Pro-active use of unattended loggers for noise and vibration monitoring

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Abstract

A network of 50 remote noise monitoring stations has been developed New Zealand wide capable of measuring and reporting 1-second L_{Aeq}, $L_{A50(15min)}$, $L_{A90(15min)}$, $L_{A95(15min)}$, L_{AFmax}, L_{AFmin}, one-third octave band data and audio recording in real time to a web server. Fifty SMS commands allow such things as remote calibration, remote configuration and diagnostics from a cellphone. This paper describes a recent application of an unattended noise logger and vibration analyser as an adjunct to hand held monitoring at a bridge building project. Some of the technical advantages of remote monitoring are described, and some technical detail of the equipment used is included.

Original peer-reviewed paper

1. Introduction

In December 2017, the author was tasked with managing noise and vibration emissions from construction of a new bridge across the Manawatu River in Palmerston North City. The site is approximately 70 m from the nearest dwellings. Of major concern was noise from driving of three piles, one of which was 78 m from dwellings in Dittmer Drive and from earthworks during the construction of the bridge abutment on the city side of the river. Construction started in January 2018, with consented noise levels aligned with the construction standard NZS 6803:1999, and vibration limits of 1 ppv (Peak Particle Velocity) at the dwellings. The project is expected to take 18 months, so will not be completed until late 2019.

An extensive noise management plan was developed, which included noise and vibration predictions from the various phases of construction.

2. Equipment employed

In order to more accurately manage noise and vibration and to supplement hand held measurements, a permanent Jepsen noise logger and an RDL-vibe[1] vibration logger were deployed.

The Jepsen noise logger can be mains or solar powered and continuously records 15-minute L_{Aeq}, L_{A10}, L_{A90}, L_{Amin} (L_{AFmin}), L_{Amax} (L_{AFmax}) and 1-second L_{Aeq}. In addition, audio recordings are made whenever the audio level exceeds a preset L_{Amax}, a time trigger, or whenever manually triggered by SMS.

The noise logger was placed on the boundary of a dwelling at 22 Ruhar Street using a heated Norsonic Nor1216 microphone fitted with a wind screen at 2.5 m above ground level. The microphone was in direct line of sight with all bridge piling sites and the city side abutment site works.

Vibration was also monitored continuously (24 hours per day), using the RDL-vibe online vibration analyser (See figure 1). This logger utilizes a 3-axis geophone that can be programmed to sample for alarm purposes at a rate of 10 Hz – 500 Hz. Results of 500 Hz sampling are presented as ppv against time for each axis. The 3-axis geophone was placed in a level position on a concrete pad that was part of the building foundation at ground level, with a 10 kg lead shot bag laid over the geophone, on the side of the building foundation facing the vibration source, in accordance with DIN 4150-3, part 5.4.

Figure 1: RDL – Vibe 3 axis geophone

The construction company communicate the daily work schedule with the author, and manual triggering by SMS is used whenever new works are started, so that representative records of what new sounds are being generated are obtained. These recordings can later be compared with recorded noise levels and used to proactively manage future work and the handling of any noise complaints. For example, it was recently discovered that a subcontractor's trucks were still using tonal reversing beepers. This was missed by hand-held monitoring to date but picked up on a logger recording.

3. Noise Analysis

The bridge construction started in January 2018 and the noise logger was deployed in time to capture noise generated by the vibro-piling of the closest pile to the dwellings. Noise levels from the piles located in the river, and on the east bank of the river are at a greater distance from the dwellings and predictions that these sites would not generate significant noise levels were confirmed by hand held measurements.

Piling was carried out using an ICE 600RF power pack and ICE 55NF vibro-hammer (See figure 2). Preliminary calculations of predicted noise levels at the nearest dwellings suggested that levels up to 72 dB $L_{Aeq(15min)}$ were likely from the vibro-piling and associated machinery.

Figure 2: ICE 55NF vibro-piling rig

Figure 3 is the daily noise record when vibropiling took place. The gradual rise in 15-minute L_{Aeq} and L_{A10} at 6-am to 8-am is due to an increase in local traffic. The two peaks at 9-am and again at 12-pm are uncharacteristic of a daily plot in the absence of piling, and examination of the 1-second L_{Aeq} plot (figure 4) confirmed that piling was taking place.

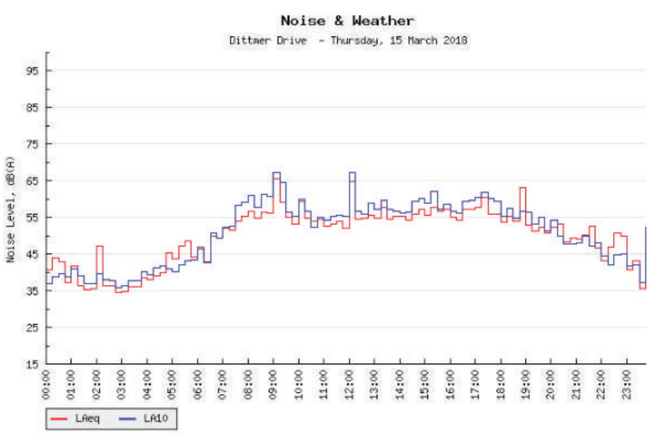


Figure 3: 15-minute L_{Aeq} and L_{A10}

Vibro-piling was very easily identified from the 1-second L_{Aeq} plots (figures 4 and 5) - much more so than from the 15-minute L_{Aeq} and L_{A10} graphs of figure 3.

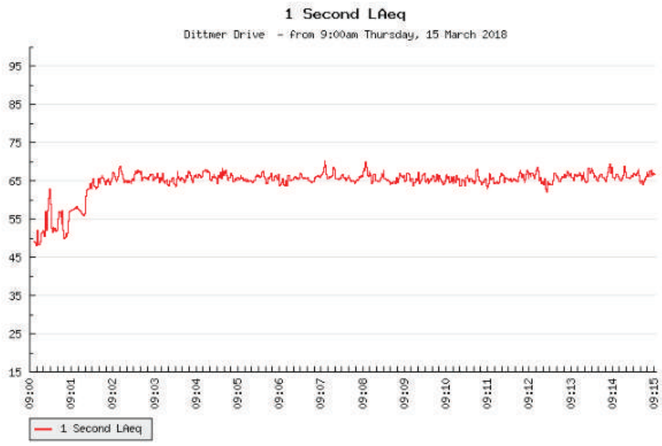


Figure 4: 1-second L_{Aeq} record for a 15-minute period

The small noise peak in figure 4 prior to 09:01 is from a passing car; the vibro-piling began at 09:01 with a noise level of 66 dB L_{Aeq}, and produced a characteristic step in noise level at the microphone. Vibro-piling took place again at 12-pm, seen in figure 5.

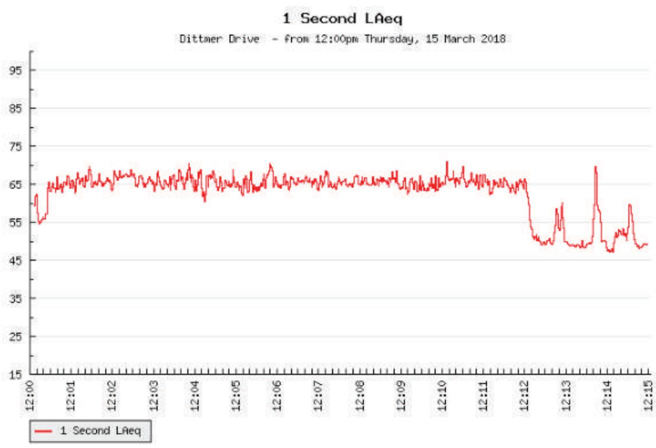


Figure 5: 1-second L_{Aeq} - Vibro-piling starts at 12:00 and finishes at 12.12 pm. Peaks at 12:12 – 12:15 are passing vehicles.

Consented noise levels, in line with the construction standard, are 70 dB $L_{Aeq(15min)}$ and the lower measured result of < 65 dB will give confidence to predictions of other works to come and allow mitigation to be proactive.

4. Vibration Analysis

The consented vibration levels for the project are 1 mm/s ppv in occupied ‘Category A’ dwellings during the hours of 0730–2000 in accordance with DIN 4150-3:1999. This standard is more appropriate to vibration analysis with respect to building damage, rather than health and annoyance. The standard considers the absolute maximum value of the velocity signals in any one of three directions, and is not the vector sum or root mean square, referenced in the NZTA vibration guide [2].

Vibration was sampled continuously during the vibratory piling process at 500 Hz, and piling was easily identified from the mm/s graph for that day, shown in Figure 6.

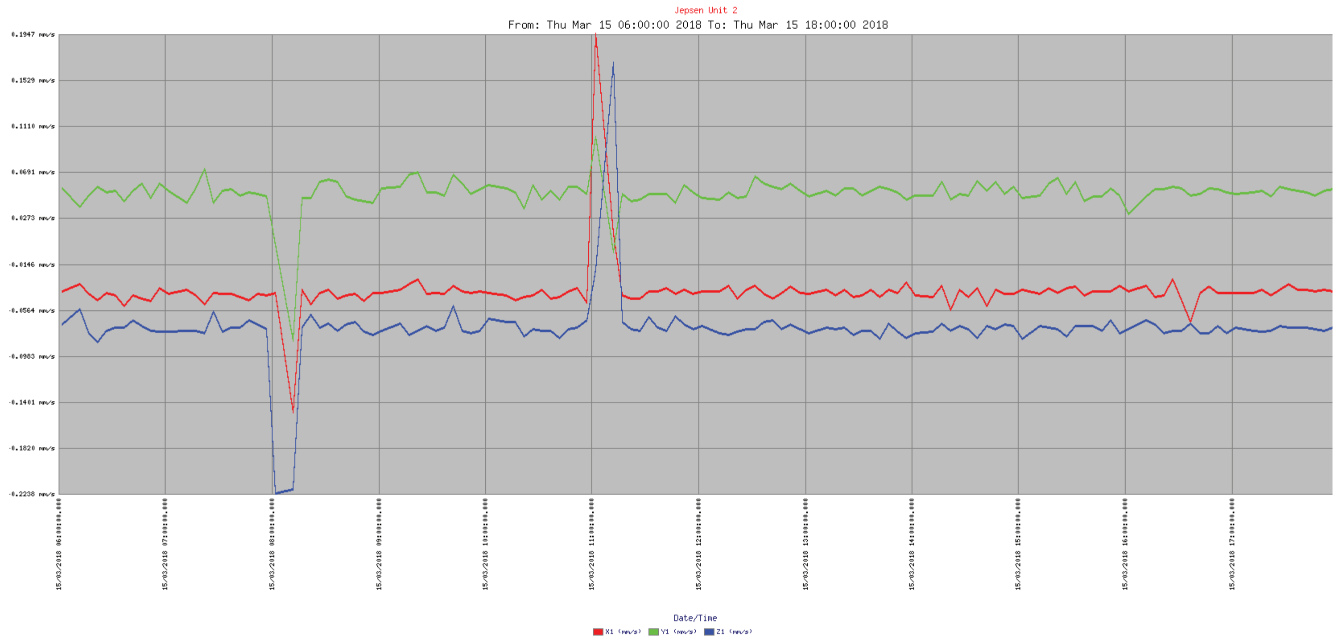


Figure 6: ppv in mm/s for three axes - March 15, 2018. (Time axis does not include DST)

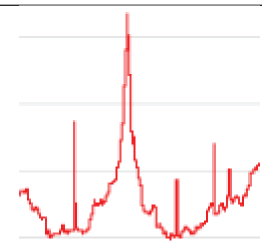
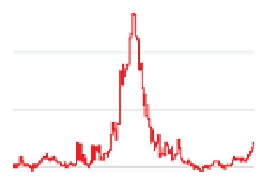
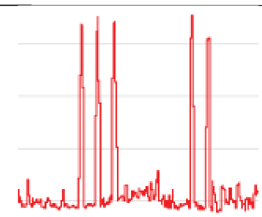
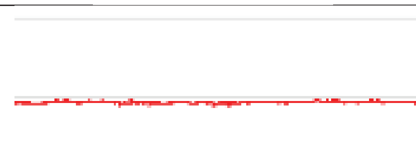
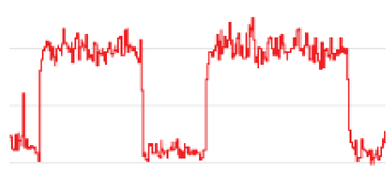
Interestingly, the magnitude of both events was similar, reaching 0.2 mm/s in the morning event and 0.195 mm/s in the midday event[1], but with a phase reversal between events. It is possible that the vibration frequency or the depth of the pile, and therefore the soil structure was different between the am and the pm event. The length of the driven pile was also different between events, because at the end of the first event, which is usually terminated because of increased soil resistance, a clam shell is used to remove stone and sand from within the pile, before the next vibration cycle, and the next pile extension is welded in place. Hence the damping, resonant frequency of the pile, and soil resistance can vary markedly between vibration cycles. Assuming that most of the energy from the piling process is carried by spherical Raleigh waves, at speeds of 50–300 m/s in soil, at the frequency of the vibrating hammer (1700 Hz) the wavelength (λ = v/f) could vary from 30 mm – 200 mm, which may explain the phase reversal at the geophone.

5. Audio Recording

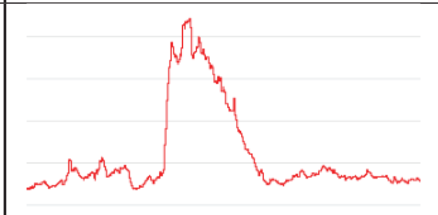
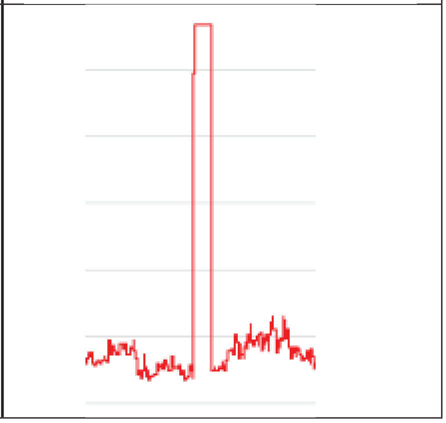
Remote noise monitoring without boots on the ground, or audio recording will only provide noise levels, with no real evidence as to the identity of the source. Common noise sources can with experience be easily identified from the 1-second L_{Aeq} traces (See Table 1).

However, the ultimate is being able to listen to good audio recordings of noise events as well as see the graph. To this end - a huge amount of effort has gone into developing a system where logger noise events can be recorded, and the audio uploaded as MP3 and FLAC (Free Lossless Audio Codec) files to the server. This work has taken several years to develop, and we can now automatically generate noise recordings of virtually any length from 10 seconds to several minutes that are triggered by - date and time,

Table 1: 1-second L_{Aeq} tracings of noise events

Passing car	
Aircraft passing overhead	
Bird sound	
Midnight ambient in the country	
Human made noise	

1 The apparent 1-hr time discrepancy between noise and vibration graphs is due to the fact that the Jepsen noise logger takes care of DST but the RDL-vibe does not.

Pile driving	
Passing train	
92 dB remote calibration	

time of day, noise level (L_{pA}, $L_{Aeq(15min)}$, $L_{A10(15min)}$, $L_{A95(15min)}$, L_{Amax}), rainfall, IR beam, or by SMS. The length of the recordings is only limited by the cost of the cellular data, and the time it takes to listen to these recordings. Happily, recordings each of 5 minutes or so are now significantly less in cost compared to 5 years ago.

At Dittmer Drive, the consented noise level at the dwellings ranges from 55 dB (6.30 – 7.30 am) to 70 dB L_{Aeq} during the day. The noise logger was set to record for 30 seconds every time noise at the microphone exceeded 70 dB L_{pA} (SPL). This setting resulted in many, many recordings of passing cars, but also captured all vibro-piling events and is capturing, at the time of writing, most of the other construction noise. This allows accurate identification of captured noise events and the ability to quantify the noise levels and determine compliance with consented levels on a day by day basis, without huge amounts of time on site. Regular hand-held measurements are still undertaken from time to time to support the remote logger findings.

6. How it works

All loggers use the Norsonic Nor140 Class 1 sound level meter, which has an RS232 I/O serial port. This port is used for serial communications with the meter and all of the Lx data is collected and telemetered via this port to the local processor electronics. A cellular modem transfers this data once every 15 minutes[2] to the server (www.noiseandweather.co.nz); the cellular connection also facilitates 50 text (SMS) remote control commands and interrogation features as required.

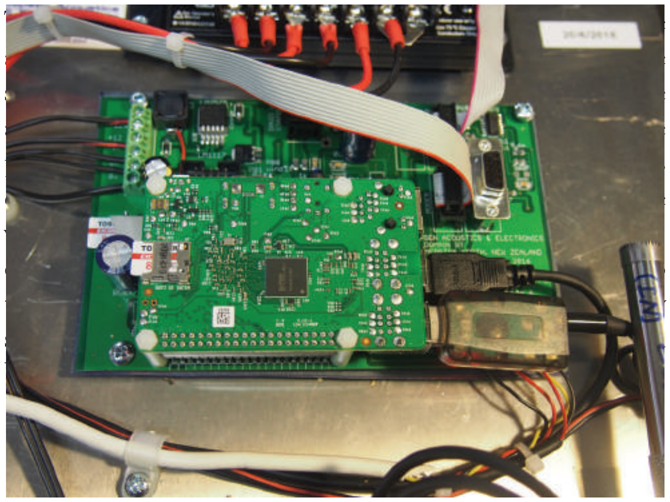


Figure 7: The processor electronics

7. Remote Calibration

From time-to-time, a 'calibration' SMS sent to the remote logger will trigger the Norsonic 'mic cal' source, which injects a calibrated 90 dB signal into the microphone preamp.

8. Sample Recordings

Samples of the noise sources shown in Table 1 can be listened to on line at www.noiseandweather.com\sample. The quality and clarity of NZ native bird song captured during the night at some locations is a pleasure to listen to. Other recordings of aircraft, passing cars, container handling at ports, pile driving, and others are also included.

Figure 8: Photograph taken seconds after a 93 dB L_{Amax} trigger event on June 26 at 10:59 am.

9. Future Work

Dropping of containers at a port is a source of continued annoyance; identifying which container was dropped when, by which straddle loader and how loud was required at a NZ port; this prompted the inclusion of cameras at various sites. An image (see figure 8) is now taken when a noise event is triggered, an email is sent, and the image is date-time stamped, with the L_{Amax} as part of the header. This work is ongoing.

References

1. RDL-vibe remote battery-operated vibration monitoring system, with on-line access. Mfd by Caption Data, www.captiondata.com
2. State highway construction and maintenance noise and vibration guide. www.nzta.govt.nz/assets/resources/sh-construction-maintenance-noise/docs/construction-maintenance-noise-vibration-guide.pdf

2 Once every 10 minutes in the case of wind farm remote monitoring.