BEFORE A COMMISSIONER APPOINTED BY THE OTAGO REGIONAL COUNCIL AND THE CENTRAL OTAGO DISTRICT COUNCIL

IN THE MATTER OF the Resource Management Act 1991

AND

IN THE MATTER OF applications by Cromwell Certified Concrete Limited for resource consents to expand Amisfield Quarry

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STATEMENT OF EVIDENCE OF RUTH UNDERWOOD ON BEHALF OF CROMWELL CERTIFIED CONCRETE LIMITED

(HORTICULTURAL CONSULTANT)

Dated: 30 November 2021

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1 INTRODUCTION

1.1 My name is Rachel Ruth Underwood, known as 'Ruth'. I am a Director of Fruition Horticulture (BOP) Ltd and work as a Horticultural Consultant based in Tauranga. I have a Bachelor of Horticultural Science with First Class Honours from Massey University, awarded in 1986. I have also completed additional study in environmental economics, marketing, sustainable nutrient management and adult education.

1.2 I have spent over 30 years as a consultant in the horticultural industry. Since 2003, I have worked for Fruition Horticulture (BOP) Ltd based in Tauranga. Previously I worked as a Horticultural Consultant with Agriculture New Zealand in Tauranga, and as a Horticultural Advisory Officer in Hawkes Bay and Tauranga with the Ministry of Agriculture and Fisheries, as it was then named.

1.3 I tutor botany, soil science and management courses for Horticultural Diploma students from Lincoln University's Regional Programme in the Bay of Plenty and for industry trainees studying towards a NZ Certificate in Horticulture and have had practical experience in the Horowhenua, Nelson and Hawkes Bay areas, working on a wide range of fruit and vegetable crops.

1.4 A significant part of my consultancy work relates to understanding the effects of growing conditions on plant performance and manipulation of growing conditions to favour productivity.

1.5 I have relevant experience in the impacts of dust on fruit trees and fruit from the prevalence of this issue in the Bay of Plenty where there are considerable distances of unsealed roads. I have also conducted recent 'desk-based' work relating to the cherry industry in New Zealand.

1.6 From time to time, I have been an expert witness in applications for resource consent or disputes relating to horticultural matters. I was engaged by Cromwell Certified Concrete Limited to provide advice to Mr Cudmore in relation to assessment of the potential effects of uncontrolled quarry dust on cherry trees/crops. My advice has been informed by my knowledge of plant physiology (including cherries) and a literature review. Due to the limited number of studies relating specifically to cherries, my review included dust impacts on orchard production systems and vegetation in general.

1.7 Due to the limited timeframe and Covid-19 limitations, I have been unable to physically visit the quarry site and the surrounding area, but I have done so virtually by viewing recent drone footage of the quarry site and aerial views of the site and the wider area via Google Earth, which includes useful imagery at irregular dates between 2005 and 2021.

2 SCOPE OF EVIDENCE

2.1 In my evidence I address the following:

(a) The nature of cherry crops;

(b) Potential effects of dust on cherry orchards and viticulture.

2.2 In preparing this evidence, I have read and considered the following documents:

(a) The application, including the Assessment of Environmental Effects and its 'Appendix 4' (supporting technical report prepared by BECA in relation to air discharges[1]); but not Appendices 2-3 or 5-9);

(b) The applicant's response to the requests for further information[2];

(c) A memo by Lisa Arnold (WSP) – literature review regarding effects of dust on horticultural crops;

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1 Amisfield Quarry – Technical Assessment of Potential Effects of Dust Discharges by Beca Limited, 22 October 2020.

2 Letter from BECA to Landpro, *Amisfield Quarry Air Discharges- RC 200343 - Response to Request for Further Information from Central Otago District Council*, dated 1 March 2021. The BECA response also includes a draft Air Quality Management Plan for CCC AND Letter from BECA to Landpro RM20.360.03 Amisfield Quarry Response to Request for Further Information also dated 1 March 2021.

(d) The evidence of Roger Cudmore (air quality expert) relating to wind and wind direction, and aDust Management Plan (in draft);

(e) Submissions on the proposal relevant to effects of dust on cherry orchards (by Hayden Little Family Trust, Amisfield Orchard Ltd and Douglas Cook).

2.3 Whilst this is a Council hearing, I acknowledge that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses, contained in the Environment Court Practice Note 2014. My qualifications as an expert are set out above. Other than where I state that I am relying on the advice of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

3 SUMMARY

3.1 There are two key times in the year when cherry orchard activities are most sensitive to the impact of dust.

3.2 The expected most sensitive time of the year is around harvest which, depending on the variety being grown, runs from early December to mid-February. However, as export-destined cherries are washed during packing, the risk of cherries being rejected based on light dust contamination is relatively low.

3.3 The other sensitive time of the year is likely to be when cherries are flowering until after petal fall when they have been pollinated. Blooms can open from late August and the pollination period typically runs until the end of September. This timing will vary slightly depending on the variety that is being grown. The success of pollination will determine the fruit set. High amounts of dust on flowers could potentially reduce pollination effectiveness, although cherries naturally do not set fruit from every flower.

3.4 The <u>least</u> sensitive times for cherry trees to dust are during their winter dormant period and in the period after harvest from late summer through autumn.

3.5 More detail of the growing conditions suitable for cherries and the seasonal production cycle are included in this evidence. Brief commentary is also included on viticulture regarding most sensitive times of year to dust and key factors affecting sensitivity to dust in the production cycle.

3.6 There are no published criteria or guidelines in relation to acceptable levels of dust on cherry (or other) crops. However dust mitigation measures can significantly reduce potential dust impacts. Effective shelter around orchards can also significantly reduce any potential impacts of dust.

3.7 The dust likely produced by the quarry has been described as similar to roading materials and not chemically reactive.

3.8 Studies on the effects of uncontrolled dust from unsealed roads are helpful to determine the distance at which uncontrolled dust can affect sensitive crops. Key factors are the wind direction (with more dust being distributed in the prevailing downwind direction), and the height of the crop (with taller crops being affected for a shorter distance from the source of the dust). These studies also showed that presence of effective shelter trees can also significantly reduce the distance dust is likely to travel from its source and affect crops.

3.9 Based on those studies, the likely distance at which uncontrolled road dust could affect cherry crops (which are tall trees) is 25-100m from the dust source, and 50-150m for grapevines (which are of medium height). This is an indication of the distance that dust from the quarry could potentially carry and affect these crops when downwind of uncontrolled dust.

3.10 I understand that wind directions at the quarry site are indicated as broadly along the valley, with dominance of winds from two directions, being from the north to north-east and from the south to southwest.

3.11 The Dust Management Plan for the quarry includes controls which take into account the most sensitive times in the growing season for neighbouring orchards and possible atypical wind directions.

4 CHERRY CROPS

4.1 Cherries are a deciduous perennial tree crop.

4.2 Sweet cherries are the type of cherries grown in New Zealand. The highest value of the fruit is as fresh fruit. New Zealand cherries are targeted at export markets, with Central Otago the prime growing region. There has been significant recent expansion of plantings in the region, driven by high prices in the targeted export markets, analysis indicating additional market capacity, high quality attributes of New Zealand cherries and the general investment environment including low interest rates and an increase in funds targeting non-dairy primary sector investments.

4.3 The fruit is grown to target export markets, particularly in Asian countries. The Chinese New Year festival period is a key market window. The festival dates vary from year to year over about a month, and cherry growers use a range of cherry varieties with differing maturity periods to help align their production with the shifting time of greatest market opportunity.

4.4 The impacts of Covid-19 on reduced freight pathways, increased costs and reduced availability of labour are a significant current stressor within the cherry industry, compounded by this occurring at a time of growth in production.

Site factors

4.5 Cherries require:

(a) Chilling in winter during tree dormancy;

(b) Low incidence of spring frost;

(c) Warmth during pollination in early spring;

(d) Low spring and summer rainfall, but water supply for irrigation of trees during those periods;

(e) High heat / sunshine for ripening in early to mid summer; and

(f) Good soil drainage, especially outside their dormant winter period.

4.6 Central Otago's cold winter and hot, dry summer are a combination that suits cherries and other summer fruit such as apricots, and the region is long established as a significant growing region. Production varies significantly from season to season due to weather conditions, with particular problems being frost in spring, rain and/or cold temperatures at pollination, and rain leading up to harvest.

4.7 Traditionally, spring frost was dealt with via overhead sprinklers, which coat the blossoming tree in a continuously freezing film of water. The water film protects from the lower frost temperatures as water releases a small amount of heat during the freezing process. The water applied to the foliage from sprinkler frost protection is not ideal as it can spread disease and impair pollination, and can overwhelm the soil drainage when soil moisture tends to be close to the usual winter high level.

4.8 More recently, frost fans ('wind machines') have been more widely used to help prevent frost in conjunction with selecting sites that have cold air drainage pathways such as towards a water course. These don't protect from all frosts but do help with the most common type of frost where there is a colder layer of air near to the ground and a warmer layer higher. The frost fans move the colder air away and draw in the warmer air. The 'terrace' landform near to the quarry site provides a landform that helps with air movement down the terraces towards Lake Dunstan, so helps to prevent damaging spring frosts and is helpful during frost fan operation.

4.9 The prevailing dry summer climate in the area is helpful for maintaining fruit quality as rainfall near harvest causes significant fruit splitting which makes affected fruit unsaleable. Seasonal variation means significant rainfall and fruit splitting occurs in some seasons.

The rain in early January 2021 was a recent example, which caused significant crop losses. However, significant crop losses from fruit splitting damage can occur from just a few millimetres of rain at the most sensitive time for the variety. Some growers have installed rain covers to keep rain off the cherry trees to prevent most of this damage.

4.10 The rain covers tend to be a translucent 'plastic' fabric 'hat' over the tree row, of an inverted 'V' shape with the peak over the row of trees and a gap allowing rain to drain to the ground in between the tree rows. If it rains while the covers are in place, any dust is likely to be washed off to the between-row spaces with the rain. The rain covers may be put in place (or unrolled or un-bunched) for the few weeks before harvest and stay on until harvest is completed. It is possible automated rain covers which can be put on and off more often may become more widely used in the future.

4.11 Bird-exclusion netting is also used, which is rain-permeable. This may be permanently installed over the trees, with the entrances closed for the period when the crop is attractive to birds but otherwise kept open for easier access. Where there is bird netting and rain covers, the bird netting creates a 'cage' over the top of the rain covers. Permanent bird netting over the crop can also help to reduce frost damage by warming the covered area. The bird netting also reduces wind speed. Bees can get through the gaps in bird netting, but permanent permeable covers like hail netting have caused some disruption to pollination in horticultural crops as bees can become disorientated.

4.12 Irrigation is necessary during spring and summer, and is usually set up as under tree sprinklers. These intentionally do not wet the tree foliage, unless there is some foliage hanging low or severe distortion of the plume of water from the sprinklers due to wind or the sprinklers being knocked. Water is typically taken directly from groundwater or surface water and may be stored, usually in ponds but sometimes in tanks, to work within consented quantities and provide the quantity of water over the duration required, which is particularly important if sprinkler frost protection is being used.

4.13 The preferred orientation of tree rows is in a north-south direction to even out light interception within the orchard.

4.14 Orchards need some shelter to protect crops from wind. Some may have a perimeter of tall shelter trees surrounding the cherry trees. Others use 'self-sheltering' by the cherry trees themselves, accepting that performance of the outside rows of cherry trees is reduced due to their exposure to wind. Others may use artificial shelter cloth, often incorporated into the bird-exclusion netting.

4.15 Tall shelter trees around a boundary may compete with the producing crop for light, water and nutrients which is why self-sheltering or artificial shelter cloth is sometimes preferred. It is a trade off between orchard layout, space and level of set-up investment. Shelter trees may be established alongside artificial shelters to take over perimeter shelter from the cloth shelters in the longer term.

Lifespan/Juvenile phase

4.16 Cherry trees are grown for several years in the orchard before they begin to produce fruit. The earliest production occurs 2-3 years from planting well-grown nursery trees. Orchards are expected to reach mature production from about year 7-9 and can continue to produce for decades. Tree health may decline over time and trees may be replaced with new varieties with superior features as they become available. Superior features may relate to fruit quality, time of harvest, pollination attributes, yield and rootstock characteristics including disease tolerance and vigour which affects tree size at maturity.

4.17 Orchard set-up varies considerably, and newer orchards are being set up with trees significantly closer together, aiming for precocious and high production.

Seasonal production cycle

4.18 Cherry trees are dormant during winter, and require a duration of cold temperatures during their winter dormancy for good spring flowering and growth.

4.19 In spring, flowers begin to open first, with leaves developing as the later flowers are opening. Full leaf canopy develops over about a month from budburst. Honeybee hives are brought into the orchards to aid pollination. Most cherry varieties need cross pollination from a compatible variety that flowers at the same time. Honeybees only work in low-wind conditions and during dry weather. Bee activity may be impaired under permanent crop covers. Other insects perform pollination, such as native bees, bumble bees, flies and moths but these are not actively managed within orchards under current practices, although trials of commercial bumblebee hives have been done in some outdoor crops.

4.20 Crop protection activities (such as spraying) within orchards are important and occur through the year. Timing of those activities is more flexible during dormancy and after harvest, but timing of pre-blossom and pre-harvest applications is especially important. The stage of the tree growth is very important and unsuitable weather conditions can be a constraint to application of crop protection products. Suitable weather to apply agrichemicals is fine, with low windspeed, to deliver the agrichemical to the cherry trees and avoid off-target drift. Wind direction is also important to avoid off-target movement of the materials being sprayed. These are weather conditions when there is likely to be little dust movement. Equipment for applying agrichemicals to the trees is usually tractor-towed or self-contained sprayers calibrated to apply sprays according to the size of the trees and quantity of vegetation at the time of application.

4.21 Most crop protection agrichemical products are relatively 'rainfast' when fully dry, which is within a few hours after application under the weather conditions when they are normally applied. The quantity of liquid applied each spray is typically up to 2,000 litres per hectare with the highest volume of total liquid described as 'spraying to run off', aiming to cover all parts of the tree with the diluted agrichemical.

4.22 Herbicides (agrichemical weedkillers) are used within the orchard to create a vegetation-free strip directly under the row of trees. They may be applied with hand-guns, booms or knapsack sprayers and risk of off-target drift is reduced by these being applied in a downwards direction.

4.23 The sward (grass between the rows of trees) between tree rows is mowed regularly. Presence of sward within an orchard, which usually receives some of the irrigation applied to the ground underneath the trees, helps to reduce generation of dust within the orchard itself. However, access tracks and driveways can become a source of dust, and growers typically manage to avoid dust problems by measures including low vehicle speeds.

4.24 Cherries have a short interval between flowering and fruit maturity compared to many other tree crops. Fruit development is rapid, with up to 25% of the fruit growth occurring in the last week or so before harvest.

4.25 When the fruit reaches maturity, it is picked. Picking is done in several passes through each part of the orchard, picking a portion of the fruit of that variety each time that is the correct maturity and fruit size. Picking is generally done by hand, using ladders to reach higher fruit as required. Fruit is picked into buckets which are then placed into bins on trailers that are then towed to an onsite packhouse or to a loading area for transport to a packhouse elsewhere for packing.

4.26 The industry trend (especially for export cherries which require specialised packing) is for centralised, specialised packhouses handling the fruit from large-sized or multiple orchards, rather than packing being done on each orchard. During packing, the highest grade fruit is packed for export, other suitable fruit for domestic markets and fruit that is unsuitable for fresh sale is removed, although may be able to be processed.

4.27 Packing in modern packhouses includes floating the cherries in water from the picking buckets and bins to the grader. The water has several key roles, being to gently transport the fruit to minimise handling damage, to wash the fruit and to cool the fruit. The water helps to remove surface deposits, including any dust. The fruit is then graded, sized and packed, with some of the newer packhouses using a high degree of automation for all packhouse processes. Fruit is chilled after packing, and a cool chain is maintained. Cherries have a relatively short storage life after harvest and maintaining cool temperatures after harvest prolongs shelf life. Export fruit is trucked to airport facilities and airfreighted to overseas markets. Domestic fruit is trucked to wholesale or retail customers or may be delivered directly to consumers.

Vulnerability to dust during this cycle

4.28 In terms of the potential effects of dust on cherry crops, I consider the most sensitive stage of the cherry crop to dust is the period from shortly before harvest to the end of harvest, covering approximately late-November through to mid-February. However as described above, export cherry crops are 'washed' at packing and light dust deposited on fruit would be removed.

4.29 The glossy cherry fruit surface and 'washing' during packing make dust on the fruit itself only likely to persist if a substantial quantity accumulated around the fruit stalk. Given picking occurs during dry weather and irrigation does not reach the fruit, and there is some shielding of fruit by leaves, this is unlikely to occur to levels which would cause a material amount of product to be rejected.

4.30 The next most sensitive stage to dust is flowering, likely occurring over 3-6 weeks from late August. The pollen-receptive surface of the flower (the stigma) is sticky and if high levels of dust stuck there, this could impede pollination. However, the effect would be contained as:

(a) flowers are orientated in every direction;

(b) to reach the stigma surface, dust would have to get around the petals and stamen, which shield the stigma to some extent;

(c) not every flower develops into fruit; and

(d) there is naturally a level of fruit drop in the period soon after flowering.

4.31 Dust on the cherry leaves could also reduce photosynthesis if deposited in sufficient quantities. Photosynthesis is the process where plants make carbohydrates in their leaves using energy from the sun, carbon dioxide from air and water taken up by the roots.

4.32 Photosynthesis occurs during daylight when the tree is not dormant. McCrea (1990) charted both reduction in light and reduction in photosynthesis due to dust in his research, with the graphs included in my Appendix as Figures 7 and 8. These both show very little effect of reduction in light or photosynthesis at low levels of dust accumulation on the leaves. I consider the likelihood of dust appreciably reducing photosynthesis is negligible at an orchard scale unless very high levels of dust were deposited onto wet foliage that then dried, significantly blocking light from the leaves. This is because dust is mainly likely to sit on the leaf's upper surface and in dry conditions, a high proportion of it is likely to then fall off or be otherwise redistributed as wind moves the leaves again. During wet conditions there is less likely to be dust blown around, so it is only if a lot of dust was blown around when leaves were still wet after rain that dust may stick or cake on leaves.

4.33 Dust is more likely to accumulate on the leaf upper surface than the lower surface. The stomata (pores allowing gas exchange into the leaf) are on the leaf lower surface of cherries so they are unlikely to be blocked by dust.

4.34 I consider some minor accumulation of dust on rain covers or bird netting reducing light received by the cherry trees will also not cause a material decline in photosynthesis.

Potential effects of dust on orchard fittings such as bird-exclusion netting and rain covers

4.35 As described above, bird netting is used in orchards to protect ripening fruit from birds, while rain covers are applied to stop rain damaging the fruit. Where rain covers are used, they are typically put on a few weeks before harvest and stay on till harvest is finished. In Central Otago, harvest occurs early Dec – mid Feb. Bird netting may be on all year round, or be erected after pollination in the weeks leading towards harvest.

4.36 The ‘plastic’ cloth used for bird netting and rain canopies are generally rated for 10 years in terms of durability of the cloth to UV exposure. Most growers expect the coverings to last longer than this and undertake seasonal repairs and replace sections to extend the life of the whole structure. The permanent parts of the canopy such as poles and cables should last considerably longer than the cloth.

4.37 Trees do not use all the light that they receive for photosynthesis. All crop covers reduce light available to the crop by varying extents, all over 10 percent. There would need to be a great deal of dust on covers for them to further reduce light permeability to a significant extent.

4.38 Cloths (bird nets) and rain covers may also provide some shield between the crop and dust, with rain covers likely to direct collected dust to the ground between the tree rows. Dust caught in bird netting may be dislodged by further wind events or rain events and then likely redistributed to ground rather than being captured within the cherry trees. Overall, I consider bird netting or rain covers are likely to be neutral regarding quantity of dust on the trees underneath.

4.39 Wind-blown dust could reduce the effectiveness of covers if it reduced the reliability of mechanical parts or effective lifespan of fittings due to increased wear. However, design of fittings and canopies can include placement and protection to generally extend their life and reduce likelihood of wear, or repair being required. These strategies would also increase resilience to dust, such as:

(a) Cloth stored in situ being under covers (a bit like sail covers on yachts);

(b) Covers over machinery housings;

(c) Fittings sited in the lee of prevailing winds where they have some protection from weather, which would also reduce dust-exposure.

5 DUST AND CHERRY ORCHARDS

5.1 Most of the literature on dust is general to effects of dust on vegetation and horticultural crops, rather than specifically the effect of dust on cherries.

5.2 The dust generated from Amisfield Quarry is understood to be inert sedimentary dust originating from predominantly greywacke parent materials that are naturally found in the area. As this sedimentary dust is chemically inert, it would not be expected to have chemical interactions that can sometimes occur when even very low levels of chemically reactive dust are present on horticultural crops. My evidence is therefore focused on the potential physical impacts of inert dusts.

5.3 There is limited specific information on dust effect on crops in the field as dust events are varied and it is a difficult topic to perform valid research projects.

5.4 Research undertaken by WSP via a literature review gives a good overview of the main potential effects of inert dust on crops and correctly identifies the most sensitive stages of the growing season for cherries. One key reference I reviewed is a Lincoln University Master's Thesis from 1990 by P.R. McCrea "The Effects of Road Dust on Agricultural and Horticultural Production Systems in New Zealand: A Systems Approach." Work on road dust is relevant to the type of material produced at the quarry which I understand is similar to material used on road surfaces. The quarry also contains internal unsealed roads.

5.5 I also reviewed several additional papers from our files[3], including two[4] further public-domain reports authored by P.R McCrea about the effects of roading and construction dust on primary production, which include detail and literature reviewed prior to the 1990 Masters Thesis. Review of the additional McCrea sources focussed on the parts of these reports covering different material from the master's Thesis.

5.6 Key points from this literature review about spread of dust from an unsealed road without mitigation were:

(a) Significantly more dust is deposited downwind than upwind from the dust source;

(b) Wind direction is a major factor in dust distribution, with most dust being spread in the direction of the prevailing downwind;

(c) The height of a crop, called 'roughness' by McCrea, affects how far dust spread from source, with the distance it spreads being less for taller crops like cherry trees, medium for mid-height crops like grapes and further for lower growing crops like pasture;

(d) Leaves with a rougher surface hold more dust. Both cherry trees and grape vines have rough leaves;

(e) Effective shelter, such as a continuous row of trees with permeability of 50%, can reduce dust. The range estimated by

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3 Armbrust, D. V. 1986. "Effect of Particulates (Dust) on cotton Growth, Photosynthesis and Respiration." Agronomy Journal Vol 78, November-December 1986.
Also, Hirano, T. Kiyota M. and Aiga, I. 1994. "Physical effects of dust on leaf physiology of cucumber and kidney bean plants." Environmental Pollution Vol 89, No. 3 pp255-261.
And from less formal sources:
Das, T.M. undated but likely 1970's. "Effect of Deposition of Dust Particulates on Leaves of Crop Plants on Screening of Solar Illumination and Associated Physiological Processes."
Phillips, Phil. A. 1996. "Revisiting Dust: A real threat to successful biological control." Citrograph, May 1996.

4 PR McCrea, 1984. "Road Dust. An assessment of the effects of road dust on farming systems in Tauranga County." A report to Tauranga County Council. Agricultural Economics Research Unit, Lincoln College.
P.R McCrea, 1986. "The Effect on Horticulture of Dust and Ash: Proposed Waikato Coal-Fired Power Station." Research Report No. 185, Agricultural Economics Research Unit, Lincoln College.

McCrea was 20-70% with 40% selected as a medium estimate of the amount of dust reduction by effective shelter belts.

5.7 Key factors affecting the amount of dust generated from unsealed roads without mitigation were:

(a) The proportion of fine silt-sized particles (2-50 microns in diameter) at the road surface, with more dust generated when there were more fine particles;

(b) The number of vehicle movements, with more dust generated by more vehicle movements;

(c) Vehicle speed, with more dust generated by vehicles moving faster.

5.8 More detail of the literature findings are appended, including some key results tables.

5.9 Mr Cudmore's analysis of wind at the quarry location indicates the main winds occur broadly along the valley from the north-north-east and the south-south-west directions with little wind occurring from the other quarters. His wind analysis indicates wind directions at the site do not fit neatly into prevailing upwind and downwind directions, with the two main wind quarters being broadly opposite with broadly similar occurrence.

5.10 Thus the dust deposition likely from dust events arising from the quarry can be considered to occur to roughly equal distances in the two main wind directions, being the north-east quarter from the quarry site and the south-west quarter from the quarry site.

5.11 Thus, in McCrea's Table 3 (appended as Figure 6), the 'prevailing downwind' wind direction combined with cherries 'rough' ground surface crop height and grapes 'medium' ground surface crop height can be used to estimate the distance from the quarry where effects of dust on production could occur without dust mitigation strategies.

5.12 Using figures for the prevailing downwind side from McCrea's 'Table 3' (Figure 6 of my appendix), significant effects of uncontrolled dust on production could occur in each major wind direction for cherries for a range of 25-100m from the edge of the dust source and for grapes for a range of 50-150m from the dust source.

5.13 I note that Mr Cudmore references the lack of specific industry or national guidance for dust criteria for the protection of crop production and I agree that this is the case.

5.14 With respect to short term standards, Mr Cudmore has noted the literature that indicates adverse impacts on photosynthesis occur above 1.0 g/m^2/day of dust and as such recommends this as the appropriate limit in this instance. This is consistent with the McCrea literature reviewed in Figure 8 of my Appendix.

5.15 In the absence of such standards or criteria, Mr Cudmore has used the long term nuisance criteria for settleable dust (4 g/m^2/30 days) as a limit below which adverse effects on crops will be avoided. This appears reasonable, given it is four times the daily figure, which was consistent with McCrea's review referred to in my previous paragraph, but is considerably less than the daily figure calculated for a 30 day period.

6 VITICULTURE

6.1 Viticulture, or winegrapes, are a lower growing crop than cherries, so are likely to be affected by dust further from the dust source due to this lower crop height. Like cherry trees, grape vines are also deciduous, with a winter dormant period, and their leaves are not smooth. The pollination and harvest periods are also the likely most sensitive periods for viticulture and there are a range of varieties grown in the region. Pollination occurs later in spring than for cherries, as in spring the vines first produce new shoots with leaves before the flowers appear in October to early November. Grapes are wind pollinated, and warm, dry conditions favour good pollination.

6.2 Harvest occurs in autumn, mostly in March-April. A range of varieties are grown which extends the harvest period. Bunches of grapes are somewhat tucked under the vine leaf canopy and so are 'sheltered' from dust, but leaf plucking towards their ripening stage exposes more of the fruit.

6.3 Bird exclusion netting is commonly erected over the crop rows as harvest approaches. In vineyards, the bird netting is seasonal and is completely removed after harvest, with the system sometimes described as 'throw over' cloths. Winegrapes may be damaged by rain close to harvest but it is not current practice to provide rain covers for vineyards.

6.4 The winegrapes are processed into juice to make wine. This makes them a little more tolerant of small quantities of dust than cherry crops as the juice is separated from the stalks, skins and so on during processing, providing more resilience to imperfections than if grown for sale as fresh fruit like cherries.

6.5 Like cherries, the least sensitive times of the year for vineyard sensitivity to dust is during winter dormancy and after harvest, so approximately from May through the winter until mid to late September.

6.6 I consider that the dust quantity criteria used by Mr Cudmore in relation to cherry crops discussed in my paragraphs 5.14 and 5.15 is equally applicable to winegrapes.

7 SUBMISSIONS

Nature and broad content of submissions relevant to dust and horticulture

7.1 Submissions from Douglas Cook, Hayden Little Family Trust and Amisfield Orchard Ltd were reviewed with respect to their concerns about dust.

7.2 To familiarise myself with the areas referenced in these submissions, I have viewed aerial images of the orchards in the area using Google Earth views.

7.3 I note the following general observations in relation to these areas. It appears there are frost fans installed on a number of the nearby orchards and a number of orchards in the area around the quarry have ponds to store water.

7.4 Most of the orchards in the area around the quarry have rows orientated close to north-south, with the main exception being the narrow block to the south of the quarry on the northern side of Amisfield Road where the rows are nearer to an east-west orientation.

7.5 It appears most of the orchards around the quarry have some perimeter shelter trees. Bird-netting is in place in aerial views from November 2021. The orchard to the east of the proposed quarry expansion site and to the south of the existing site appear to be younger as they do not appear to have bird netting in place in recent aerial photos when other nearby orchards have them in place.

7.6 The submissions from the Hayden Little Family Trust and Amisfield Orchard Ltd refer in part to the same piece of land to the east of the proposed expansion site and have considerable common content so are discussed together, referred to as the 'Little' submissions.

7.7 The submissions refer to lack of shelter around the existing quarry, spread of dust from the existing quarry in high wind events and concern that an expanded quarry will generate more dust that will adversely impact their orchards, particularly reducing pollination, reducing effectiveness of pest and disease sprays applied, with accumulation of dust in bird netting and rain cover structures then likely being deposited on the trees and irrigation sprinklers becoming blocked by dust.

7.8 The 'Little' submissions comment that irrigation micro-sprinklers are currently being blocked by dust, although does not elaborate how widespread this is and whether one or both of the two orchards are affected. Sprinklers can become blocked from dust (although this is not common), insects, from sediment in water used to supply the sprinklers, from chemical precipitation (especially if the water is high in iron or manganese), and from deterioration of the sprinkler materials as they age, although I would not expect the latter to be the case in such a young orchard. Water used in the sprinklers would usually dislodge small amounts of dust.

7.9 From recent aerial views via Google Earth, tree establishment appears variable on the 'south' orchard, especially at the eastern end. In the 'east' orchard, there appear to be three areas of patchy tree establishment towards the north, central and west-central portions of the orchard, most being well inside the orchard boundaries where the trees are most likely to be most exposed to any dust from the existing quarry. Viewing aerial pictures from 2005 (in the photos in Figures 1 and 2 below) suggests the areas appearing to have poor tree establishment are in areas where the aerial view shows variation in the soil in 2005.

Figure 1: Aerial view of 'Little' east orchard site in 2005 from Google Earth.

Figure 2: Aerial view of 'Little' east orchard site in November 2021 from Google Earth, suggesting correlation of areas of poor tree establishment with soil differences visible in the 2005 aerial view.

7.10 Regarding the site to the immediate south of the quarry (owned by Hayden Little Family Trust), the increase in boundary to the cherry orchard with the proposed quarry expansion is modest. From viewing Google Earth aerial view of imagery from 6th November 2021, the rows appear to be orientated east to west with no external shelter trees (Figure 3 below). The east end of the orchard is adjacent to 'bare' streambed of the Amisfield Burn. There is a very incomplete shelter tree row on the south edge of the existing quarry to the north edge of the orchard, especially at the east end of the orchard.

Figure 3: Aerial view from Google Earth - imagery dated 6 November 2021. The 'Little' southern cherry orchard is the long piece of land between the Amisfield Burn stream and Amisfield Road to the south of the existing quarry. North is at the top of the picture.

7.11 The Amisfield Orchard property to the immediate east of the proposed quarry expansion area has rows orientated north-south and appears to have boundary shelter, although it is not clear from the recent Google Earth view how much is trees. It appears likely that most of the shelter is artificial cloth shelters except on the east edge nearest to Lake Dunstan where the shelter appears to be trees. Shelter trees between the quarry and orchards and around the orchards would contribute to dust suppression although I note that Mr Cudmore does not support these given his experience that large shelterbelts can collect dust from a wide area and discharge it in a plume in strong wind.

7.12 The closeness of the 'Little' east orchard to the proposed quarry expansion site and the degree of immediate boundary to the north of the orchard increases the potential risk of dust effects on the orchard from the proposed quarry expansion. The main wind directions should mean limited carry of dust from either the existing or expanded quarry to the ‘Little’ eastern orchard based on the three-year average of data in Mr Cudmore’s modelling, although there were some winds directly from the north during 2020 which could have blown dust into the orchard from the quarry expansion site. I understand that continuous and real time dust and wind monitors are proposed to be used as part of the dust management approach, particularly when excavating close to sensitive receptors such as the east orchard.

Figure 4: Aerial view from Google Earth - imagery dated 6 November 2021. The 'Little' eastern cherry orchard is the piece of land between the existing quarry and Lake Dunstan, with the proposed quarry expansion site immediately to the west of the orchard at the north-east of the existing quarry. North is at the top of the picture.

8 **CONCLUSION**

8.1 Cherry orchards are most vulnerable to dust during the harvest and pollination periods. However cherries for export are ‘washed’ at packing which would remove loose surface dust on the fruit. High amounts of dust on flowers could potentially reduce pollination effectiveness, although cherries naturally do not set fruit from every flower.

8.2 There are no published criteria or guidelines in relation to acceptable levels of dust on cherry (or other) crops. In the absence of these, I consider the criteria used by Mr Cudmore to be appropriate. The measures proposed to control dust will be important at all times, but especially during the period leading up to harvest of the cherries, during blossoming in spring, and during any atypical wind directions.

Ruth Underwood

30 November 2021

Appendix

1 Useful information about the effects of dust from papers reviewed includes P. R. McCrea, 1984 regarding dust from unsealed roads, which included about 80 references in the whole document. The proportion of unsealed (and uncontrolled) road dust estimated to fall back on the road, for a 20 metre road width was 22.2%. The proportion that was estimated distributed in the prevailing upwind direction was estimated at 19.9%, with about half estimated to occur within 30 metres of the road edge. The proportion of road dust estimated to be distributed in the prevailing downwind direction was 57.6%, with about half estimated to occur within 70 metres of the road edge.

2 The upwind and downwind distribution of dust from unsealed roads was summarised in McCrea's 1986 paper as the percentage of dust estimated deposited and cumulative percentage deposited in the table following, pictured from that report (Figure 5), noting the quantity of dust is listed as a percentage and adds to 100 percent when both upwind and downwind deposition are combined.

TABLE 11

Percentage and Cumulative Percentage Depositions

of Road Dust Away from an Unsealed Road

Distance from Road (Metres)	TOTAL DEPOSITION Downward Percentage	Upwind Percentage	Cumulative Downwind Percentage	Cumulative Upwind Percentage
0 - 10	13.4	9.1	13.4	9.1
10 - 20	7	3.5	20.4	12.6
20 - 30	4.9	2.7	25.3	15.3
30 - 40	3.7	1.7	29.0	17.0
40 - 50	3.3	1.5	32.3	18.5
50 - 60	2.6	1.0	34.9	19.5
60 - 70	2.2	0.8	37.1	20.3
70 - 80	1.8	0.7	38.9	21.0
80 - 90	1.7	0.6	40.6	21.6
90 - 100	1.5	0.6	42.7	22.2
100 - 150	6.5	2.0	48.6	24.2
150 - 200	5.0		50.6	
200 - 250	4.1		57.7	
250 - 300	3.1		60.8	
300 - 350	2.4		63.2	
350 - 400	2.4		65.6	
400 - 450	2.1		67.7	
450 - 500	1.8		69.5	
500 - 550	1.3		70.8	29
TOTAL	71%	29%	71%	29%

Source: McCrea (1984)

Figure 5: Picture of Table 11 from McCrea, 1986 showing estimated dust distribution in the prevailing upwind and downwind directions from an unsealed road. Note, the percentages add to 100% of dust.

3 The effects of vegetation 'roughness' were also estimated in McCrea's 1984 paper. Dust was shown to travel further over smooth crops and progressively less distance over 'medium' and 'rough' crops, because more of the dust was taken up by the vegetation nearer to the dust source. Pasture was 'smooth', medium height crops 'medium', including 'cane grown berry crops' - which we could equate with vineyards - and orchards were a 'rough' surface, which would include cherry orchards and other similarly tall crops such as olives and nut trees.

4 Shelter belts were assessed as likely to retain about 40% of dust from a continuous row of trees with 50% wind permeability.

5 Crops with leaves that were not smooth likely accumulated more dust than those with smooth leaves like citrus. (Cherries, other summerfruit, and grapes all have leaves that are not smooth). This effect persisted despite complete lack of leaves during dormancy for deciduous crops, i.e. the quantity of dust accumulated when leaves were present on rough-leaved deciduous crops was more than accumulated over 12 months on glossy-leaved evergreen plants.

6 McCrea's summary of estimated distances from the roadside in which road dust must significantly affect production are shown in the picture below (Figure 6).

TABLE 3

Estimated Range of Distances from Roadside in which Road Dust may be Significant to Production.

Type Ground Surface	Prevailing Downwind Side		Prevailing Upwind Side	
	Low	High	Low	High
Smooth	100m -	250m	25m -	60m
Medium	50m -	150m	15m -	40m
Rough	25m -	100m	10m -	25m

Figure 6: Picture of Table 3 from McCrea, 1984 showing estimated distance from dust source from which dust impact on production may be significant.

7 McCrea included a high and low estimate to acknowledge the figures are estimates. The 'high' figure is the distance where approximately 80% of the dust is likely to have settled and the 'low' where approximately 60% of the dust is likely to have settled. McCrea described wind direction as "probably the single most important determining factor in the distribution of dust and ash deposition."[5]

8 Given cherries ("rough" ground surface) and grapes ("medium" ground surface) likely represent the most dust-sensitive crops grown in the environs around the quarry, an upwind distance of 25-40 metres and a downwind distance of 100-150 metres can be considered sensitive

[5] McCrea 1986 p45.

environments, where effects of significant levels of dust on production could occur.

9 The wind at the site was estimated in the Beca report based on data collected over 12 months in 2019 at a site 2km away. In the Cudmore Appendix, data was modelled for wind for the three separate years 2018, 2019 and 2020, and a windrose for each year and the combined three-year period was compiled. These showed some difference between the three years, but generally the main winds being broadly along the valley from the north-north-east and the south-south-west directions and little wind from the other quarters. The Cudmore Appendix makes a comparison with some data from the 'harvest' weather information collected for a period from the Cook orchard, which indicated slightly more easterly direction of wind and lower wind speeds in the Cook Orchard data. This wind analysis indicates wind directions do not fit neatly into prevailing upwind and downwind, and the two main wind quarters are broadly opposite and have broadly similar occurrence. Thus the dust deposition from dust events can be considered to occur roughly equally in the north-east quarter from the quarry site and the south-west quarter from the quarry site. So, working from McCrea's figure above, significant effects of dust on production could occur for 25-100m in each major wind direction for cherries and 50-150m for grapes.

Assessment criteria/guidelines

10 There are no assessment criteria or guidelines for effects of dust (either ambient concentrations or deposition based criteria) on cherries. Quantitative dust impact criteria and modelling specific to vegetation is relatively scarce in the literature.

11 For his master's thesis, McCrea (1990) developed a "Horticultural and Arable Production Submodel" to predict the impact of road dust on photosynthetic yield losses for crops in New Zealand. The model includes specific parameters relating to roads such as road length, speed range and traffic counts. Estimates of the distance dust travelled from the source, in this case the road surface, were based on experiments in the literature review contributing to construction of the

model for the thesis, for example an experiment reviewed which recorded distance dust travel downwind from an instantaneous line source of 1gm/m^2 of dust. Key aspects in McCrea's model adapting figures for measured dust compared to dust likely to be retained on crop foliage were reductions due to greater density of crops compared to flat surfaces, texture of leaf surface and presence of shelter belts. All the calculations had wide variables to reflect the uncertainty.

12 The reduction in light intensity due to various levels of dust on leaves is shown in the graph below (Figure 7), indicating little reduction in light levels from low levels of dust.

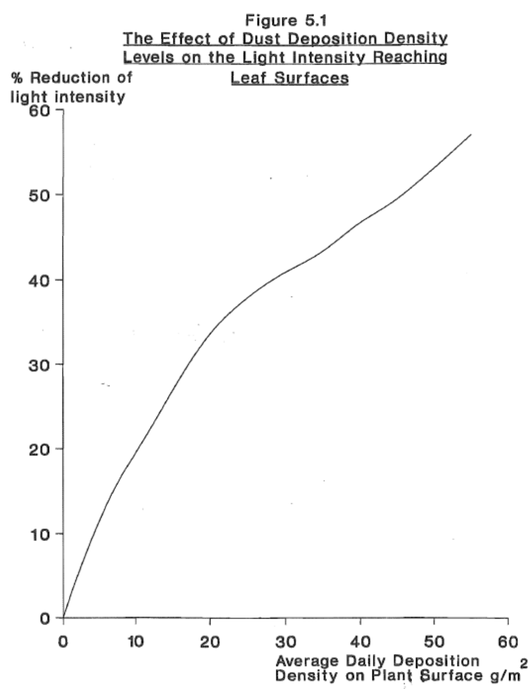

Figure 7: Reduction in light intensity on leaf surfaces due to road dust. From McCrea 1990.

13 The reduction in photosynthesis due to various levels of dust on leaves follows on from the reduction in light available to the leaves. This is shown in the graph below (Figure 8), indicating little reduction in photosynthesis from low levels of dust. Only the 'summer' figures are relevant to cherries and grapes as both crops are dormant during winter so would not be photosynthesising at that time.

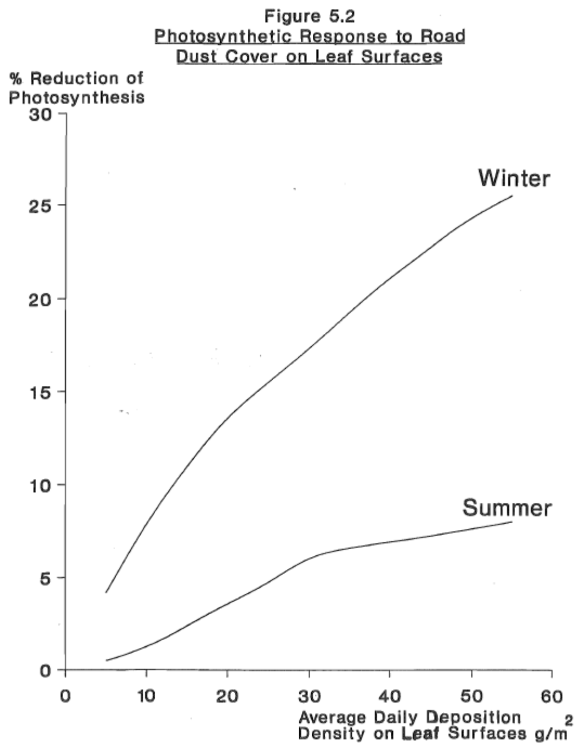

Figure 8: Reduction in photosynthesis due to road dust on leaf surfaces. From McCrea 1990.

14 McCrea's figures modelled reduction of dust due to crop density being more to a flat surface. To explain, because the surfaces of a plant adds to more than the surface of the ground area it covers, dust is spread more thinly on the foliage than if collected on the ground surface. McCrea's figures for this, as a percentage reduction from the quantity of dust recorded on a flat surface, were a low estimate of 20%, medium estimate of 35% and high estimate of 70%.

15 For leaf texture, McCrea's figures modelled the reductions for a smooth leaf surface were a low estimate of 5%, medium estimate of 15% and high estimate of 50%. The leaf surface of cherries and grapes is rough, i.e. not smooth, so no reduction would be modelled on these crops.

16 For the effect of a row of shelter trees with 50% permeability to wind, McCrea's figures modelled the reductions in dust were a low estimate of 20%, medium estimate of 40% and high estimate of 70%. These figures would apply to the quarry area if there was shelter of this description, but the current shelter is too sparse to be effective and would likely have little to no current effect on reducing dust.

17 McCrea identified key factors for dust generation were traffic speed, size of dust particle (indicated by the proportion of silt-sized particles in the road surface material, which are 2-50 microns in diameter) and number of vehicle movements. The effect of vehicle speed is especially significant, as the quantity of dust generated was found to be a squared function of vehicle speed, so a vehicle travelling twice as fast would generate four times the quantity of dust.

18 McCrea's work (1986) on modelling of construction of a power station included calculations of the likely effect of water mitigation strategies. Mitigation with water was modelled to reduce dust emissions by 43% during a 'major construction' phase over one summer and by 58% during a further two year construction phase. These figures, although modelled and old, indicate that mitigation strategies can significantly reduce the quantity of dust generated. They did not include modelling of the more recent polymer technology now available and which I understand is included in the quarry dust management strategy proposed.