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LA TROBE UNIVERSITY

WINES OF THE KING VALLEY

NE VICTORIA VINEYARD SMOKE SENSOR NETWORK



FINAL PROJECT REPORT

Project Number: **LTU 2003**

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Research Organisation: **La Trobe University**

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NE Victoria vineyard smoke sensor network

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This report relates to the funding agreement between the State of Victoria and Wines of the King Valley Inc., for the project entitled *NE Victoria Vineyard Smoke Sensor Network* which ran 15 June 2021 to 30 June 2022.

Project funding was provided by Wine Australia, La Trobe University, the wine regions of NE Victoria and the Victorian Government through a successful application by Wines of the King Valley to the Bushfire Recovery Regional Economic Stimulus and Resilience Grants Fund, administered by Regional Development Victoria (RDV) under the Local Economic Recovery (LER) program.

A project variation was executed between Wine Australia and La Trobe University to extend the project to 30 June 2023 to support the network. This report corresponds to the period **15 June 2021 – 30 June 2023** and is derived primarily from:

- The project Completion Report prepared by Wine Australia and La Trobe University for submission by Wines of the King Valley to Regional Development Victoria in June 2022
- The 12-month Post-Completion Evaluation Report prepared by Wine Australia and La Trobe University for submission by Wines of the King Valley to Regional Development Victoria in June 2023.

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1. Abstract

The bushfires in 2019-20 had a devastating effect on many wine regions in Australia. In North-East Victoria, they provided the catalyst for a successful application to the Victorian Government for a Local Economic Recovery (LER) grant, to support the long-term viability of the region by future-proofing vineyards from smoke damage. The project delivered a world-first network of 100 sensor stations, called Wine Industry Smoke Detectors (WISDs), located in vineyards across NE Victoria. The loggers are able to record, analyse and report the exposure of wine grapes to smoke events in real time and measure accumulated smoke across the entire season. An electronic dashboard provides a traffic-light smoke taint risk assessment back to producers, significantly reducing stress and allowing timely decisions to manage potential smoke effects. The proof-of-concept network is a world first and is designed to be scaled to support other regions across Victoria, with the potential to be deployed nationally and globally.

2. Executive Summary

North-East Victoria is one of the most bushfire-prone wine regions in Australia and was impacted greatly by the bushfires of 2019-20. Although direct fire damage to vineyards was low, smoke damage to fruit across all five regions resulted in thousands of tonnes of grapes being lost or downgraded in quality, with an estimated $140 million lost to grape and wine businesses in the region.

The five wine regions (Alpine Valleys, Beechworth, Glenrowan, King Valley and Rutherglen) responded with formation of the North-East Wine Zone (NEWZ), to facilitate a collaborative and shared strategic view of the industry. Wines of the King Valley made a successful application to the Victorian Government's Local Economic Recovery program for a collaborative project with La Trobe University, Wine Australia and NEWZ to establish a network of dedicated wine industry smoke sensors in NE Victoria. The proposal attracted significant support from local government councils, Wine Victoria, Australian Grape & Wine and the member associations of NEWZ, which represent 110 grape growing and winemaking businesses in the region.

The project built on previous and current work of La Trobe University (LTU 1601, LTU 1901, LTU 2001), which established close correlations between smoke measurements, grape and wine chemistry and sensory outcomes in wine. Further, this work showed that smoke measurements taken in close proximity to an exposed vineyard can provide an early indication of risk of smoke damage to grapes and wine, and resulted in the development of prototype Wine Industry Smoke Detector units (WISDs).

The project achieved the following:

- Established a world-first regional network of 100 WISDs throughout vineyards in NE Victoria to provide continuous, real time "smoke dosage" data

- Generated new data from smoke events to further refine a model which will, with a high level of accuracy, be able to predict the risk of smoke taint based on the smoke dosage the grapes received
- Developed a fully accessible internet dashboard and smartphone app that will provide growers with real time information to inform risk of smoke taint through a traffic light system, across eight key winegrape varieties
- Showed how early information on smoke taint risk, provided by the network of sensors, can inform critical downstream business decisions including grape testing, vineyard management, and winemaking strategies to manage smoke effects
- Provided a blueprint for deployment of a smoke early warning system in wine regions across the rest of Australia and internationally.

The WISD network is a predictive real-time instrument that enables timely, grape varietal-specific, on-farm decision making by grape growers and winemakers to manage the effects of smoke from any fire event. It is a vital tool in supporting the long-term viability of Australian grape and wine businesses in the face of increasing bushfire risk into the future.

3. Background

Smoke taint occurs when vineyards are exposed to smoke from any burn (e.g. bushfires, controlled burns, private land burn-off) and is a significant issue for the wine sector. Compounds in the smoke are absorbed by grapes and can be tasted in the wine as undesirable 'burnt' or 'ashy' characters. The catastrophic bushfires in Australia in 2019-20 resulted in little direct fire damage to vineyards, but smoke damage to fruit was extensive. A study by Walpole (2020)[1] estimated grape losses in 2020 in North-East Victoria alone to be worth $21.8 million. However, this is small in comparison to the value of retail wine forgone, which was calculated at $141 million lost to grape and wine businesses across the five wine regions of North East Victoria.

The five wine regions (Alpine Valleys, Beechworth, Glenrowan, King Valley and Rutherglen) responded with formation of the North East Wine Zone (NEWZ), to facilitate a collaborative and shared strategic view of the industry. NEWZ made a successful application to the Victorian Government's Bushfire Recovery Regional Economic Stimulus and Resilience Grants Fund, administered by Regional Development Victoria (RDV) under the Local Economic Recovery (LER) program.

The proposal attracted significant support from local government councils, Wine Victoria and the member associations of NEWZ, which represent 110 grape growing and winemaking businesses in the region. Australian Grape & Wine and Wine Australia management assisted Wines of the King Valley on behalf of NEWZ with writing of the application.

[1] Walpole (2020) The Financial Impact of 2020 Summer Bushfire Smoke on the Wine Regions of North East Victoria. A report commissioned by The Rural City of Wangaratta with the assistance of the North East Catchment Management Authority

4. Objectives

The project took a broader strategic view of supporting the long-term viability of the region by future-proofing vineyards from impacts associated with smoke damaged fruit. It builds on previous and current work of La Trobe University, funded by Wine Australia, to address the key priority area of smoke measurement as an early warning of smoke taint risk. Smoke measurements taken in close proximity to an exposed vineyard can provide an early indication of risk of smoke damage to grapes and inform critical downstream business decisions including grape testing, vineyard management, and winemaking strategies to manage smoke effects.

The project objectives were to:

- Establish and validate a network of smoke sensors throughout vineyards in NE Victoria that provide real time “smoke dosage” data
- Combine data from new sensors with that collected in previous fire years, to further refine a model which, with a high level of accuracy, is able to predict smoke taint based on the smoke dosage the grapes received
- Develop a publicly-available website and mobile app that provides growers with real time information to inform risk of smoke taint through a traffic light system across a large range of different grape varieties
- Provide generic guidance to support business decisions based on information provided by the network of sensors.
- Provide a blueprint for deployment of a smoke early warning system in wine regions across the rest of Australia and internationally.

5. Project Achievements

5.1 Deployment of 100 sensor stations in vineyards across North East Victoria

The primary output from the project was a network of 100 smoke sensor units designed to provide an early warning system for smoke damage to wine grapes. The logger units, called Wine Industry Smoke Detectors (WISDs), were constructed by a local company, 4Research, in consultation with industry and the research team at La Trobe University. The units are custom-designed to be stand-alone, low-cost and multifunctional.

Features of the hardware include:

- GPS enablement
- Dual-laser, calibrated smoke sensors for smoke particulate matter (PM2.5) data collection, as a measure of smoke dose
- Three forms of communication capability: Wi-Fi, LoRaWAN and 4G (NB-IoT) for connection to a central server
- Air temperature and humidity sensors
- A unique QR code to allow web access and development and access to the data through the WISD phone app (still under development)

- Ability to run on mains power or through in-built solar panels
- Tailor-made structural frame for rapid mounting in the field
- Provision for the addition of soil temperature, soil moisture and solar hour sensors in the future (outside of project brief).

The project team overcame significant logistical and supply challenges to construct, validate and deploy the sensor network, which is the first of its kind globally and provides a lasting legacy to the region. An initial tranche of prototype loggers was evaluated during autumn of 2022 prior to commissioning of the complete network. Owing to the inability to conduct controlled burns in NE Victoria in that year due to wet seasonal conditions, most prototype sensors were tested at other locations throughout Victoria.

Loggers were evaluated for durability in the field as well as general performance, accuracy and reliability against quality standards provided by research VESDA®s (Very Early Smoke Detection Apparatus) that in themselves have been previously validated against EPA Standards. Data from smoke, grape and wine samples collected around controlled burns was processed and collated with previous data bases, and also compared against cumulative smoke dose measured by the loggers and VESDA®s.

Testing and validation continued across the 2022-23 growing season, by which time 100 loggers were deployed in and near vineyards in the wine regions of North-East Victoria. They were set up so they could provide telemetry for smoke composition, temperature and humidity directly back to a server at La Trobe University. Locations were chosen in consultation with the Project Governance Group on the basis of relevance to both bushfires and controlled burns and to provide coverage across the region. A map of sensor unit locations appears in Appendix 1.



Examples of WISDs deployed in and around vineyards of NE Victoria

Owing to the wet summer and autumn season in 2023, the need for risk prediction from the loggers by growers was smaller than anticipated. However this allowed the team to

focus on the durability and performance of the loggers and further development of the dashboard (see below).

The issues addressed included:

(i) Identifying and providing solutions for issues affecting the function of individual loggers, which included general durability, sensor performance, connectivity and pest (e.g. wasp) colonisation. Fortunately, such issues affected a very low percentage of loggers

(ii) Addition of new circuitry to improve performance and solar capability during periods of low solar radiation

(iii) Integration of a default mechanism to wake loggers after a power outage

(iv) Establishing that the loggers operate effectively on WI-FI, which, when available, circumvents annual costs associated with use of 4/5G communication

(v) Tailoring dashboard presentation for PC as compared to the App viewed on an iPhone/android phone. Whilst built-in phone defaults caused delays in rolling out individual logins for growers, the lack of smoke events allowed time to overcome dashboard presentation issues

(vi) Closed loop calibrations of the loggers to ensure accuracy and durability over time

(vii) Preliminary trial of low-cost cellular connectivity via NBIOT, to establish communication in extra-urban regions where Wi-Fi is not available

(viii) Replacement of faulty sensors – only 5% of the sensors needed replacement, a rate far lower than anticipated. As there is redundancy built into the loggers (ie two sensors in every logger), and faulty sensors were never in the same unit, operation across the whole network was unaffected.

5.2 Establishment of a cloud-based data-storage service that will receive and store the telemetry data from each of the sensor stations

Significant data management activities were required to develop the data storage and feedback system required to underpin the network. The established data flow is depicted below and can be summarised as:

(i) Data on smoke composition (PM2.5 and PM10) from each of the duplicate sensors in each logger, as well as temperature and humidity, is collected in 5 to 10 minute time intervals

(ii) Data is uploaded to the cloud every 15 minutes and initially communicated to a central server located at 4 Research *via* WiFi or the 4G network

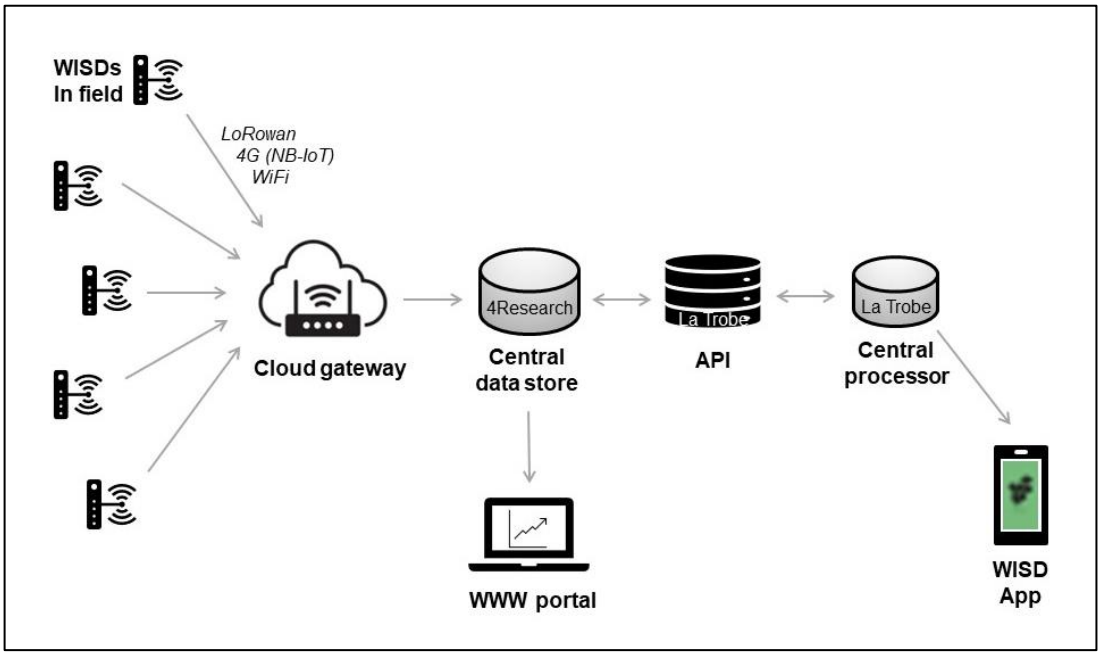
(iii) This data is converted into daily and hourly outputs of air temperature, humidity and smoke dose and available as graphics on a website tailored to each individual grower (see below)

(iv) Data on the server is also accessed website via an Application Programming Interface (API) command to a database at La Trobe University. It is there that algorithms developed by a team at La Trobe University convert complex data into a smoke taint risk rating, which is communicated to the grower via the mobile phone WISD

application and on a PC website (see below).

A new fully functional server developed at La Trobe University was able to, in real time, both receive information and provide a risk assessment back to industry for the smoke dose and smoke taint risk outcome.

Even though there were only very minor smoke events during the 2023 season in the northeast region of Victoria, data on cumulative smoke dose and smoke taint risk was continuously transmitted from every property monitored.



5.3 Development of a cloud-based software service that analyses the stored sensor data to provide predictive real-time grape-variety specific smoke exposure information for nearby vineyards

A database which links PM measurements to the levels of taint compounds in smoke and in turn to those in grapes and wine, and to sensory outcomes, had been built by the research team in previous projects over a number of years and was housed at La Trobe University. This project built on the existing database with considerable amounts of new data. Work in this project used API commands and Python software added algorithms to convert smoke data with either linear or polynomic relationships into a prediction of smoke taint risk. The IP in the datasets and algorithms is jointly owned by La Trobe University and Wine Australia and protected as a trade secret.

The algorithm is a correlation between PM measurements in smoke and taint risk, with various loadings applied to account for factors such as distance from the burn, grapevine variety, age of the smoke and timing of exposure during the season. Smoke taint thresholds are being set for varieties with skins off (e.g whites, Rosé) and those with skins on (e.g.reds) and include Chardonnay, Pinot Gris, Sauvignon Blanc, Shiraz, Cabernet Sauvignon, Fiano, Aglianico, Pinot Noir, Sangiovese and Marsanne.

For visualisation of WISD outputs and smoke taint risk, expressed as a red-green-amber traffic light rating, a public domain ThingsBoard platform was used as a base dashboard. While ThingsBoard has some limitations, a tailored dashboard for access by each grower with an individual login and password was able to be developed within the project.

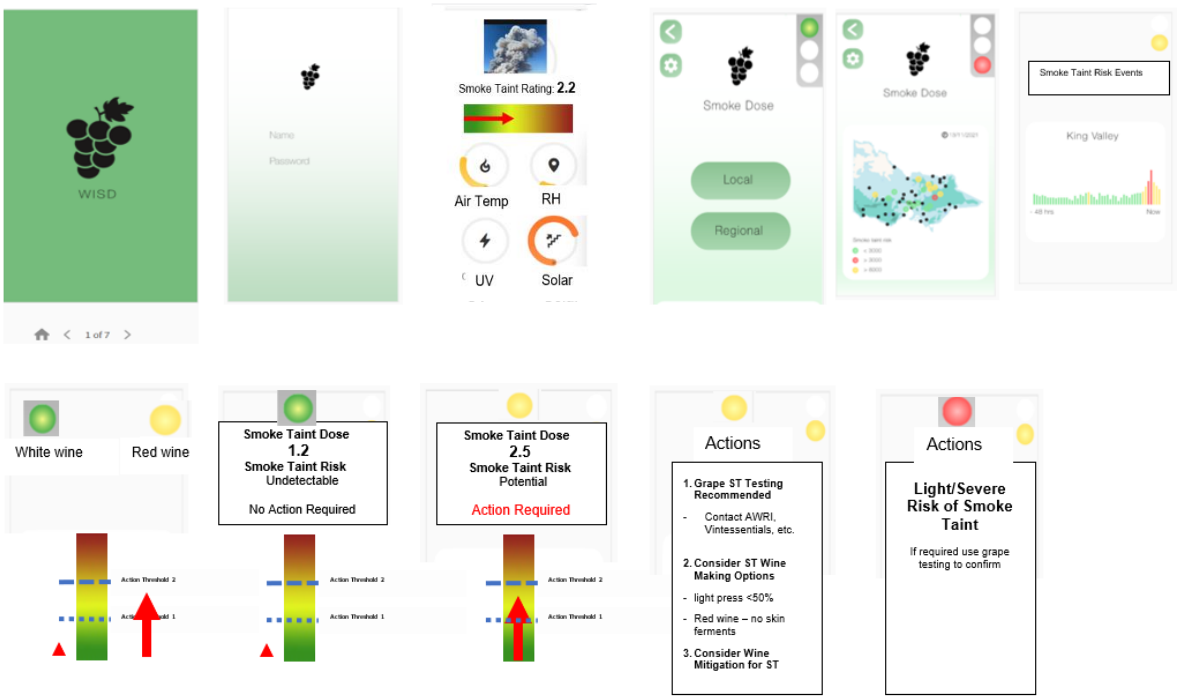
This allowed the construction for the first time anywhere in the world a traffic light system for smoke taint. The traffic light risk levels are being further refined as new data is obtained from the loggers in the field. In addition to the 100 vineyard sites, this project added data from another 100 locations around controlled burns (41 vineyards and over 60 non-vineyard sites) to contribute to the large database of information collected in the past at 150 sites around a large number of controlled burns and bushfires in Victoria in 2020 and 2021. The data from this project was integrated into the database and converted into risk prediction for smoke taint at different times through a burn and during the grape production season.

5.4 Development and deployment of a mobile app/website that allows grape growers and wine makers to obtain real-time decision support in the field

As a result of this project, growers are able to visualise the prediction of smoke damage risk for their location using a dashboard (described above) which is accessed *via* the internet on a PC or *via* a mobile phone application (WISD app). In addition to the smoke dose, the web portal and app both serve to provide a summary of the current and historical data collected.

The output required significant modification and adaptation to display correctly on android and iPhone mobile devices as well as on a PC.

Further value will be added to the app after this project, with inclusion of a decision tree of actions that will be aligned with mitigation strategies for smoke-affected grapes and wine presently being employed or evaluated by the wine sector. A working draft of the visual layout of the WISD app dashboard appears below.



5.5 Creation and deployment of a management system for the authentication and authorisation of smoke sensors and their collected data across the network

Information from the loggers is transferred in real time through two servers (at 4Research and La Trobe University). All data is securely held, requiring registration and a password for access. The database at La Trobe is actively maintained and is also held in multiple locations in order to provide fail-safe storage of data. Each WISD unit has a media access control (MAC) address, which uniquely identifies it to the communications network and all logged sensor data is both time and geolocation stamped.

Individual logins and passwords for each grower were established, and activities commenced with individual growers to load applications and improve the data visualisation on phones. The system was intended to be fully functional for the 2024 season.

6. Communication Activities

- Updates on project progress were supplied to regular meetings of a Project Governance Group which included representation from Wines of the King Valley, all regions in the North East Wine Zone, Regional Development Victoria, Wine Victoria, Australian Grape & Wine, Agriculture Victoria and Wine Australia. The group met three times during the course of the project and provided valuable strategic input as well as direction on the placement of the sensor network.

- Demonstration of the future use of the smoke taint predictive risk system was provided to

the industry in NE Victoria at grower forums in Rutherglen on 23 November 2022, Milawa on 6 December 2022 and Beechworth on 4 February 2023, and to a NEWZ Grower Forum in Wangaratta in June 2023.

- Porter, I.J. (2021) Towards an early smoke detection network. Helping producers better manage the effects of smoke on wine grapes. Australian and New Zealand Grape grower and Winemaker 66-69
- Article in Wodonga Chronicle 12 January 2022: *Project making sense of smoke impact on grapes*
- Report on local Prime7 News March 2022 https://www.prime7.com.au/news/7473709-smoke-sensors
- Victorian wineries to trial first bushfire smoke taint detector system. https://www.abc.net.au/news/rural/2022-02-19/smoke-taint-detectors-for-winegrowers-trial/100839474
- Research delivers smoke taint toolkit. https://www.latrobe.edu.au/news/articles/2020/release/research-delivers-smoke-taint-toolkit
- Poster presentation at AWITC June 2022: *Wine Industry Smoke Detection (WISD) system for early warning of smoke taint risk in wine.* Australian Wine Industry Technical Conference Poster, 26th June 2022
- Workshop presentation at AWITC June 2022: *New wine industry smoke sensors and smoke taint prediction system*
- Article in Wangaratta Chronicle 22 June 2022: *Smoke sensor rollout to vineyards is world first* Wangaratta Chronicle article June 22 2022.pdf
- Wine Australia RD&A News article 12 Mar 2021 Game-changer for smoke taint risk | Wine Australia
- Wine Australia RD&A News article 29 April 2022 Green light for early warning smoke detection system | Wine Australia

7. Future Work

Recommended activities to further develop and support the WISD system include the following:

- In the latter half of 2022, a consultant was engaged by La Trobe University to establish the market potential of the WISD system, attract a commercialisation partner and negotiate terms to deliver the technology to the industry. These efforts, in collaboration with Wine Australia, are ongoing

- Continue to develop the grower interface (website and app) for testing by users during the 2023/24 season and incorporate any improvements into the hardware and software outputs.
- Continue to develop the communication capacity and hardware of the existing WISD prototype and upgrade all existing loggers
- Validate the risk prediction system and performance of the sensor network in real life smoke events whenever possible
- Use additional smoke, grape and wine data collected around bushfires and controlled burns to refine the algorithm and improve the risk thresholds and predictions
- Develop a governance and management model for ownership and maintenance of the logger network infrastructure by the grape and wine sector
- Develop a governance and management model to ensure the sustainable provision of data through the app, and to address data privacy and ownership considerations
- Explore network expansion to interested wine regions in Victoria and across Australia
- Continue to communicate to the grape and wine sector the benefits of WISDs, through compilation and delivery of case studies, journal article publication, delivery of a newsletter to producers who have WISDs on their properties and presentations at workshops, seminars and other sector events.

8. Sector Impact

This is the first time globally that a smoke detection system has been deployed to provide real-time prediction of smoke taint risk to the wine industry. Accurate prediction during the 2020 bushfires in Australia could have conservatively saved industry $100M worth of fruit being able to be processed rather than dropped or destroyed, as well as recovering the value of the wine made.

The real value to grape growers and winemakers experiencing smoke in their region, whether from bushfires, controlled burns or stubble burns, is knowing immediately whether they have a problem or not. In most cases, the smoke load will be insufficient to cause smoke taint, so the presence of the loggers alleviates a significant amount of stress. This has been consistently expressed by the industry to the research team during deployment and maintenance of the network on grower properties.

In heavier smoke events, the sensor outputs will inform critical downstream business decisions including grape testing, vineyard management and winemaking strategies to manage smoke effects. This could include the knowledge that a crop is going to be tainted early in a season and thus avoidance of the substantial harvest and maintenance costs associated with managing the crop to maturity.

The prototype WISD system set up in NE Victoria is working and has potential for expansion throughout Australia. In seasons to come, the network will accurately record smoke dose and translate that information back to industry as an easy-to-use traffic light

prediction system for smoke taint risk from fire events.

APPENDIX 1

Location of Wine Industry Smoke Detectors (WISDs) in North-east Victoria (five GI regions)

