e) I have been engaged by the Council since 1981 to peer review wind tunnel test reports and to advise on matters related to building aerodynamics as they affect pedestrian comfort and safety. In that capacity I have assisted with the drafting of the 1984 Wind Ordinance and subsequent revisions of these performance standards through the more recent transformation of the Ordinances into the District Plan formulation under the Resource Management Act 1991.

(f) I have audited over 270 wind reports – more than half of which would be full wind tunnel test reports. The majority of these audits have been for the Wellington Council, but I have also provided advice on pedestrian aerodynamics for buildings in Auckland, Lower Hutt, Christchurch and Palmerston North.

(g) In the period 2006-2008 I worked with Nick Locke of Opus Central Laboratories and the Wellington City Council to rewrite the performance requirements for the Council in terms that make them

easier for councillors, Council officers and the public to compare the likely impact of the changes in wind performance to the other positive and negative effects of a building upon the environment.

1.2 I have been asked by the Council to prepare this annexure to the s42A report on Proposed Plan Change 83.

1.3 Along with contextual information and other matters of fact, this report includes my personal views on the proposal. These views and are my own, except where I indicate otherwise.

1.4 Though not a requirement of Council plan change hearings, I have read and agree to abide by the Code of Conduct for Expert Witnesses, and have prepared this report in accordance with it. The report content is within my area of expertise except where stated otherwise. I have not omitted to consider the material facts known to me that might alter or detract from the opinion expressed in this report.

1.5 In preparing this report, I have read

a. Submission by Angela Garty of 138 Homebush Rd

b. Submission by Anthony Norton

c. Plan of the contours of the site, existing and proposed from the document "Appendix C – rehabilitation Plan"

d. Greater wellington GIS Mapping tool screen capture showing the distance of 146 Mandalay Tce from the peak of the existing hill

e. References as appended

Report Scope and Structure

1.6 This report addresses potential wind effects arising from landform change that may result from future implementation of the plan change.

1.7 More specifically, my report covers the following:

a. **Section 2** briefly quotes the submissions that have raised wind effects;

b. **Section 3** outlines my evaluation of the two alternative analytical approaches by which the issue raised by submitters might be assessed in a desktop study as there is no clearly applicable option;

c. **Section 4** reports my analyses;

d. **Section 5** draws conclusions.

Summary of key findings

1.8 I have adopted two very different analytical approaches in order to provide as balanced an analysis as possible in this desktop study of the potential effect of removal of the Kiwi Point Quarry hill on houses on the Mandalay Terrace / Homebush Road ridge in the lee of that hill.

1.9 One approach treats the 190m-high Kiwi Point Quarry hill as a wind break some 60m tall and 400m long relative to the 130m base height of the Mandalay/Homebush ridge. This windbreak approach is based on a formula developed in wind tunnel tests of the sheltering effect of hedges and walls up to 120m long and 10m high; it extends the method well-beyond its normal application.

1.10 The second approach works on the assumption of an infinitely long, perfectly shaped hill (an “escarpment”) potentially providing shelter to the Mandalay/Homebush ridge. The potentially sheltering hill is clearly not this shape.

1.11 Without considerably more study such as on-site measurements and modelling, it is hard to see this as a definitive analysis. There is a slight possibility that at present the ridge on which Mandalay Terrace and Homebush Rd sit is sheltered for the small part of its length that is directly in line with the peak of the hill that is proposed for removal; however, even this small area that might experience a lowered average is likely to suffer from more extreme gust variations than in the open.

1.12 Because of the existing shape of the hill which could be removed this potential sheltering effect will not be experienced along the full length of the ridge. Thus, removal of the hill is unlikely to result in wind speeds that are higher along the full length of the Mandalay/ Homebush ridge.

1.13 What can be said is that there is no clear pointer from either calculation method to the possibility that the wind on the Mandalay / Homebush ridge will be made worse after the removal of the Kiwi Point Quarry hill. On one calculation, treating the sheltering effect Kiwi Point Quarry hill as a windbreak, the shelter appears to be lost after a distance of 250-330m downwind; on the alternative approach, treating the hill as an escarpment, the shelter appears to be lost after a distance of 400m downwind.

1.14 Overall, I consider that the potential wind effects arising from the proposed plan change cannot be definitively assessed from a brief study of this type. Without considerably more study, such as on-site measurements and modelling, it is hard to see this as a definitive analysis. What can be said is that the risk of significantly increased wind speeds on the Mandalay/Homebush ridge is slight.

2.0 SUBMISSIONS

2.1. Fourteen submissions raised concerns about the potential wind-related effects arising from the plan change, including:

a. wind-related transport of dust and other particulates from the quarry to neighbouring sites[1]; and

b. changes in wind dynamics and intensity arising from the landform change enabled by the plan change.[2]

2.2. The submissions addressing windborne dust and other particulates have been addressed by others and are not a focus of my report. Rather, the discussion below addresses the latter of the two submission points summarised above – wind effects from landform change.

2.3. The brief therefore was to conduct a desktop analysis of the following submissions:

"*I believe the removal of the ridgeline will remove some of the current shelter that this hill provides from northerly and westerly winds. My property is already in a Very High Wind Zone with strong and gusty winds that often shake the house. This will be exacerbated by the proposal, due to further exposure.*" – part of submission of Angela Garty at 138 Homebush Rd, Wellington 6035

"We are also concerned that with the removal of this section of the hillside that the wind flow will change and the impact this could have on the local area and residents." – part of submission of Mr Anthony Norton

[1] Submissions 2, 4, 7, 13, 16, 18, 20, 22, 23, 24, 26, 29, 32, 36
[2] Submissions 7, 36

3.0 ANALYSIS APPROACH

3.1. In the introduction I note that my expertise is in the field of the effect of structures on the environmental wind flows around buildings. The general principles of flow around large buildings and even larger hills are not too dissimilar and thus I can advise on the likely downwind effect - the extent of the wake – of a hill, treating it somewhat as one does a windbreak where the effect downwind from various studies is roughly 6 times the relative height of the wind break above the observation point.

3.2. My expertise is not in the area of classification of structural analysis, or the classification of risk to building structures due to exposure to wind as a result of that wind exposure.

3.3. In conducting this desktop analysis, I reviewed information on the estimation methods for the effect of wind breaks on the wind – within my expertise; I also ran a brief search of the associated literature on the potential effect of a much larger obstacle (or wind break) the size of a hill. This second search was not exhaustive but revealed that a hill of the scale of that which is proposed to be removed does redirect wind flows far more than a smaller scale wind break. I have therefore conducted two analyses – one using the wind break analysis, the other using 2 recent papers reporting wind tunnel studies of hills.

Calculation method 1: Windbreaks

3.4. As a windbreak analysis one imagines the situation outlined in the following figures: Figure 1 shows the distance (approximately 400m) from the peak of the hill that it is proposed to be removed for quarry works to the residential properties in the upper Homebush Road and Mandalay Tce as illustrated in the Garty submission. This is, apparently, the closest potentially affected residence to the hill. It also shows the relative height of these two positions: 190m for the peak of the hill and 130m for Mandalay Tce and 140m for 138 Homebush Rd.

FIGURE 1 IMAGE SUPPLIED BY WCC OF THE CONTOURS OF THE HILL, THE TYERS STREAM GULLY, THE SUBMITTERS HOUSE AT 138 HOMEBUSH RD AND THE CLOSEST HOUSE AT 146 MANDALAY TERRACE

3.5. While the dimensions are vastly different, the simple principles illustrated in Figure 2 for windbreak design seemed likely to be indicative: 1) of the likely current effect of a hill (windbreak) at its highest 60m tall in height relative to 146 Mandalay Tce, at a distance of 400m; and 2) the likely impact of its removal.

3.6. As is noted in this figure, the area behind a windbreak where the shelter represents a reduction of wind by a factor of 2 has been found in wind tunnel tests to be proportional to the Length of the sheltering windbreak to the power of 1.3, and to the height to the power of 0.7. The other two formulae are for areas where the wind speed is reduced by a factor of 3 or 1.2. The former is an area so close to the sheltering object that height is not a factor, and reducing the wind slightly (factor of 1.2) seems not particularly relevant here.

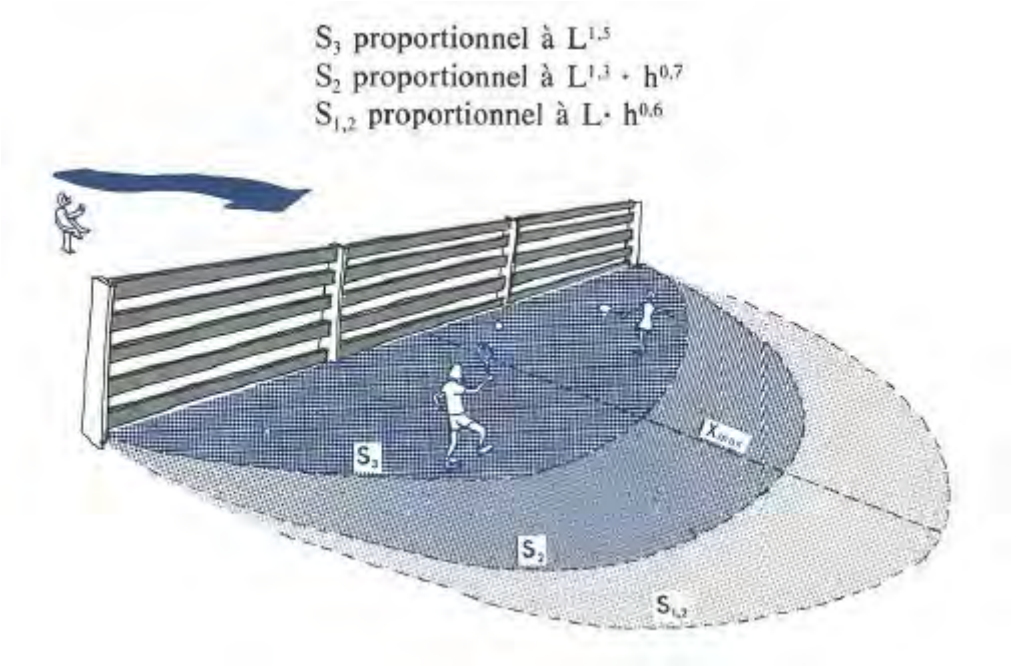

FIGURE 2 IMAGE FROM "LA PROTECTION CONTRE LE VENT" - FRENCH TEXT BOOK ON WINDBREAK DESIGN

3.7. On the basis of the above approach, it is necessary to calculate the average height of the existing hill above 146 Mandalay Terrace / 138 Homebush Road. The width of hill above the 130m height of observation point appears to be symmetrical about the peak and roughly 400m wide (scaled from the contours in Figure 1). Referring to Figure 4, it can be seen that the hill is not shaped like the windbreak in Figure 2. The best that can be done in this circumstance is to estimate of the average height of the hill of 30m above the potentially affected sites (20m for 138 Homebush). The advantage of this analysis is that this calculation does allow for a finite length of the wind break, so wind is assumed to blow around the ends, hence the eroded elliptical shape of the sheltered area shown in Figure 2.

FIGURE 3 IMAGE FROM GOOGLE MAPS OF HILL, GULLY AND 138 HOMEBUSH RD

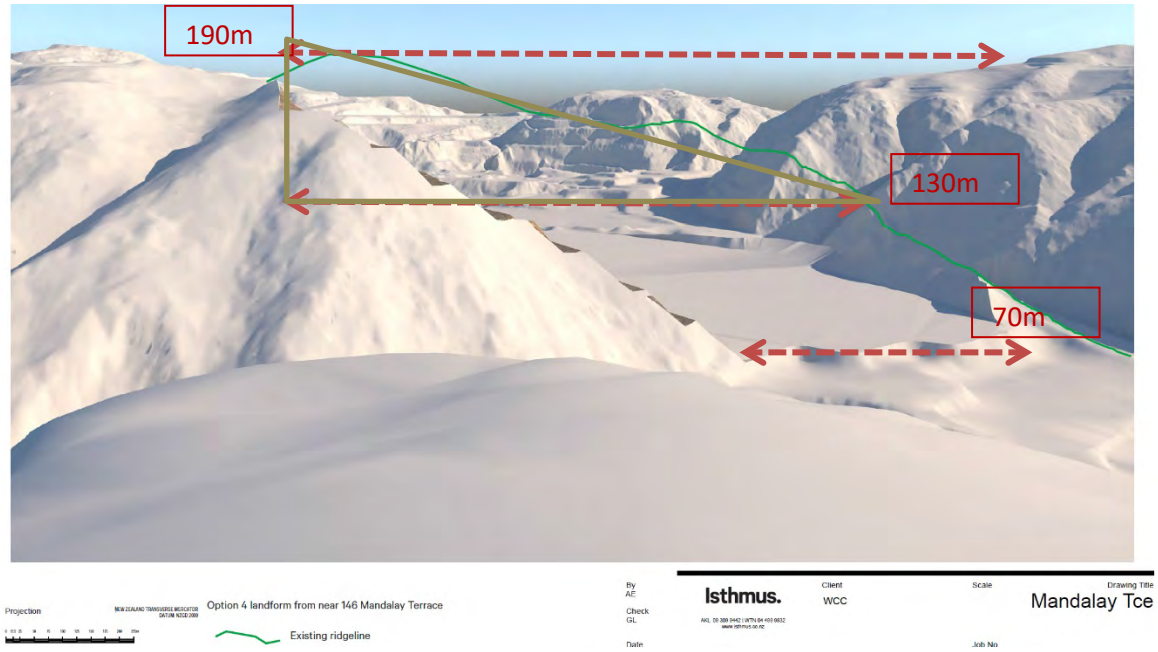

FIGURE 4 ESTIMATION OF THE LIKELY WIDTH AND HEIGHT OF THE WIND BREAK CREATED BY THE EXISTING HILL - BROWN LINE OUTLINES THE EFFECTIVE WIND BREAK SIZE ABOVE THE OBSERVATION POINTS IN MANDALAY TCE AND HOMEBUSH RD

Calculation method 2: Escarpments

3.8. In preparing the windbreak analytical framework, I noted that there is another way of looking at this situation that is obliquely referenced in the "very high wind zone" comment of one of the submitters. This is the effect of what are known as "escarpments" in determining this type of classification of wind zones for structural purposes. These classifications are based on the effect of wind flows accelerating up and over ridges.

3.9. It is my understanding that the hill that is proposed to be removed plays little part in the current structural classification of the site at 138 Homebush Road; rather, it is determined by the shape and steepness of the site around 138 Homebush Road and 146 Mandalay Terrace. The literature on this topic is less familiar to me, as I focus typically on the environment outside buildings and local effects, not the structural integrity of buildings in these zones. However, the airflow characteristics reported in the wind tunnel tests are within the same field as my expertise.

3.10. The simplest explanation of the effect of a hill that I could find is illustrated in Figure 7, Figure 8, and Figure 9.

3.11. Figure 7 shows the speed distribution around two hills. The data has been standardized in terms of height H of the hill. Thus, the vertical axis represents 1, 2, 3 up to 6 times the height of the hill; the horizontal axis represents distances from 10 times the height in front of the hill to 15 times the height downwind. In terms of the current project, I have added a large arrow indicating approximately where the 138 Homebush Road/146 Mandalay Terrace points of concern are on these scales, if we assume the height of the hill being removed is approximately 100m. This analysis is very like the wind break analyses as they have been conducted in wind tunnels. However, these analyses assume two-dimensional flow; they illustrate flow up and over, not around hill.

3.12. What is clear from this simple analysis is that the effect of a hill of 100m height can be felt up to 10 times the height of the hill downwind. Figure 7 plots the wind speeds relative to near ground level winds: Yellow/Orange is the incoming, undisturbed wind speed; green shades represent reduced wind speeds; blue is reversed wind speeds; and deep orange is accelerated wind speeds.

3.13. Figure 8 shows the same data as Figure 7, but in vector terms, so the direction is easier to follow as the arrows show direction and strength (length) of the wind.

3.14. Figure 9 shows how gusty the wind is; at lower speeds, and in the zone between the two hills, the fluctuations are far bigger as a percentage of the average. Contrary to the wind break analysis, the extent of the redirection of the wind by the scale of the hill is far greater than is experienced with a much smaller windbreak. This is clearest in Figure 5

where the orange accelerated winds reach proportionally far higher into the atmosphere above the hill than is typically found with wind breaks.

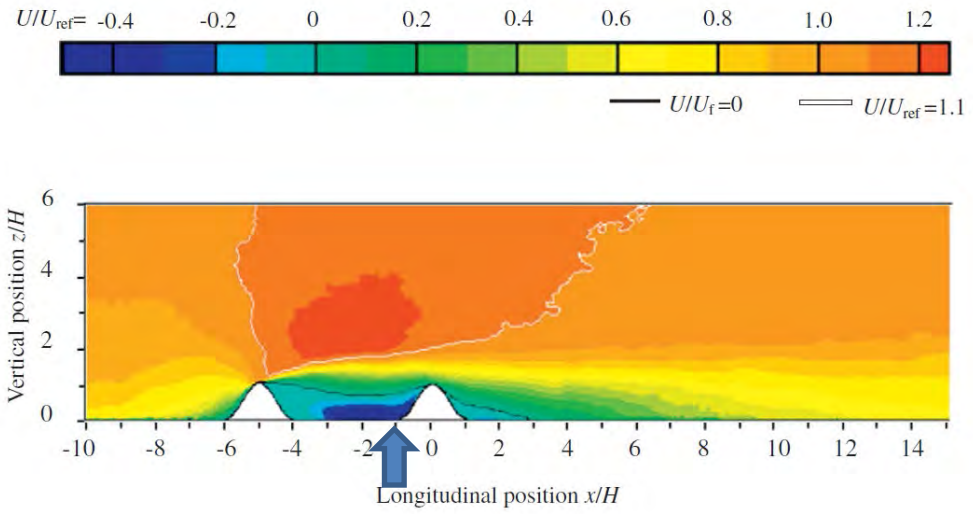

FIGURE 5 WIND SPEED REFERENCED TO UNDISTURBED SPEED - FLOW FROM LEFT TO RIGHT

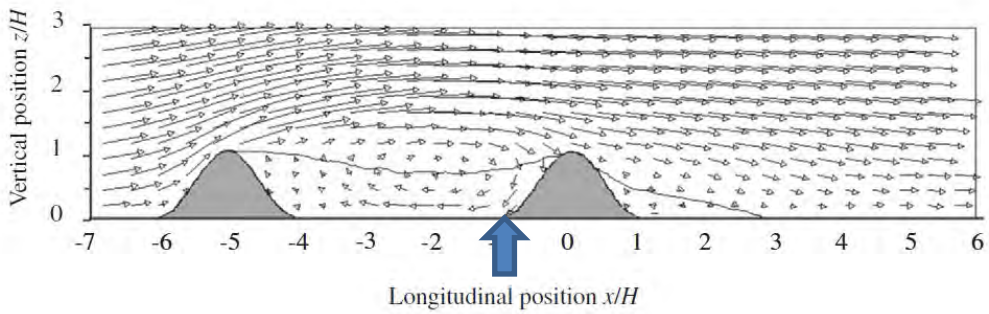

FIGURE 6 WIND SPEEDS PICTURED AS FLOW ARROWS: " THE LENGTH AND DIRECTION OF THE ARROWS REPRESENTED THE VALUE AND DIRECTION OF WIND VELOCITY, RESPECTIVELY." (LI, ET. AL. 2017)

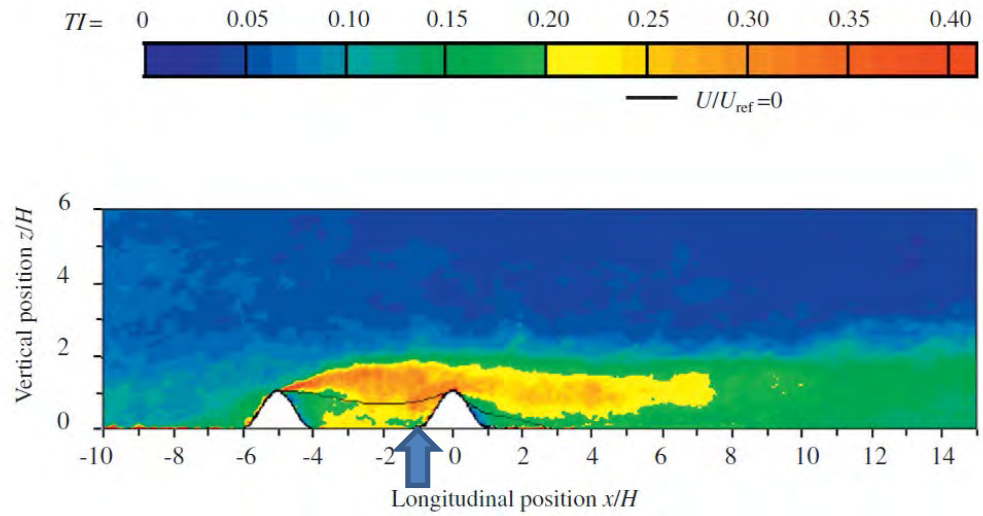

FIGURE 7 FLUCTUATIONS OF THE TURBULENCE

4.0 ANALYSIS

4.1. I have run both analyses as neither seem perfectly suited to this situation.

4.2. A common denominator between the two analyses is that the wind is essentially at right angles to the ridge line of the hill that is to be removed, so working with an approximation of the hill as a windbreak or as an escarpment is essentially a 2D analysis. Without significant further work, the two analyses together are likely to be a reasonable approximation to reality. Beyond a 30 degree variation in wind from flow at right angles to the wind, the sheltering effect of any barrier is likely to be near zero.

4.3. Figure 10 shows the situation assumed for these two analyses: a hill that is essentially an East-West barrier to the wind indicated by the dashed line. The wind rose shows that the strongest winds are from the Northwest and Southwest (the jagged orange triangles inside the 'rose'). Focusing only on the Northerly winds, this incident angle would reduce to near zero the effectiveness of the windbreak or hill as a barrier to these strongest winds because at this angle the wind rolls and twists over and along the length of the hill.

4.4. Focusing on the Northerly winds to which the Mandalay/Homebush ridge is exposed, the bars on the outside of the rose show the frequency of winds: the more common winds, the ones that frequently occur when it is warmer (indicated by the blue bars inside the rose being larger), are more directly at right angles to the assumed line of the windbreak-hill and thus it is more likely to stop these 'prevailing' winds.

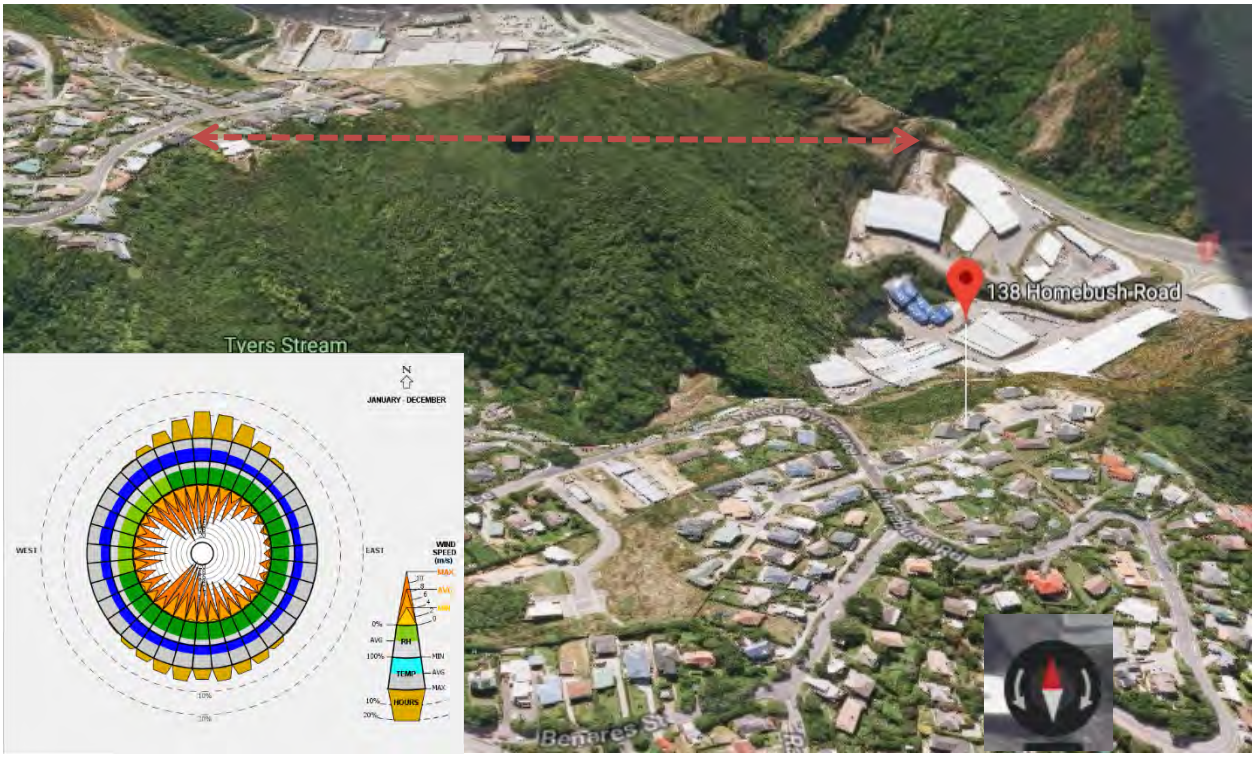

FIGURE 8 WIND ROSE AND SITE PLAN - THE WIND IS ESSENTIALLY AT RIGHT ANGLES TO THE LINE OF THE HILL THAT THE QUARRY PROPOSES TO REMOVE

Windbreak analysis

4.5. For a windbreak estimated to be 400m wide and 30m tall running East West the simple arithmetic of the effect of the small height of the top of the hill to be removed above the height of 138 Homebush road or 146 Mandalay Terrace is such that there will be no discernible effect 400m downwind of the removal of the hill, as the effect will be felt at most 250m downwind.

4.6. The area currently sheltered behind the Kiwi Point Quarry hill where the wind speed will be less than half the open field wind speed is illustrated by the blue ellipse in Figure 9; the largest downwind dimension of this sheltered area is this 250m. The area where the windspeed is a factor of 1.2 less than the open field wind speed is indicated by the dashed line ellipse in Figure 9; here the downwind distance is at maximum 330m.

FIGURE 9 AREA (IN BLUE) POTENTIALLY SHELTERED TO 50% OF INCIDENT WIND SPEED DUE TO THE HEIGHT OF THE HILL TO BE REMOVED ABOVE THE HEIGHT OF HOMEBUSH ROAD OR MANDALAY TCE

Escarpment analysis

4.7. The data in in Figure 7, Figure 8, and Figure 9 show that in all probability, a continuous hill of around 100m in height just 400m to the windward side of Homebush Road and Mandalay Terrace would reduce the wind speed on these streets to 50% of what it would be with no hill (i.e. after the proposed removal). Therefore, removing a hill of that scale risks a doubling of the site wind speeds.

4.8. However, this 2D analysis assumes that the ridge is infinitely long. This is clearly not the case as can be seen in Figure 12: the dashed line indicates the top of the ridgeline. The rest is where the existing cliff rapidly falls away to the Ngauranga Gorge/Centennial highway road in the top right. Because of the gorge and the existing ridge, the wind through the gap created by the road will be significantly accelerated – perhaps as much as a doubling. This accelerated wind will swirl around the ridgeline and into Tyers Stream gully.

4.9. We can obtain an estimate of the effect of the 3D variability of the hill from the work of Liu et al (2016). This is shown in Figure 11. The 3D hill modelled by this research has flow around both sides. It is clear that in such a situation the wind swirling around the sides reduces the downwind effect to perhaps 2-4 times the height of the hill, rather than the effect predicted by the 2D ridge where the effect is up to 10 times the hill height downwind. From this it is possible to anticipate that the maximum sheltering effect of the existing hill downwind would be felt at most 400m downwind. By 400m downwind, the position downwind of the Mandalay/Homebush ridge, the wind is likely to return to its full force.

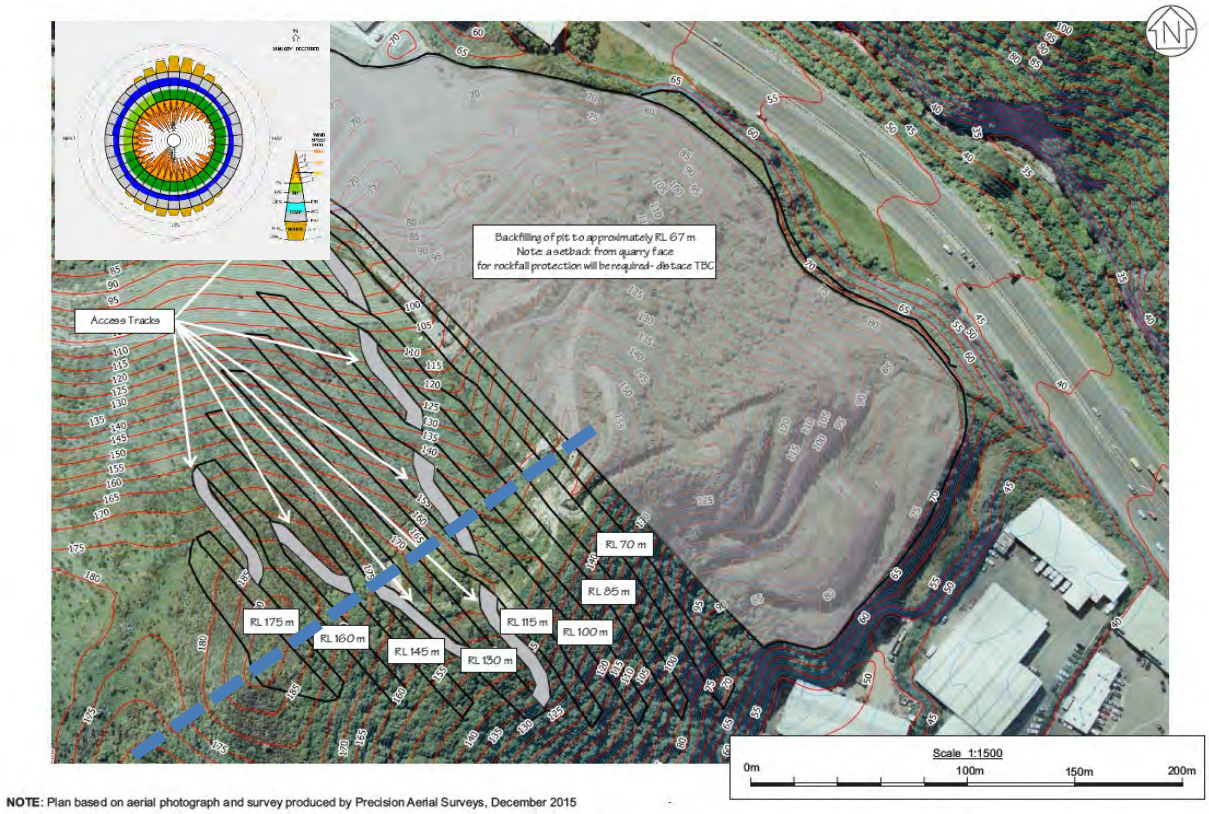

FIGURE 10 ORMISTON ASSOCS. 2016 PLAN OF SITE CONTOURS BEFORE AND AFTER

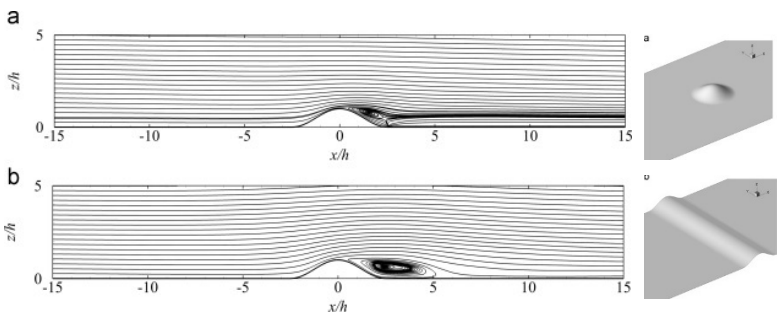

FIGURE 11 FLOW OVER A 3D HILL (A AT TOP) AND OVER A 2D RIDGE (B BELOW) FROM LIU ET AL (2016) SHOWING THE DOWNWIND EFFECT OF THE 3D HILL IS OVER A MUCH SMALLER DOWNWIND DISTANCE WHEN FLOW AROUND EACH SIDE OF THE HILL IS ACCOUNTED FOR

5.0 CONCLUSIONS

5.1. Without considerably more study such as on-site measurements and modelling, it is hard to see this as a definitive analysis. There is a slight possibility that at present the ridge on which Mandalay Terrace and Homebush Rd sit is sheltered for the small part of its length that is directly in line with the peak of the hill that is proposed for removal; however, even this small area that might experience a lowered average suffers from more extreme gust variations than in the open.

5.2. Because of the existing shape of the hill which could be removed this potential sheltering effect will not be experienced along the full length of the ridge. Thus, removal of the hill is unlikely to result in wind speeds that are higher along the full length of the Mandalay/ Homebush ridge.

5.3. What can be said is that there is no clear pointer from either calculation method to the possibility that the wind on the Mandalay / Homebush ridge will be made worse after the removal of the Kiwi Point Quarry hill. On one calculation, treating the sheltering effect Kiwi Point Quarry hill as a windbreak, the shelter appears to be lost after a distance of 250-330m downwind; on the alternative approach, treating the hill as an escarpment, the shelter appears to be lost after a distance of 400m downwind.

Michael Donn

10 December 2018

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Qing'an Li, Takao Maeda, Yasunari Kamada, Keisuke Yamada, *Experimental investigation of flow over two-dimensional multiple hill models* Science of the Total Environment 609 (2017) 1075–1084 http://dx.doi.org/10.1016/j.scitotenv.2017.07.259

Zhenqing Liu, Takeshi Ishihara, Takahiro Tanaka, Xuhui He. *LES study of turbulent flow fields over a smooth 3-D hill and a smooth 2-D ridge J*. Wind Eng. Ind. Aerodyn. 153 (2016) 1–12 https://doi.org/10.1016/j.jweia.2016.03.001