



# A framework for drone noise management in an Australian context

Ryan S. McKay (1), Nicholas Henrys (2) and Darren Jurevicius (2)

- (1) Resonate Consultants, Melbourne, Australia  
(2) Resonate Consultants, Adelaide, Australia

With the number of unmanned aerial vehicle (UAV), or 'drone' flights in Australia expected to skyrocket, particularly in transport and logistics, managing their noise impacts is becoming increasingly critical. The mining industry currently accounts for a large portion of drone flights, but transport and logistics-related flights are forecast to reach 50 million annually by 2043, with forestry, agriculture, and environment expected to account for another 3.5 million flights. This rapid increase will create significant challenges, including managing the noise impacts which will increasingly reach cities, rural areas, and remote areas, instead of being more isolated in existing industrial areas. In this paper, we will discuss existing Australian regulations and propose a framework for assessing drone noise impacts within the Australian context. This framework involves using measured drone noise levels, flight operations, environmental data, propagation models, and assessment of cumulative impacts. There is a growing database of drone noise levels for flight, take-off, landing, and loiter. This can be combined with flight operations data, for example from a Flight Information Management System (FIMS), to predict noise emissions along a flight path. Noise propagation can be predicted using simple empirical models such as ISO 9613-2. The cumulative noise from multiple drone flights can then be calculated at sensitive receiver locations and assessed against noise management thresholds. Finally, we present a case study of delivery drones flying to random destinations with routes considering existing high background noise areas to discuss the impacts on people, including noise metrics and possible controls to minimise these impacts.

## 1 INTRODUCTION

Drones, also known as UAVs (uncrewed aerial vehicle), UAS (uncrewed aerial system), or RPA (remotely piloted aircraft) are an emerging technology which is set to rapidly expand in Australia in the coming decade. The mining, agriculture, and forestry industries currently accounts for most drone flights which, due to the remoteness of their operations, has limited the noise impacts on people. However, transport and logistics are expected to account for 77% (~50 million annually) of all drone flights in Australia by 2043 (Scyne Advisory, 2024). This rapid growth will create significant challenges, including managing the noise impacts which will increasingly affect people in cities, rural areas, and remote areas.

There are generally two different classes of drones:

1. Fixed-wing drones, which are similar to conventional planes with a wing that generates lift and a propeller which provides propulsion.
2. Rotary wing drones, such as a quadcopter or a helicopter, where the propeller provides both lift and thrust.

Smaller fixed-wing drones typically operate at higher altitudes, fly faster, and are quieter. Because of this, they are less likely to pose a noise issue, but they are also not as useful for goods delivery (e.g., takeaway food, groceries, parcels), which typically requires hovering or vertical landing. Unlike fixed-wing drones, rotary-wing drones have this ability to hover and take-off/land vertically. Given that goods delivery is expected to account for the majority of flights, it is likely that rotary-wing aircraft will dominate. However, many of the current delivery

drones are hybrids of these two types, featuring a wing to improve efficiency while flying and propellers that generate lift to enable hovering and vertical take-off.

The noise from a drone in forward flight is predominantly broadband noise due to self-noise, but with a strong tone at the blade passing frequency (BPF,  $= N_b \times \Omega$ , where  $N_b$  is the number of blades and  $\Omega$  is the rotational speed) due to steady loading noise. For a typical delivery drone, the BPF is expected to be around 100-200 Hz. However, in hover, the ingestion of distorted turbulence leads to a significant increase in the tonal content as well as an increase in the noise from the drone. Descent is often the loudest flight regime as there is the potential for interaction with the propellers wake, which further increases noise levels (McKay, 2021).

Whilst reducing the noise at the source is always ideal, drones inherently will always generate significant noise which will also require management. A key part of the management of drones is routing. The ideal way to route drones to minimise noise is potentially a difficult problem. A common idea is to utilise existing regions with higher allowable noise such as highways and rail corridors (Duncan, Kaliski, Old, Wygonik, & Culp, 2020). These areas have the potential to enable large numbers of drones to travel through an area while having a minimal impact on surrounding areas. However, a potentially opposing idea is to use randomised routing to have fewer noise events for people – “It’s better to have a thousand different routes to the same destination than to fly over one house a thousand times” (APEC Transportation Working Group, 2023). In either case, these routing options will often be conflicting with the ideal route, which will typically be direct. A framework should include considerations of the existing noise environment at receiver locations, as well as the cumulative impacts of all flights.

Australia is the only APEC nation to have drone-specific noise regulations or policy (APEC Transportation Working Group, 2023); however, the regulation is flexible and lacks a defined assessment approach. This paper will discuss the existing regulations and present a potential framework for assessment of the impacts of drone noise, along with a case study showing how the framework could work in practice.

## 2 REGULATIONS AND EXISTING FRAMEWORKS

Aviation noise in Australia is regulated through the *Air Navigation (Aircraft Noise) Regulations 2018*. In December 2021, following consultation which favoured a flexible reform (Department of Infrastructure, Transport, Regional Development and Communications, 2021), Section 16A was added to include noise from drones. Unlike for traditional aviation, for which the Regulations use Annex 16 to the Convention on International Civil Aviation (Annex 16 to Convention on International Civil Aviation, Volume I – Aircraft Noise, May 23, 1994), drones do not have a set process. Rather, “an applicant must give the Secretary [of the Department of Infrastructure] such information relating to the aircraft as is reasonably required by the Secretary for a proper consideration of the application”. The current interim framework is based on noise risks and focuses on operations that are likely to have significant noise impact (i.e. due to location, frequency and noise level of the aircraft). The application process requires limited information, but the Department can require noise measurements from an acoustic expert.

The Australian Government is currently developing a new framework which is intended to include a consistent process for measuring the noise output of drones, modelling noise impacts, standard noise thresholds, and consideration of noise impacts due to take-off and landing (Australian Federal Government Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 2024).

## 3 OUR FRAMEWORK

Our proposed framework covers the same aspects as is intended to be covered by the new Australian framework which is in development, but with a practical implementation based on our experience in developing policy for

assessment of a range of other transportation and industrial noise sources. In this section we will present our framework at a high level and then in the following sections we will discuss various aspects of the framework in more detail.

Our proposed framework is useful for considering the noise impact of a particular flight path, as well as the cumulative impacts of multiple flights over an area. The key aspects of this are:

- A database of drone noise sources,
- Operational data i.e. flight information management system (FIMS) or uncrewed traffic management (UTM) system,
- A method to predict the noise from the drone at a number of receiver locations,
- Environmental data i.e. wind speeds,
- Information about receivers i.e. land use or zoning etc., and
- Metrics to assess cumulative impact against management thresholds.

The interaction between each of these aspects is shown in Figure 1. Each of these aspects are expanded in sections below.

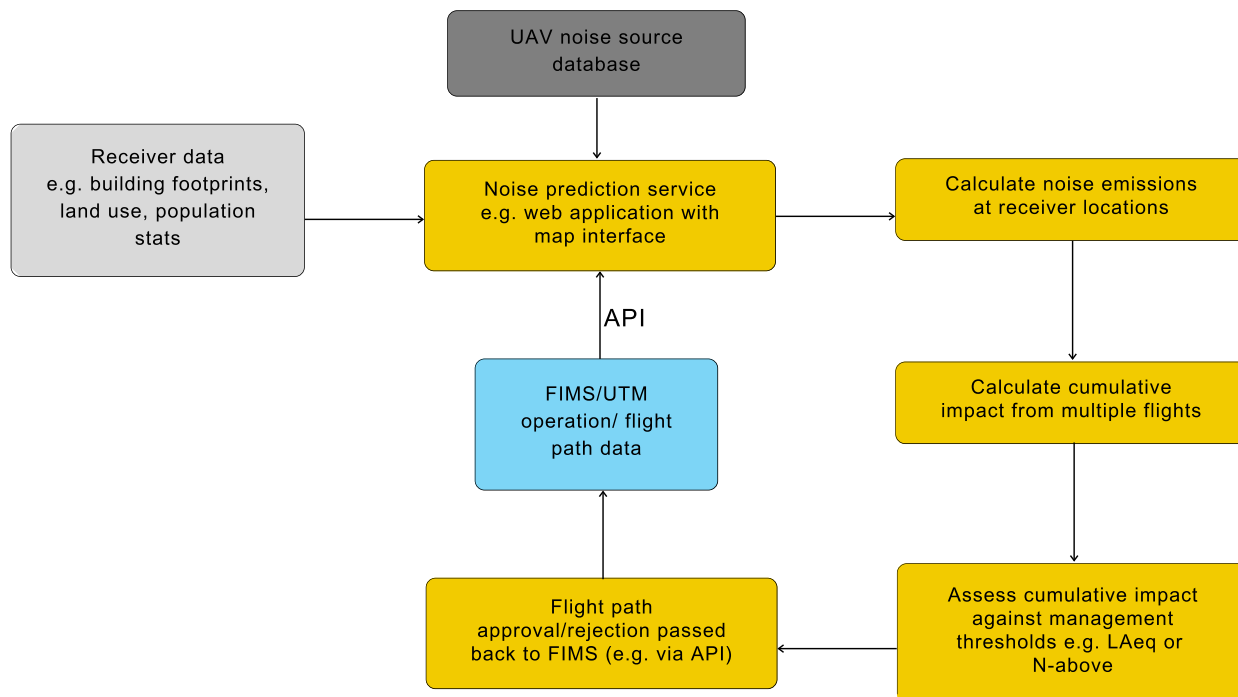


Figure 1 – Schematic of our proposed framework for assessing drone noise impacts.

#### 4 DRONE NOISE SOURCE DATABASE

There are few standards for accessing drone noise. One such standard is EU 2019/945, but it is limited to measurements in hover. ISO 5305:2024 was recently released which provides a method for measuring the sound pressure of a drone in hover, cruise, take-off and landing. ISO 5305:2024 – Noise measurements for UAS provides

methods for performing these measurements in an anechoic chamber, in an acoustic wind tunnel or outdoors. The size requirements on the anechoic chamber and acoustic wind tunnels mean that the outdoor method is typically the only appropriate method for delivery drones.

The outdoor method provided by ISO 5305:2024 uses multiple microphones with ground boards in a large flat area. The drone flies a prescribed path which allows for the sound pressure and directivity to be measured. While the standard does not include a method for directly calculating sound power, it does allow for presenting data at a common reference distance of 1 m. Since sound power is of primary interest in this context, in the absence of a standard for determining the sound power, it can be estimated with a reasonable accuracy from the measured sound pressure level using the geometry of the test area and the dimensions of the drone. It is important to note that propeller noise exhibits moderate variation in the polar direction, which should be considered in an assessment, but minimal variation in the azimuthal direction (McKay, 2021). For a fixed-wing drone, this is a variation in the pitch and yaw directions, and for a multi-rotor drone this is a variation in the pitch and roll directions.

## 5 OPERATIONAL DATA

A flight information management system (FIMS) or UAS traffic management (UTM) system will hold information about the planned and actual routing of drones in an area. This information can be used to predict the potential noise impacts on sensitive receivers in an area.

Air Services Australia is currently developing a FIMS as part of Australia's UTM ecosystem. Air Services started the development process in 2021 with four companies in a competitive process (Airservices Australia, 2024). In March 2024 they announced that Frequentis Australia will be developing this system. Once operational, this system will enable tracking flight paths for drones. Until then, any implementations of this framework would have to rely on flight information provided by individual users.

## 6 CALCULATION PROCEDURE

For a known source and flight path, we need to be able to calculate the impacts of a flight, and of other nearby flights on nearby receivers. This has the potential to become a complex calculation with a large number of flights, and as Australia is expecting to have at least 50 million flights annually by 2043 (Scyne Advisory, 2024), an efficient method which can handle a significant number of flights is crucial. For this reason, our framework uses ISO 9613-2 – Engineering method for the prediction of sound pressure levels outdoors to calculate the acoustic propagation, consistent with current Australian noise policy and regulations relating to prediction and assessment of many other environmental noise sources. This method predicts the octave-band sound pressure level at a receiver location as  $L_p = L_w + D_c - A$ , where  $L_w$  and  $D_c$  are the sound power and directivity correction from the database, and  $A$  is a correction factor correcting for propagation distance, atmospheric absorption, and ground effects. Calculation of  $A$  uses relatively straightforward empirical equations.

The flight paths of a drone for a provided flight path, or a set of flight paths from a FIMS, would be discretised into time steps. At each timestep, the flight regime would be set as either cruise, hover, ascent or descent. This would then enable the calculation of:

1. Propagation distance to receivers, which is necessary for accounting for propagation attenuation and atmospheric absorption.
2. The sound pressure level for each timestep at each observer.

This approach would also enable an approximation of the length of the noise exposure, which is useful for some noise metrics.

The ISO 9613-2 method assumes a standard set of meteorological conditions that are generally favourable for the propagation of sound and, therefore, does not account for varying wind speed/direction and other meteorological factors that can influence sound propagation. These factors could be accounted for using a different acoustic propagation model e.g. CONCAWE or Nord2000, but this would add complexity to the calculation procedure. Another consideration is that meteorological conditions also have an impact on the sound emitted by a drone (in addition to how the sound propagates). An example of this is that a drone flying into the wind will have to rotate the propellers faster to fly at the same speed relative to the ground which can have significant noise increases due to the high tip speed dependence of propeller noise. There is currently too limited information on the actual impacts of wind on drone noise to consider this in the framework.

On balance, our proposed framework uses the ISO 9613-2 method which favours computational efficiency over accurately accounting for various meteorological conditions. It should be noted that ISO 9613-2 tends to over-predict actual noise levels (by a relatively small margin) under typical conditions, and therefore provides a conservative basis for assessment of impacts. Future development of the framework could consider the effect of meteorological conditions on both noise generation and propagation; for example, a simple correction factor that considers the weight of a craft and the speed/direction of the wind.

## 7 ASSESSMENT OF IMPACTS

Although there is a building base of knowledge around which metrics best capture the annoyance of drones, there is still not a consensus. Christian and Cabell (Christian & Cabell, 2017) conducted a preliminary study with 38 participants where they correlated people's rating of annoyance with acoustic metrics and demonstrated that SEL<sub>A</sub> best fit their data. Hui et al. conducted a similar study with a more complex sound reproduction system and 37 participants and found that L<sub>Amax</sub> best correlated with annoyance (Hui, et al., 2021). Green, Torija and Ramos-Romero conducted a similar study with 30 participants and found that L<sub>Aeq</sub> best correlated with annoyance (Green, Torija, & Ramos-Romero, 2024).

Based on the ease of calculation and the limited evidence, we will use L<sub>Amax</sub> for the main assessment mechanism in our proposed framework. Additionally, we will also calculate 'number above' (n-above) metrics to assess the effect of multiple drone flights on an observer. The n-above metrics could be provided as N45, N50, N55 etc where they each provide the number of events a receiver is exposed to above L<sub>Amax</sub> 45 dB, 50 dB, or 55 dB, respectively.

Assessing the appropriate maximum level for L<sub>Amax</sub> or n-above metrics will depend on the land usage and the existing ambient noise environment at receiver locations. Further research is needed to determine appropriate noise management thresholds which are consistent with limits applicable to other noise sources in each jurisdiction, while also considering any unique characteristics of drone noise and its potential for annoyance and health impacts. It is also possible to utilise the results of large-scale mapping of road, rail and other noise sources (Henrys, 2017) to determine areas of high background noise levels which are likely to mask drone noise and therefore allow for higher noise management thresholds.

## 8 IMPLEMENTATION

Our proposed framework could be implemented in a simple online web-based application where a flight path, or a series of flight paths (including from a FIMS), could be run to confirm that a route is acceptable, or where the route could result in exceedances of the noise management threshold(s) and therefore require reconsideration. The application interface could include a map view showing a graphical depiction of the area, including any

buildings, potentially impacted by drone noise. Similar web applications have been developed for assessment and management of noise from other noise sources, for example Resonate's SOUNDSiTE.

Application Programming Interfaces (APIs) could also be used to pass data directly between FIMS/UTM and the noise calculation application, allowing for automatic assessment of noise impacts and returning of results back to the FIMS users.

## 9 CASE STUDY

For demonstration purposes, we have developed an early implementation using Python code with open-source geographic information system software QGIS for displaying the results. The below example uses a fictional drone weighing approximately 5 kg, including payload, flying from a shopping centre in Northeast Melbourne that has been proposed as a hub for drone deliveries. Our simple routing algorithm for demonstrating the framework generates 400 destinations up to 7 km from the hub and takes the most direct path or flies above nearby major roads if the additional distance added isn't significant. Due to the poor availability of drone acoustic measurements performed to standards, our drone uses sound power levels from anechoic chamber and acoustic wind tunnel measurements of a single propeller. The measurements were then scaled to account for four propellers. We have neglected directivity effects due to limited directivity data for drone propellers in cruise and the authors not knowing of directivity data for propellers in ascent or descent. We have assumed that reflections and barriers have negligible effect on the received noise due to the height of the drone. All of the predicted flight paths ascend from ground level, cruise at 30 m or 60 m above ground level (AGL) and then descend to 7 m AGL to deliver the item.

From this prediction, we can overlay the maximum noise each observer is exposed to, as shown in *Figure 2*. This figure demonstrates that the  $L_{Amax}$  people are exposed to is typically below 50 dBA, but where the drone descends to a 7 m hover, the  $L_{Amax}$  is around 60 dBA.

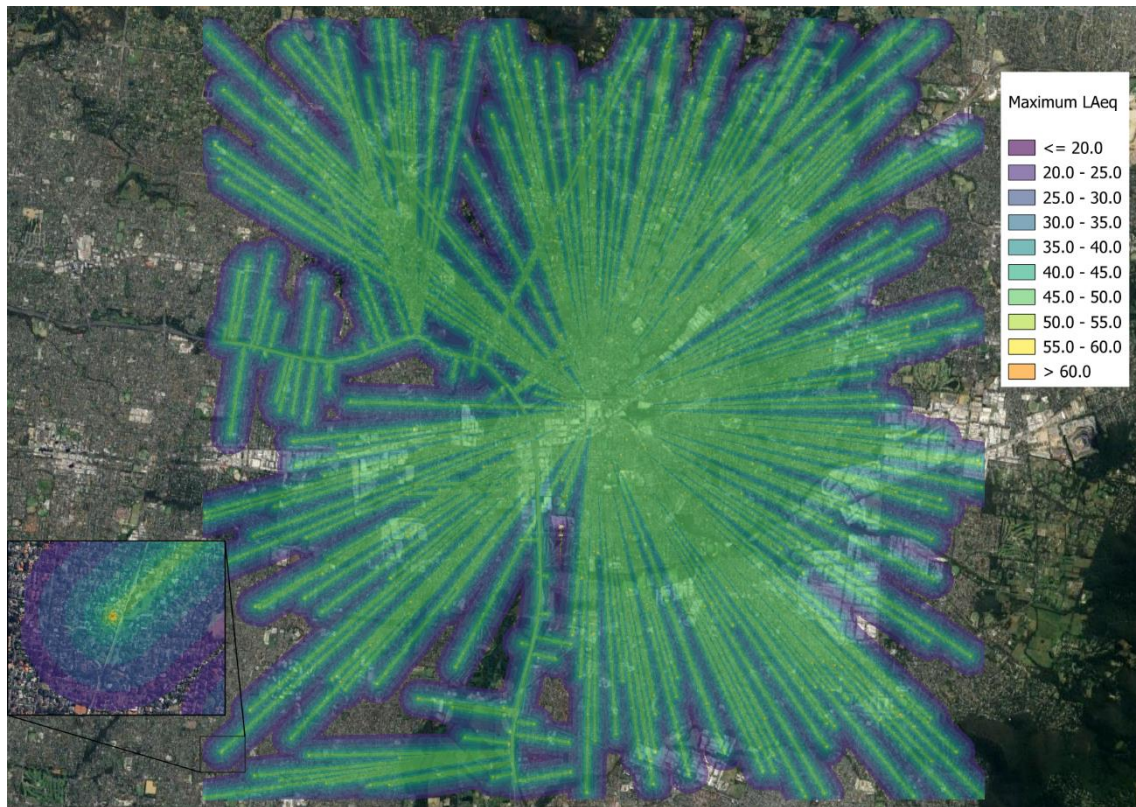
Given that most observers in an area with drone deliveries will be exposed to some noise, a potentially more useful criteria are N-above contours such as the N-above 40 dBA contours shown in *Figure 3*. This result shows that there is the potential for a significant number of noise events near the delivery hub, but that the noise impact can be mitigated by flying over arterial roads which are expected to have a high existing background noise level. A comparison between *Figure 3* (a) and (b) also shows how increasing the height of the cruise from 30 m to 60 m can have a significant reduction in the number of exposure events each observer is subjected to.

## 10 CONCLUSIONS

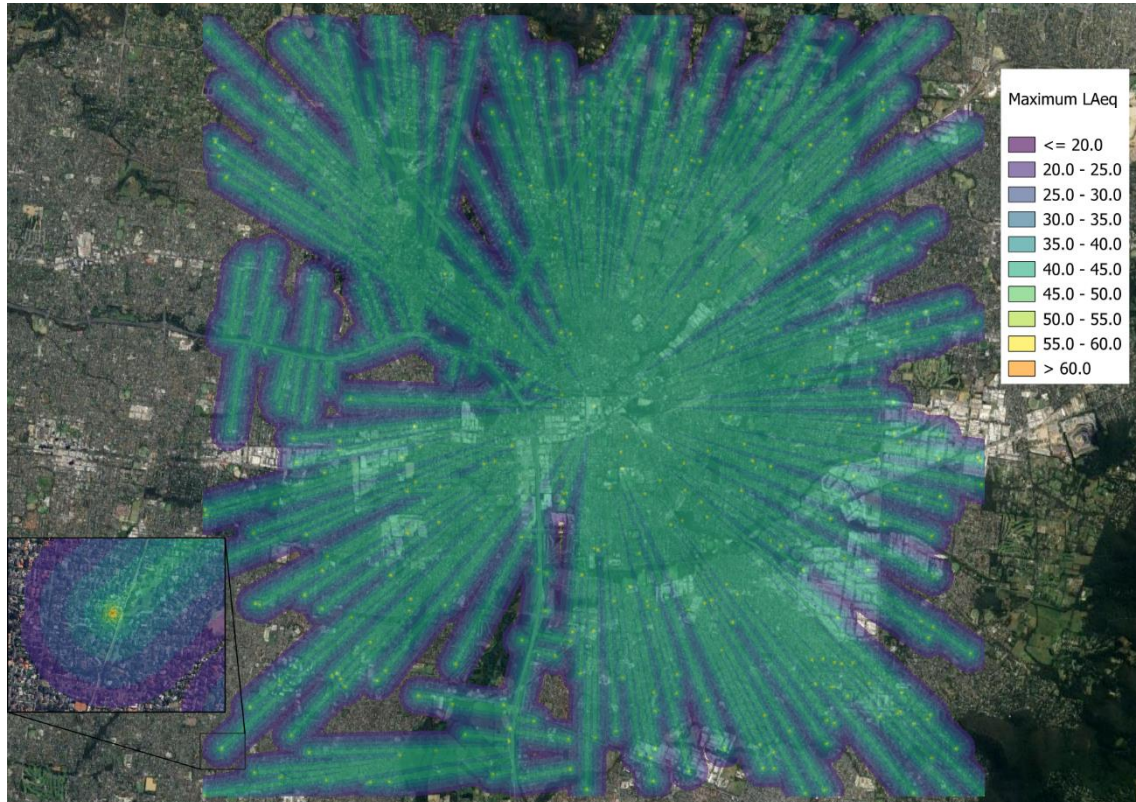
The anticipated growth of drone flights in Australia in Australia's transport and logistics sectors, requires a systematic framework for assessing noise impacts. This paper has presents an approach tailored to the Australian context, integrating existing regulations, drone noise source databases, operational data, prediction models, and assessment metrics.

Our proposed framework uses measured sound power levels in various flight modes and the ISO9613-2 model to predict noise emissions over a grid of receiver locations. By combining FIMS data and assessing cumulative impacts, we provide a method to evaluate noise at sensitive locations as drone flights expand from industrial to urban, suburban, and rural areas.

Our practical implementation of this framework would utilise a web-based application capable of dynamically assessing flight paths for compliance with noise management thresholds. Our example application illustrates the feasibility and effectiveness of this approach, suggesting potential mitigation strategies such as routing drones over areas with higher background noise levels, or increasing drone cruise height.

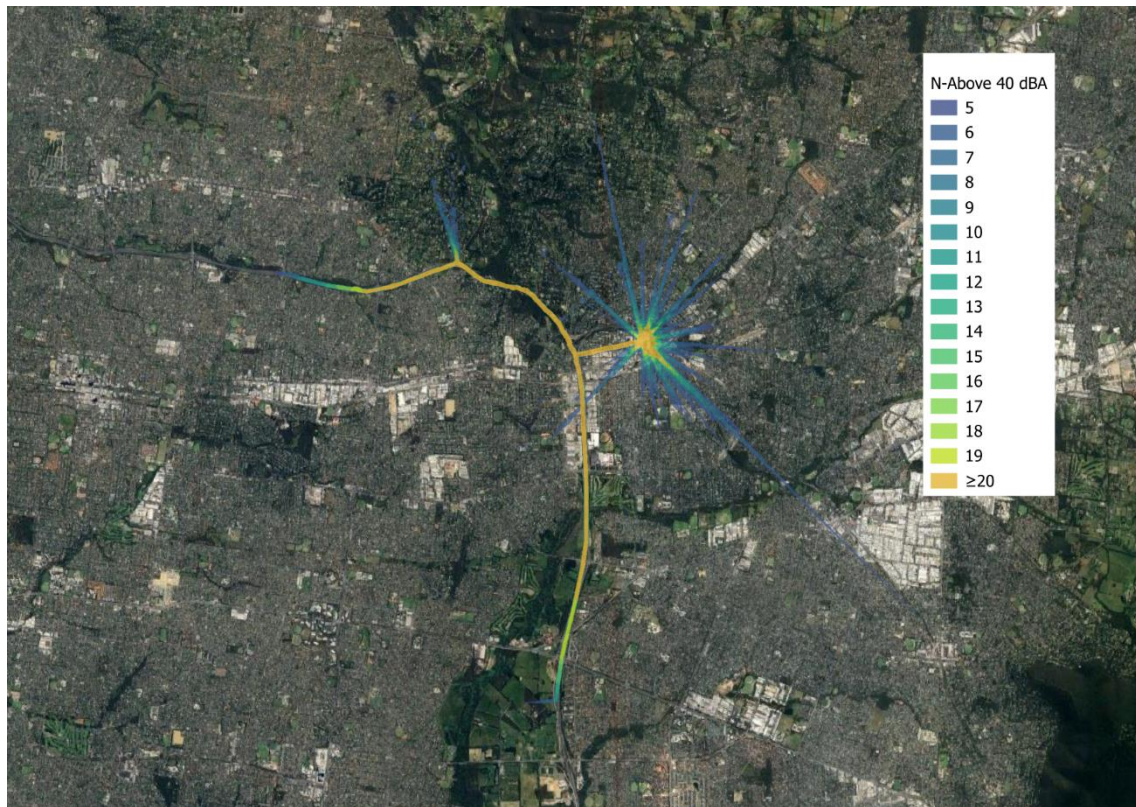


a) 30 m AGL

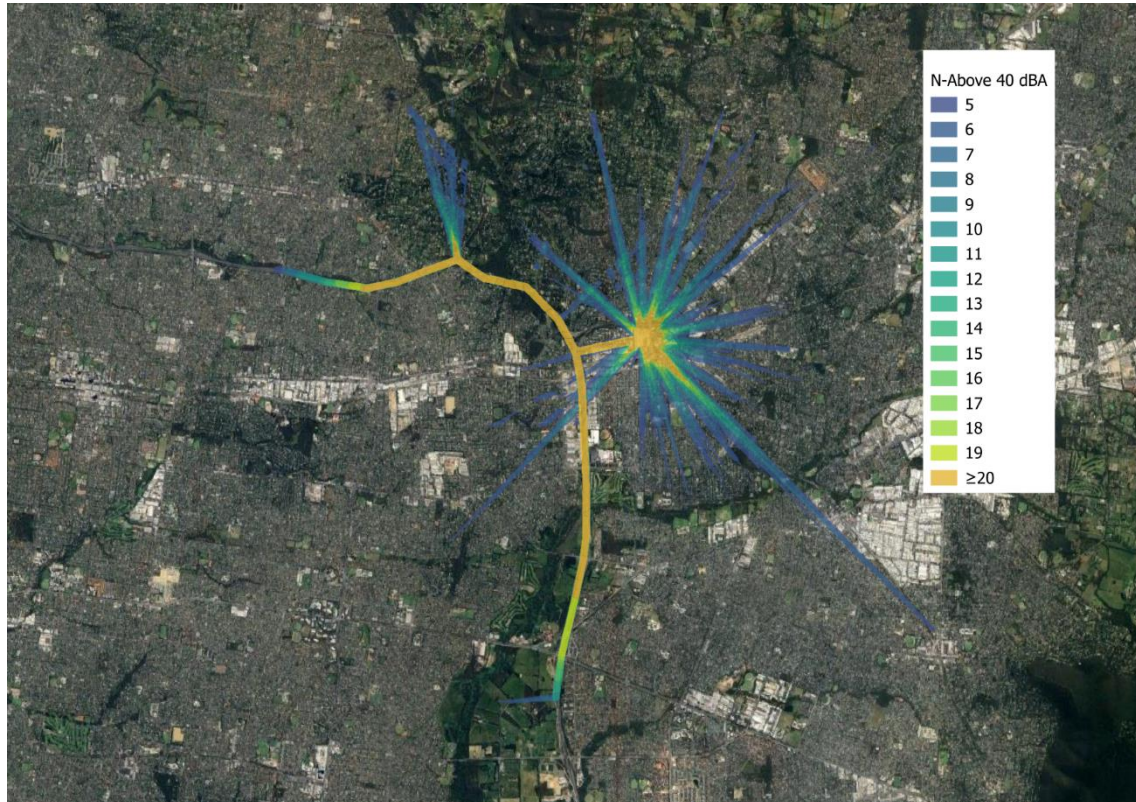


b) 60 m AGL

Figure 2 – Maximum noise observers are exposed to for a fictional drone flying to 400 random destinations. Map data © 2024 Google, Airbus, CNES / Airbus, Landsat / Copernicus, Maxar Technologies.



a) 60 m AGL



b) 30 m AGL

Figure 3 – N-above 40 dBA  $L_{Amax}$  contours overlaid on satellite imagery for a fictional drone flying to 400 random destinations. Map data © 2024 Google, Airbus, CNES / Airbus, Landsat / Copernicus, Maxar Technologies.

## REFERENCES

- International Organisation for Standardization. (n.d.). Noise measurements for UAS (unmanned aircraft systems). *ISO 5305:2024*. Retrieved from <https://www.iso.org/standard/81111.html>
- APEC Transportation Working Group. (2023). *Comparison of International Frameworks Measuring Remotely Piloted Aircraft Noise*.
- Bradley, J. S., Lay, K., & Norcross, S. G. (2023). *Measurements of the sound insulation of a wood frame house exposed to aircraft noise*. Institute for Research in Construction. Canada: National Research Council. doi:10.4224/20386147
- Christian, A., & Cabell, R. (2017). Initial Investigation into the Psychoacoustic Properties of Small Unmanned Aerial System Noise. *23rd AIAA/CEAS Aeroacoustics Conference*. Denver: AIAA. doi:10.2514/6.2017-4051
- Commission Delegated Regulation 2019/945. (n.d.). *Commission Delegated Regulation (EU) No 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems*. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0945>
- Department of Infrastructure, Transport, Regional Development and Communications. (2021). *Regulation Impact Statement for proposed reform to Remotely Piloted Aircraft noise regulations*.
- Duncan, E., Kaliski, K., Old, I., Wygonik, E., & Culp, J. (2020). Commercial Delivery Drone Routing: A case Study of Noise Impacts. *Quiet Drones 2020*. INCE Europe.
- Green, N., Torija, A. J., & Ramos-Romero, C. (2024). Perception of Noise from Unmanned Aircraft Systems: Efficacy of Metrics for Indoor and. *Journal of the Acoustical Society of America*. doi:10.1121/10.0024522
- Henrys, N. (2017). Strategic Mapping of Road Traffic Noise in Auckland, New Zealand. *Acoustics 2017*. Perth.
- Hui, J. C., Kingan, M. J., Hioka, Y., Schmid, G., Dodd, G., Dirks, K. N., . . . Shim, Y.-M. (2021). Quantification of the Psychoacoustic Effect of Noise from Small Unmanned Aerial Vehicles. *International Journal of Environmental Research and Public Health*. doi:10.3390/ijerph18178893
- International Organisation for Standardization. (n.d.). Acoustics — Attenuation of sound during propagation outdoors Part 2: Engineering method for the prediction of sound pressure levels outdoors. *ISO 9613-2:2024*.
- McKay, R. S. (2021). *Multirotor UAV propeller noise*. Department of Mechanical Engineering. Auckland: University of Auckland. doi:<https://hdl.handle.net/2292/54789>
- Scyne Advisory. (2024). *Sizing the future drone and advanced air mobility market in Australia*.
- Standards Australia. (2019). *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane*. AS 5335:2019.
- Ver, I. L., & Beranek, L. L. (2006). *Noise and Vibration Control Engineering Principles and Applications* (2nd ed.). New York: Wiley.
- World Health Organisation. (2018). *Environmental noise guideline for the European Region*. Denmark: WHO Regional Office for Europe.