Nuisance Dog Barking Investigation

6 Grit Bay Street, Bluehaven 9032

Final Report – 600-01

NoiseNet Pty Ltd ABN: 40614578120		Customer Name:	Redland City Council
noisenet.com.au		Report Number:	600-01
P: 1800 266 479		Issue Date:	20/8/2018

Customer Ref No.:	Redlands City Council	Monitoring Type:	Single Monitor
Property Type:	Residential House		
Property Address:	6 Grit Bay Street, Bluehaven 9032		
Property Code:	9032_600	Report Issue:	Final Report

1 OBJECTIVE

NoiseNet was commissioned by Redland City Council to investigate a suspected excessively barking dog at 28 Skywhin Drive, Bluehaven 9032 (referred to as the Target Property).

To facilitate the investigation, unattended noise monitoring was conducted using proprietary NoiseNet technology, with the gathered data analysed using specialised techniques to ascertain;

1) Instances of audible dog barking, howling or whining (dog noises) emanating from the Target Property,
2) The date and time when 1) occurs, and
3) The frequency and durations of 1).

Results of the analysis are compared to relevant criteria and legislation for the job locality, and conclusions drawn as to periods of criteria exceedance.

2 SITE CONTEXT AND MONITORING LOCATION

2.1 SITE DESCRIPTION

The target property, (28 Skywhin Drive, Bluehaven 9032) is located in a primarily residential area. Noise from a dog on the target property has been reported as a nuisance and impacting the complainant's property (6 Grit Bay Street). See Figure 1 for details.

To gather data and recordings of dog barking at the target property, a noise monitor was installed at 6 Grit Bay Street, located directly adjacent (north east of) the target address. For further details on the monitoring location, refer to Figure 1 and Section 2.2.

2.2 NOISE MONITORING

A single NoiseNet noise monitor was installed in the rear external living area, overlooking the back yard of 6 Grit Bay Street towards the Target Property. The monitor was positioned on a chair approximately 1.0m above ground level and 25m from the target address (refer to Figure 1 and Figure 2). There is a 1.8m high wooden fence and a garden shed between the monitor and expected locations of dog barking on the target property.

The monitoring position was chosen to allow clear measurement of dogs barking on the target property, in a location representative of external areas of the affected properties. The position also minimised the impact of other noise sources in the area which include general residential noise such as local traffic.

The noise monitor recorded noise between 1pm on 18/7/18 and 3pm on 3/8/18, and was field calibrated to ensure accuracy (decibel level and date/time) before and after installation/removal. Refer to Section A.2 for further information regarding NoiseNet noise monitoring equipment.

Where possible, the unattended noise monitoring was conducted in accordance with *Department of Environment and Heritage Protection EM1107* and *AS1055:1997* guidelines[1].

[1]The guidelines focus on methodology ensuring accurate measures of sound level in decibels (dB). As the criteria and methodology used in this report are based on noise classification, audibility and duration, a number of recommendations (particularly concerning reflecting surfaces and weather considerations) are disregarded in favour of a more representative monitoring location.

Figure 1 - Target property, surrounding residents and noise monitoring location.

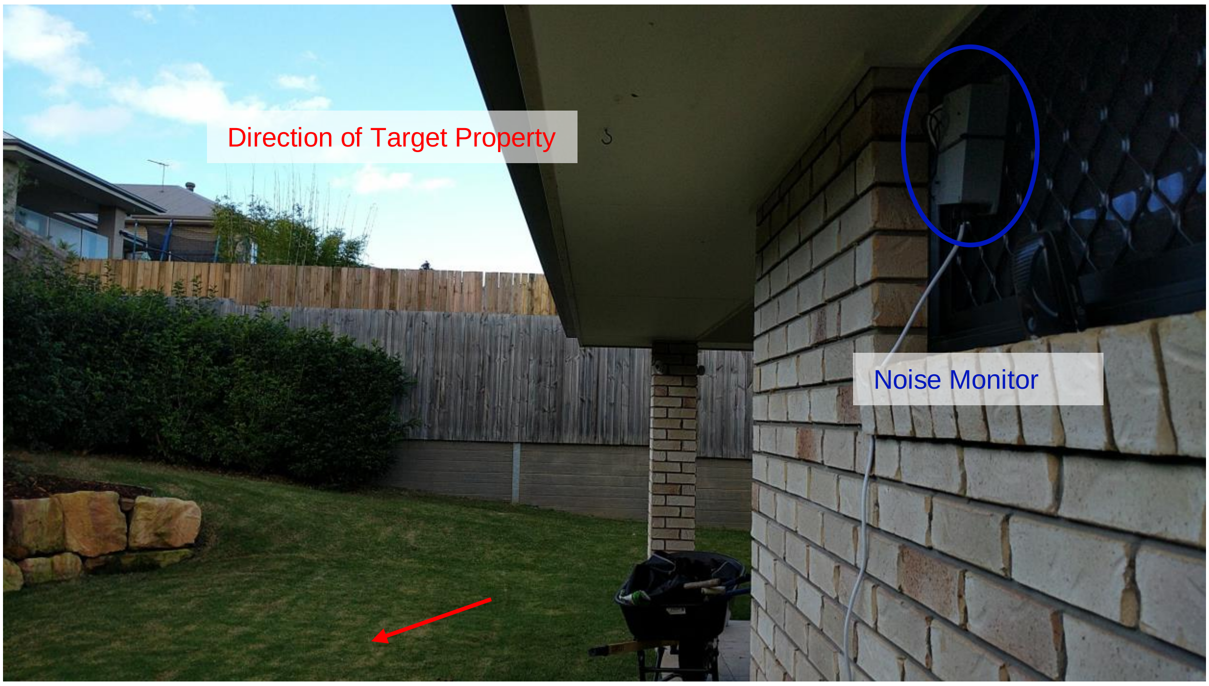


Figure 2 - Noise monitor location, in situ.

3 CRITERIA

Noise from barking dogs is managed in Redland City Council under *Local Law No. 2 (Animal Management) 2015 and Subordinate Local Law 2 (Animal Management) 2015*, which details criteria for nuisance barking as follows:

A dog is considered to be creating a noise nuisance if:

• It barks/howls for more than a total of 6 minutes in any one hour period between 7am and 10pm on any day;

• It barks/howls for more than a total of 3 minutes in any 30 minute period between 10pm and 7am on any day.

To assess levels of dog barking at the target property to these criteria, the general methodology followed is:

1. Automatically identify and tag times when dog noises are measured by the device.
2. Distinguish between noises from separate dogs, and isolate the target dog
3. Verify correct identification of dog noise events.
4. Determine the duration of the noise events from the target dog.
5. Compare durations to the relevant limits set by the above legislation.

Full details of the methodology can be found in Section 4 below.

4 ANALYSIS METHODOLOGY

The noise monitor gathers data, (audio recordings and A weighted decibel levels) via a calibrated microphone, which is analysed in a number of steps to give insights on the timing and duration of audible dog barks.

Full details of the noise monitor can be found in Section A.2.

4.1 DOG BARK IDENTIFICATION

To efficiently analyse the large amount of data gathered by the monitor, automated tools are utilised to reduce and largely remove the amount of listening required by human operators. The aim of these tools is to identify, with accuracy, times when a bark, howl or whine emanates from the target property, and is thus recorded by the monitor. Each step of the identification process is described in Sections 4.1.1 to 4.1.3.

4.1.1 AUTOMATED NOISE EVENT DETECTION

The background noise level LA_{90} is determined over a rolling time window, and is used to establish a baseline for significant and insignificant noises. If a given four seconds has a noise level significantly above the background level, a ‘noise event’ is deemed to have occurred. Each of these noise events are extracted as a recorded ‘snippet’, which contain only the most significant and impactful noises.

Examples of noises which would likely be disregarded as background noise are air-condition/mechanical plant, crickets, distant traffic or distant dog barking. Foreground sounds likely to be extracted as snippets include close proximity dog barking, bird calls or other impulsive and loud noises.

4.1.2 AUTOMATED SPECTRAL FINGERPRINT ANALYSIS

Each snippet is classified as either containing a “dog noise” (bark, howl or whine), or “non dog noise”, based on automated comparison between the spectral “fingerprint” of the snippet, and a database of spectral fingerprints from many different noise sources. The comparison and classification method is conducted using various machine learning algorithms and techniques, which provides a probability that a snippet contains a dog noise. A probability threshold of 0.6 is used as the cutoff for positive bark identification, meaning that our system is 60% sure that a dog noise has occurred, and false positive identification is minimised, while maintaining the overall balance of the model. Given the remaining possible categories, this means that it is over 1.5 times more likely that a dog noise has occurred than any other noise, such as people talking, birds chirping etc.

A similar technique can also be applied to consecutive subsections of long term audio recordings, allowing for identification of dog noises over a continuous time scale.

Refer to Section A.1 for further details

4.1.3 MANUAL VERIFICATION

A manual verification step is introduced to ensure the automated steps are working as intended. Operators observe the spectral fingerprint and listen to audio recording of snippets tagged by the automated analysis, to verify a correct identification, or re-classify an incorrect identification.

This step also allows for further refinement of the automated identification, where known instances of noises from the target dog can be tagged, and any dog noises of non-interest (such as dogs not on the target property) can be re-classified. Based on this re-classification, the automated identification can be re-run to obtain a more accurate and representative analysis result. The manual verification, re-classification, and re-analyse step can be performed as many times as deemed necessary to obtain the most accurate result possible.

4.2 ISOLATION OF TARGET DOG NOISE

To isolate noise from the target dog only, a number of samples of the different dog noises recorded are sent to the complainant, who then identifies the different dogs based on sound and their own knowledge and experience.

Once identified, the identified recordings are used as a set of reference samples, and used in conjunction with the commercially available sound analysis software. The software is used to cross reference the entire catalogue of dog noises measured by the monitor with the identified reference samples, and generate a numerical measure of similarity between them.

In this way, we are able to get a measure of the relative proportion of noise from a particular dog, occurring within each identified snippet of dog barking.

4.3 DETERMINATION OF DOG NOISE DURATION

The specific determination of barking duration or continuous barking is left largely undefined by relevant legislation, with no strict methodology in place. Typical processes used by council officers may include listening in the field or stopwatch timing from recordings.

For this analysis, automated tools are again used to determine the duration of dog noises, as follows.

The total sound energy content of a 4 second snippet of dog noise is calculated, and a threshold set based on this figure. The “start time” of a bark is deemed when the instantaneous sound energy rises above the threshold, and the “stop time” when it falls below, with the duration of dog noise as the difference between the start and stop times. Using this method, isolated barks are typically logged as approximately 0.4-0.8 seconds (depending on the bark characteristics), with multiple barks in quick succession logged as a longer duration. Refer to Figure 3 for a visual explanation.

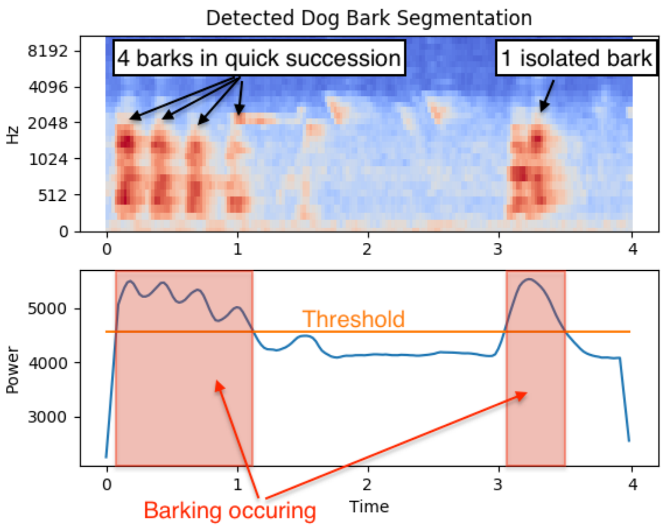


Figure 3 – Example bark duration extraction. This snippet has 1.47 seconds of dog barking.

Once the bark duration for a snippet is ascertained, it is multiplied by the proportion of noise from the target dog calculated for the same snippet in the previous step, with this number taken as the duration of dog noise from the target dog.

The durations from the target dog are tallied within the relevant 60 minute or 30 minute window (depending on the time of day) for a measure of the total duration of barking within that time period. The time periods begin either “on-the-hour” or “on-the-half-hour” as necessary and are not selectively chosen to manipulate results in any way.

Given the undefined nature of bark duration calculations for technical analysis, NoiseNet are willing to re-analyse data based on different definitions of duration, provided a clear and unambiguous definition of continuous barking is given.

4.4 SPECIFIC ANIMAL

The complainant had indicated that there were no other nuisance dogs in the vicinity and that other dogs barked rarely. We completed an analysis using our dog-bark differentiation tool and found that over 95% of the identified barks were classified as ‘very similar’. On this basis we are confident that the durations of barking have not been distorted due to other animals in the vicinity of the complainant property. There was thus no-need for us to establish tags and calculate barking from different animals in this case.

4.5 ACCURACY

Our methods can reliably distinguish between dog barks and *other* general noise events such as birds, talking, gates/doors opening and closing and objects falling. We are also confident in our ability to identify and isolate the specific target dog from other dog noises recorded, provided the various animals have sufficiently distinct barks. However, the automation techniques used are not 100% accurate, and the possibility of false positive bark identification, or misidentification of specific dog exists. This means that quoted results may differ from actual durations of dog barking. Wherever possible, results are verified with manual listening, but this is only possible for a very small portion of the entire monitored period. We encourage verification checks from complainants and/or councils, particularly in the event of borderline exceedance cases or likely legal action.

5 RESULTS

Using the methods described in Section 4.1, instances of dog noises from the target dog were successfully extracted and identified from data gathered by the noise monitor over the monitoring period. displays an example of the dog noise identification over a single hour between 6:00pm and 7:00pm on Monday 30/7/18. Figure 4a) shows the spectral trace of the audio for the hour (similar to the spectral fingerprint of an individual noise, on a more 'zoomed out' time scale), with Figure 4b) showing the corresponding probability of a dog noise at a given time of the hour.

The logic in Section 4.2 and 4.3 was then applied to isolate the target dog (we estimate 65% of all dog noise recorded was made by the Target Dog on the Target Property) and find the total duration of dog noises. Results are shown in Figure 5. Table 1 and Table 2 show the same durations for the daytime (7am-10pm) and night-time (10pm-7am) periods respectively, with solid red cells indicating a breach of criteria detailed in Section 3, and other colours indicating an implied level of nuisance in line with these limits.

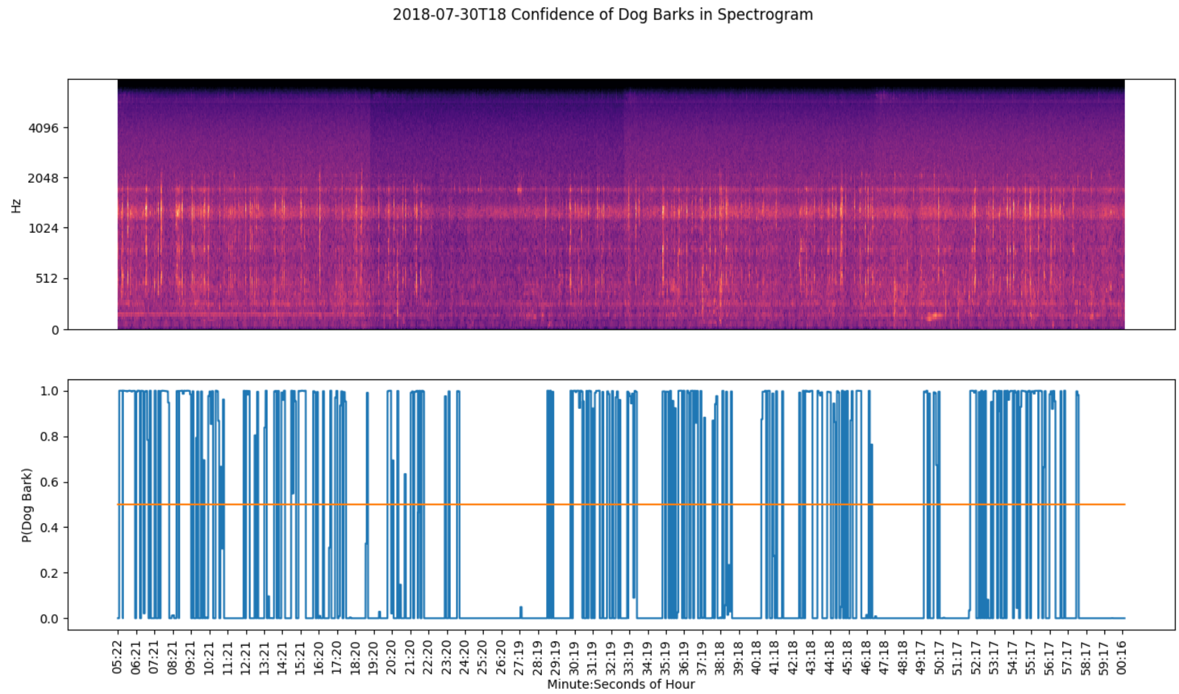
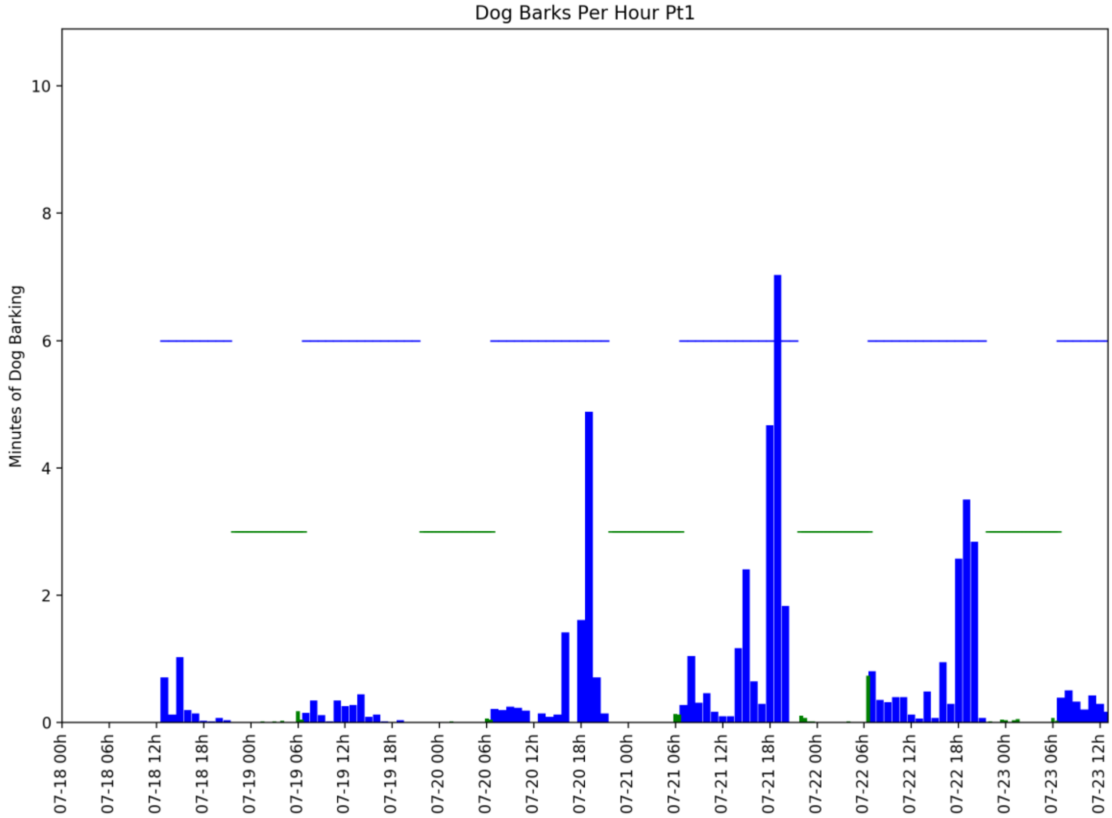
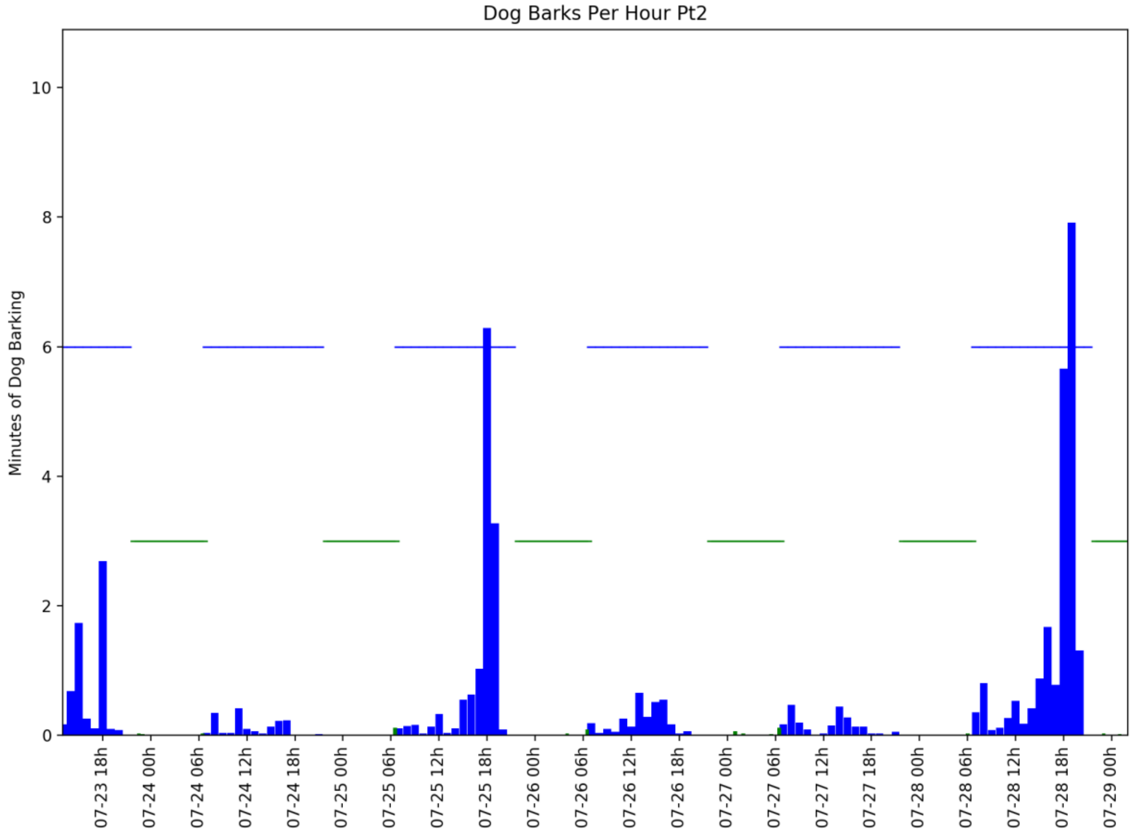


Figure 4 - (a, upper) Spectral trace of noise over the example hour with (b, lower) corresponding probability of dog noise at a given time.

Dog Barks Per Hour Pt1



Dog Barks Per Hour Pt2



NoiseNet

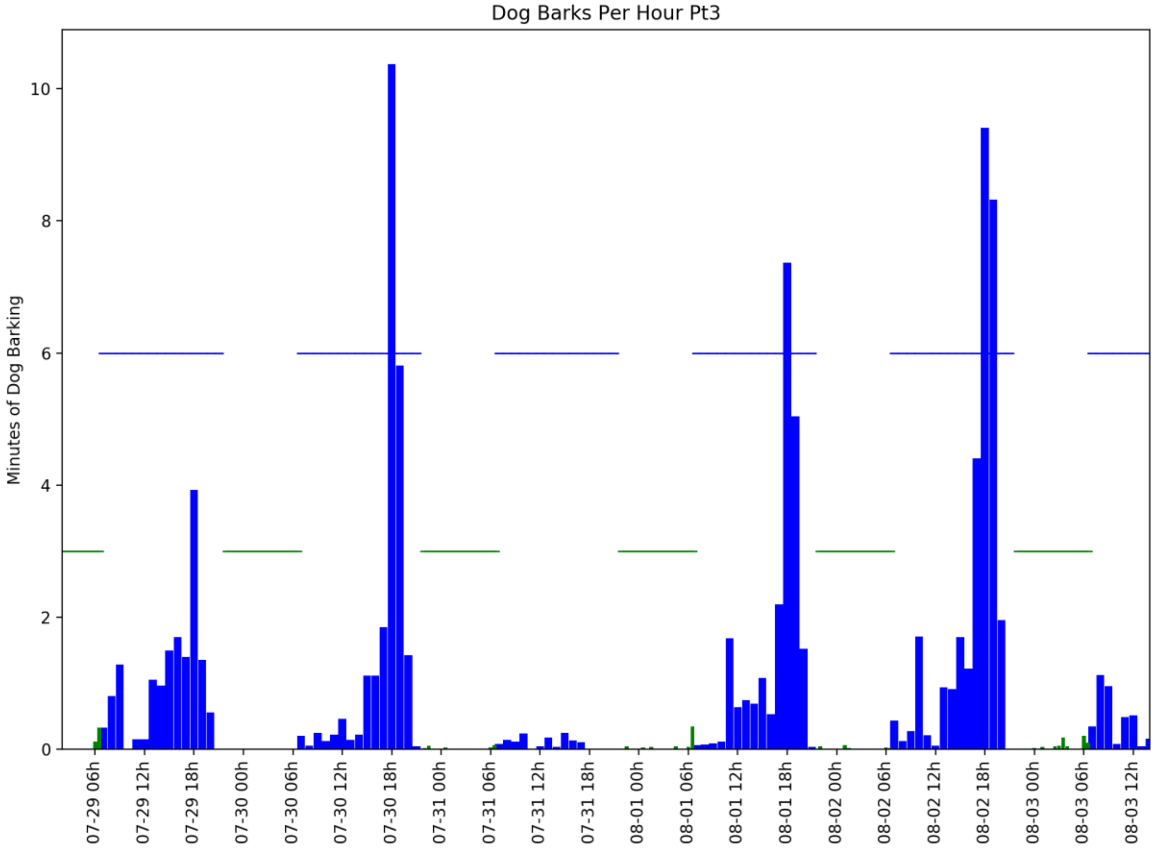


Figure 5 - Total duration (minutes) of dog noise per hour (blue, 7am-10pm) or half-hour (green, 10pm-7am).

Time	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
18/7/18							0.71	0.12	1.02	0.19	0.14	0.03	0.01	0.07	0.03
19/7/18	0.15	0.34	0.12	0.02	0.35	0.25	0.27	0.44	0.09	0.12	0.02	0	0.04	0	0
20/7/18	0.21	0.2	0.25	0.23	0.18	0.01	0.14	0.09	0.13	1.41	0	1.61	4.88	0.7	0.14
21/7/18	0.28	1.05	0.31	0.46	0.17	0.1	0.1	1.16	2.41	0.64	0.29	4.67	7.03	1.83	0
22/7/18	0.81	0.36	0.32	0.4	0.4	0.12	0.06	0.48	0.07	0.94	0.29	2.57	3.5	2.84	0.07
23/7/18	0.39	0.5	0.33	0.21	0.42	0.29	0.17	0.68	1.74	0.26	0.1	2.69	0.1	0.08	0
24/7/18	0.04	0.34	0.04	0.04	0.41	0.1	0.06	0.02	0.14	0.22	0.23	0	0	0	0.02
25/7/18	0.11	0.15	0.16	0.03	0.13	0.33	0.04	0.11	0.55	0.63	1.02	6.29	3.27	0.09	0
26/7/18	0.19	0.04	0.1	0.05	0.26	0.13	0.65	0.28	0.51	0.55	0.17	0.03	0.06	0	0
27/7/18	0.17	0.47	0.19	0.09	0.01	0.03	0.15	0.44	0.27	0.14	0.14	0.03	0.03	0	0.05
28/7/18	0.36	0.8	0.08	0.12	0.26	0.53	0.17	0.42	0.87	1.67	0.78	5.66	7.92	1.31	0
29/7/18	0.32	0.8	1.28	0	0.15	0.15	1.05	0.96	1.49	1.7	1.4	3.93	1.35	0.56	0
30/7/18	0.2	0.05	0.24	0.12	0.22	0.46	0.14	0.22	1.11	1.12	1.84	10.38	5.81	1.43	0.05
31/7/18	0.08	0.14	0.11	0.24	0	0.05	0.18	0.04	0.25	0.13	0.11	0	0	0	0
1/8/18	0.06	0.07	0.09	0.12	1.68	0.64	0.74	0.69	1.08	0.53	2.19	7.36	5.05	1.52	0.03
2/8/18	0.43	0.12	0.27	1.7	0.21	0.05	0.94	0.91	1.7	1.22	4.41	9.41	8.32	1.95	0
3/8/18	0.34	1.12	0.96	0.08	0.49	0.51	0.05	0.16							
Exceedances	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**3**	**0**	**0**
Total	**7**														

Table 1 - Minutes of dog noise per hour, between 7am and 10pm, for each monitored day. Time of day represents the start of the 60 minute period (e.g 7am-8am), with red cells indicating exceedance of the 6 minute nuisance criteria.

Time	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	22:00	22:30	23:00	23:30
18/7/18															0	0	0	0
19/7/18	0	0	0	0.01	0	0	0.01	0	0.03	0	0	0	0.18	0.05	0	0	0	0
20/7/18	0.01	0	0	0.01	0	0	0	0	0	0	0	0	0.06	0.04	0	0	0	0
21/7/18	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.13	0.11	0.07	0.02	0.01
22/7/18	0.01	0	0	0	0	0	0	0	0.02	0	0	0	0	0.73	0.02	0	0	0.04
23/7/18	0.04	0	0.03	0.05	0	0	0	0	0	0	0	0	0.07	0.03	0	0.02	0.01	0
24/7/18	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0.02	0	0	0	0
25/7/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0	0	0
26/7/18	0	0	0	0	0	0	0	0.01	0.03	0	0	0	0	0.09	0	0	0	0
27/7/18	0	0	0.06	0	0.03	0	0	0	0	0.01	0	0.02	0	0.11	0	0	0	0
28/7/18	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.01	0	0	0.03	0
29/7/18	0	0	0.02	0	0	0	0	0	0	0.01	0	0.01	0.11	0.33	0	0	0	0
30/7/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0	0
31/7/18	0	0.03	0	0	0	0	0	0	0	0	0	0	0.03	0.06	0	0.04	0	0
1/8/18	0	0.03	0	0.03	0	0	0	0	0	0.04	0	0	0.04	0.35	0.04	0	0	0
2/8/18	0	0	0.06	0.02	0	0	0	0	0	0	0	0	0.03	0.02	0	0	0	0
3/8/18	0.02	0	0.03	0	0	0.05	0.06	0.18	0.04	0	0	0	0.2	0.1				
Exceedances	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total	**0**																	

Table 2 - Minutes of dog noise per half-hour, between 10pm and 7am, for each monitored day. Time of day represents the start of the 30 minute period (e.g 10pm-10:30pm), with red cells indicating exceedance of the 3 minute nuisance criteria.

6 FINDINGS

Over the monitored period, there were a total of 7 exceedences of criteria during the day time period, and no exceedences of night time criteria. A maximum of 10.38 minutes of dog barking was measured between 6pm and 7pm on 30/7/18, with other exceedences ranging between approximately 6 and 9 minutes in duration. A number of hours were also identified with bark durations in the upper 5 minutes, approaching but not exceeding daytime criteria.

A clear pattern of barking was identified, with minimal barking in the throughout the day, but steadily increasing in the late afternoon, with worst times for excess barking observed typically between 6pm and 8pm. Further investigation may be undertaken to identify potential barking triggers that occur around this time.

7 CONCLUSION

A NoiseNet noise monitor was installed at 6 Grit Bay Street, Bluehaven to investigate a potential nuisance barking dog at 28 SkywhinDrive, Bluehaven. Analysis of recording and data gathered by the monitor identified instances of dog barking, howling or whining believed to (within the limitations described in this report) originate from the target dog on the target property.

The duration of the dog noises were tallied and compared to relevant nuisance criteria, revealing 7 instances where barking from the target dog exceeded day time criteria, and no identified exceedances of night time criteria.

The worst identified hour occurred between 6pm and 7pm on 30/7/18, with 10.38 minutes of barking measured. A clear pattern of barking was observed, with worst times for dog barking between 6pm and 8pm. Further investigation may be undertaken to identify likely triggers for barking which occur around these times.

A.1 DOG NOISE IDENTIFICATION DETAIL METHODOLOGY

This section describes in detail the methods used to automatically identify dog noises (barks, howls or whines) from the recorded audio.

Describing and categorising a wide variety of sound and noise is something a human can do remarkably quickly, subconsciously, and almost continuously on a day to day basis. As such, they are the often the “gold standard” for deciding what particular source created a noise. However, using humans to categorise sounds within a long duration recording is very time consuming process; at the quickest it can be done at a one-to-one speed, an hour recording could take an hour or more to categorise.

Using automated techniques is an obvious solution, but comes with a troublesome problem; How does a computer know what source created a sound? This question is a topic of extensive current research in Machine Learning and Artificial Intelligence. NoiseNet is on the cutting edge of this research into sound identification and categorisation, striving for accuracy, speed and solutions to real-world problems.

Machines can ‘learn’ to categorise sound in much the same way a human would. We expose them to a huge database of different sounds, which already have the correct category associated with them. Then, when a new sound needs to be categorised, the software compares it against the known database and looks for the closest match it can find.

Specifically, an individual sound is broken down into identifying markers, called features (this step is known as feature extraction). NoiseNet uses the spectral content of a sound as the identifying features, hence referring to the ‘spectral fingerprint’ of a sound. For example, a visual representation of the spectral fingerprint of a typical dog bark is shown in Figure 5. In contrast, the spectral fingerprint of a bird call is shown in Figure 6. There are immediate differences which are able to be discerned by both human inspection and by the computers learning processes, such as longer, lower pitched dog barks compared with the shorter, higher pitch vocalisations of the bird call. The features are also apparent in foreground noise, compared to background noise, allowing for identification of sounds in a complex sound environment.

While there are a vast number of variations of dog and other noises, there are both subtle and obvious similarities in spectral fingerprints within each category. It is here that computers excel at observing the subtle differences in features, and allocating a category to an unknown sound.

While there can be confounding factors in categorisation, e.g. two sounds occurring simultaneously or previously uncategorised sounds, these can be identified (low certainty classifications), correctly categorised by manual listening, and the model re-run. This is the method that NoiseNet uses to ensure the highest accuracy and most appropriate analysis for each specific job.

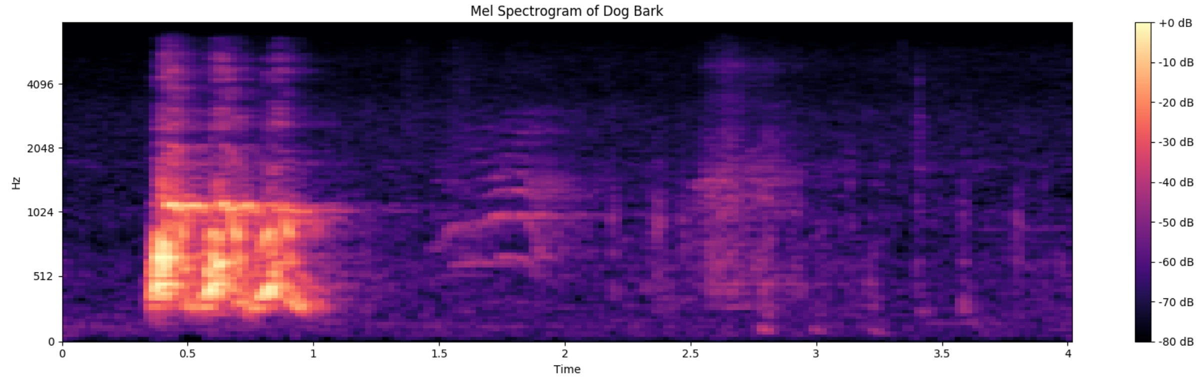


Figure 5 - Typical features (spectral fingerprint) of a dog bark.

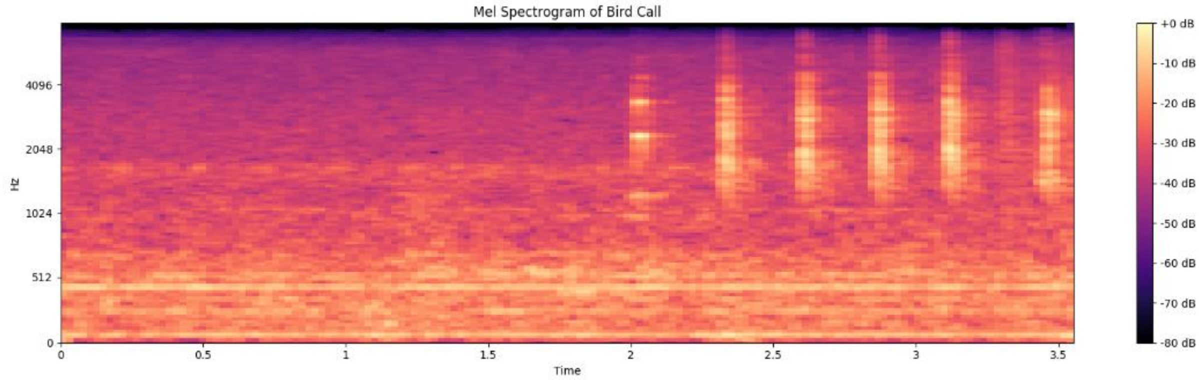


Figure 6 - Typical features (spectral fingerprint) of a bird call.

A.2 NOISE MONITOR DETAILS

NoiseNet uses a custom-built noise monitor for our measurement and analysis, with basic onboard components as follows:

- MEMS microphone (SPH0645), digital I2S connection
- Rapsberry Pi 3 micro-computer
- 3G/WiFi wireless communication

Noise data is processed and encrypted on-device, before being transmitted wirelessly to NoiseNet databases. Further processing and analysis is completed on a job specific basis, before being compiled for a client report.

Our noise monitors are designed and built with flexibility, size and low-cost in mind, and with systems in place to provide the benefits of an on-site field technician (sound recognition, spectral and time based analysis, automated data processing), without the associated costs.

To maintain flexibility, our devices are not currently certified to Australian Standard AS IEC 61672.1-2004, which specifies the construction, function and operations of sound measurement devices.

All device components are thoroughly pre-tested in-house for acoustic performance, stability and reliability and have been tested for repeated accurate measurement of:

- descriptors including L_p, L_{eq}, L_n,
- fast response integration time,
- unweighted and A weighting,
- broadband and single octave, between 63Hz and 16kHz
- all of the above to within ± 3dB, for sound levels between 27dB and 90dB SPL.

Each device is field calibrated using a handheld calibrator before and after each deployment, and operation monitored using the wireless connection throughout the deployment.