



Contractor



**Forth Crossing** Bridge Constructors

HOCHTIEF Solutions  
American Bridge International  
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Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT  
JUNE 2015**

00	15/07/15	First draft	MRN	LSN	LSN
<b>Rev</b>	<b>Rev. Date</b>	<b>Purpose of revision</b>	<b>Made</b>	<b>Reviewed</b>	<b>Approved</b>
Document status					
<b>FOR REVIEW</b>					
Made by Michael Richardson			Checked By: Liam Soden		
Initials: MRN			Initials: LSN		
Document number					Rev
<b>REP-00237</b>					<b>00</b>
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## INTRODUCTION

- 1.1.** Monitoring of construction vibration is being undertaken by FCBC during the construction of the new Forth Crossing and associated road network. This report covers the month of June 2015. The objective of this report is to detail the vibration monitoring that has been undertaken across the site during this period, which has been done so in accordance with the Code of Construction Practice (CoCP), and Noise and Vibration Management Plan (NVMP).
- 1.2.** FCBC carefully risk assesses noise & vibration likely to result from all construction activities, through the production of Plans for Control of Noise & Vibration (PCNVs). During the preparation of PCNVs, vibration prediction assessments are made. These assessments illustrate that no construction plant, equipment or methodology to be used by FCBC are envisaged to induce any levels of vibration at sensitive receptors that would exceed the vibration threshold levels stated in the CoCP. These assessments/predictions have been validated by means of the vibration monitoring results displayed in this report.

## **2. MONITORING SUMMARY**

- 2.1.** Due to the location and sensitivity of vibration monitoring equipment, the exceedances presented in the graphs included in the appendices of this report do not represent levels generated by construction, but rather show local interference around the monitoring equipment. This can include, for example, Residential activity, or indeed any significant movements occurring close to the monitoring equipment.
- 2.2.** According to the BS5228-2 (2009) there is minimal documented proof of actual damage to structures or their finishes resulting from construction, and damage resulting solely from well-controlled construction and demolition vibrations is rare. There are many other mechanisms which cause damage, especially in decorative finishes, and it is often incorrectly concluded that vibrations from construction and demolition sites are to blame. In many cases it is not possible to ascertain the exact source of vibration, though it is possible to rule out construction as a source on an activity basis.
- 2.3.** The works carried out in each of the various construction work areas as well as the related vibration assessments are summarised in Appendix A.
- 2.4.** Considering the distances between the various construction work areas and sensitive receptors as well as working methods utilised, the risk of any damage to structures or nuisance to residents occurring as a result FCBC construction related vibration is highly unlikely.
- 2.5.** The number of threshold exceedances at the various vibration monitoring stations during the period in question are shown in Table 1 below.

**Table 1: Exceedances of thresholds set out in the CoCP**

*June 2015*

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s <sup>-1</sup> )	Intermittent (10 mm.s <sup>-1</sup> )	Day (0.4 m.s <sup>-1.75</sup> )	Night (0.2 m.s <sup>-1.75</sup> )
Linn Mill	8	12	1	1
Butlaw Fisheries	0	0	0	0
Clufflat Brae	10	0	1	0
Dundas Home Farm	1	0	1	0
Echline	2	1	0	0
Inchgarvie Lodge	1	0	0	0
Scotstoun	0	0	0	0
Springfield	2	3	1	1
Tigh-Na-Grian	2	0	0	0
Whinnyhill	11	0	0	0

- 2.6.** Peak Particle Velocity (PPV) is used to measure vibration through a solid surface. When a vibration is measured, the point at which the measurement takes place can be considered to have a particle velocity. This particle vibration will take place in three dimensions (x, y and z).
- 2.7.** The Peak Particle Velocity is the highest velocity that is recorded during a particular event, and as such is appropriate for the measurement of activities such as blasting, piling and compacting. The thresholds for the Forth Replacement Crossing are 5 mm.s<sup>-1</sup> for continuous construction (e.g. piling), and 10 mm.s<sup>-1</sup> for intermittent construction (e.g. blasting).
- 2.8.** These thresholds are set to protect against building damage. For this monitoring period, all the exceedances have been investigated thoroughly and appear to have been generated as a result of standalone, instantaneous events arising from local interferences, the exact source of which remains unknown.

- 2.9.** Vibration Dose Value (VDV) is a metric used in vibration monitoring. It is calculated by taking the fourth root of the integral of the fourth power of acceleration after it has been frequency-weighted. The frequency-weighted acceleration is measured in  $\text{m.s}^{-2}$  and the time period over which the VDV is measured is in seconds. This yields V DVs in  $\text{m.s}^{-1.75}$ .
- 2.10.** The vibration dose value (VDV), a cumulative measurement of the vibration level received over an 8-hour or 16-hour period, is recommended in BS 6472 as the appropriate measure to evaluate human exposure to vibration in buildings in residential and other uses.
- 2.11.** During the monitoring period, vibratory rollers and whacker plates were used intermittently at several locations around the site. No exceedances were recorded as a result of the use of this equipment, where exceedances did occur it resulted from non-project related activity around the monitor.
- 2.12.** In addition, detailed investigation of all exceedances (i.e. review of PPV levels over 30 seconds periods) has shown that each resulted from isolated, non-construction related events, which likely occurred close to the monitoring station.
- 2.13.** Within the Appendix B, there are short gaps of missing data in the PPV and VDV graphs. These occurred due to a number of power supply problems and corrupt files.

### **3. CONCLUSION**

- 3.1.** Considering the distance between FCBC construction works and sensitive receptors, the methods of working utilised and programme of works. The risk of damage to structures or nuisance to residents resulting from vibration is highly unlikely.
  
- 3.2.** Due to the location and sensitivity of vibration monitoring equipment, the exceedances presented in the graphs included in the appendices of this report are unlikely to be generated by construction, but rather show local interference and maintenance around the monitoring equipment.



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**APPENDIX A – MONITORING LOCATIONS & VIBRATION ASSESSMENTS  
FROM RELEVANT PCNVs**

**Table 2: Monitoring Locations**

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During June 2015
M1	Whinny Hill	Network	<ul style="list-style-type: none"> <li>• Earthworks/Fill placement</li> <li>• New Ferrytoll Road</li> <li>• FT03&amp;FT04 deck works</li> <li>• FT09 works</li> <li>• FT19 Retaining Wall</li> <li>• Roadworks</li> </ul>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck table installation works</li> <li>• North Tower rebar, formwork, concreting works deck table installation works</li> <li>• Pier N1 rebar formwork &amp; concrete works</li> <li>• AVN works</li> </ul>
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> <li>• Pier S1 rebar, formwork &amp; concrete works</li> <li>• Cleaning, Blinding pour and Rebar installations at Pier S2</li> <li>• Central Tower rebar, formwork, concreting works deck table installation works</li> <li>• South Tower rebar, formwork, concreting works deck table installation works</li> </ul>
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> <li>• Launch – Install lateral Guides, Launch phase 11 &amp; 12</li> <li>• Pier S1 rebar, formwork &amp; concrete works Cleaning, Blinding pour and Rebar installations at Pier S2</li> <li>• Central Tower rebar, formwork, concreting works deck table installation works</li> <li>• South Tower rebar, formwork, concreting works deck table installation works</li> <li>• Main Carriageway earthworks</li> </ul>
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> <li>• Launch – Install lateral Guides, Launch phase 11 &amp; 12</li> <li>• No night time or Sunday construction in the vicinity</li> <li>• Excavation, Break rock, fill/trim mainline &amp; fill launch</li> </ul>

M13	Clufflat Brae	Crossing / Network	<ul style="list-style-type: none"> <li>• Launch – Install lateral Guides, Launch phase 11 &amp; 12</li> <li>• No night time or Sunday daytime construction in vicinity.</li> </ul>
M14	Springfield	Network	<ul style="list-style-type: none"> <li>• Launch – Install lateral Guides, Launch phase 11 &amp; 12 N.B. No night time or Sunday daytime construction in vicinity.</li> <li>• Earthworks South Abutment area</li> <li>• Excavation, Break rock, fill/trim mainline &amp; fill launch</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• Launch – Install lateral Guides, Launch phase 11 &amp; 12</li> <li>• No night time or Sunday construction in the vicinity</li> <li>• Earthworks South Abutment area</li> <li>• Excavation, Break rock, fill/trim mainline &amp; fill launch</li> </ul>
M16	Scotstoun	Network	<ul style="list-style-type: none"> <li>• Arup access works</li> <li>• Footpath works</li> <li>• Utility works</li> <li>• Concrete finishing works at ESQ04</li> <li>• B800 North road works including bridge works</li> </ul>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> <li>• Utility works</li> <li>• Concrete finishing works ESQ04</li> <li>• B800 South roadworks including bridge works</li> <li>• Main carriageway works</li> </ul>

Table 2: The main construction activities undertaken in the locality of each of the vibration monitors during the period of June 2015.

**Table 3: PCNV Predicted PPV & VDV Levels**

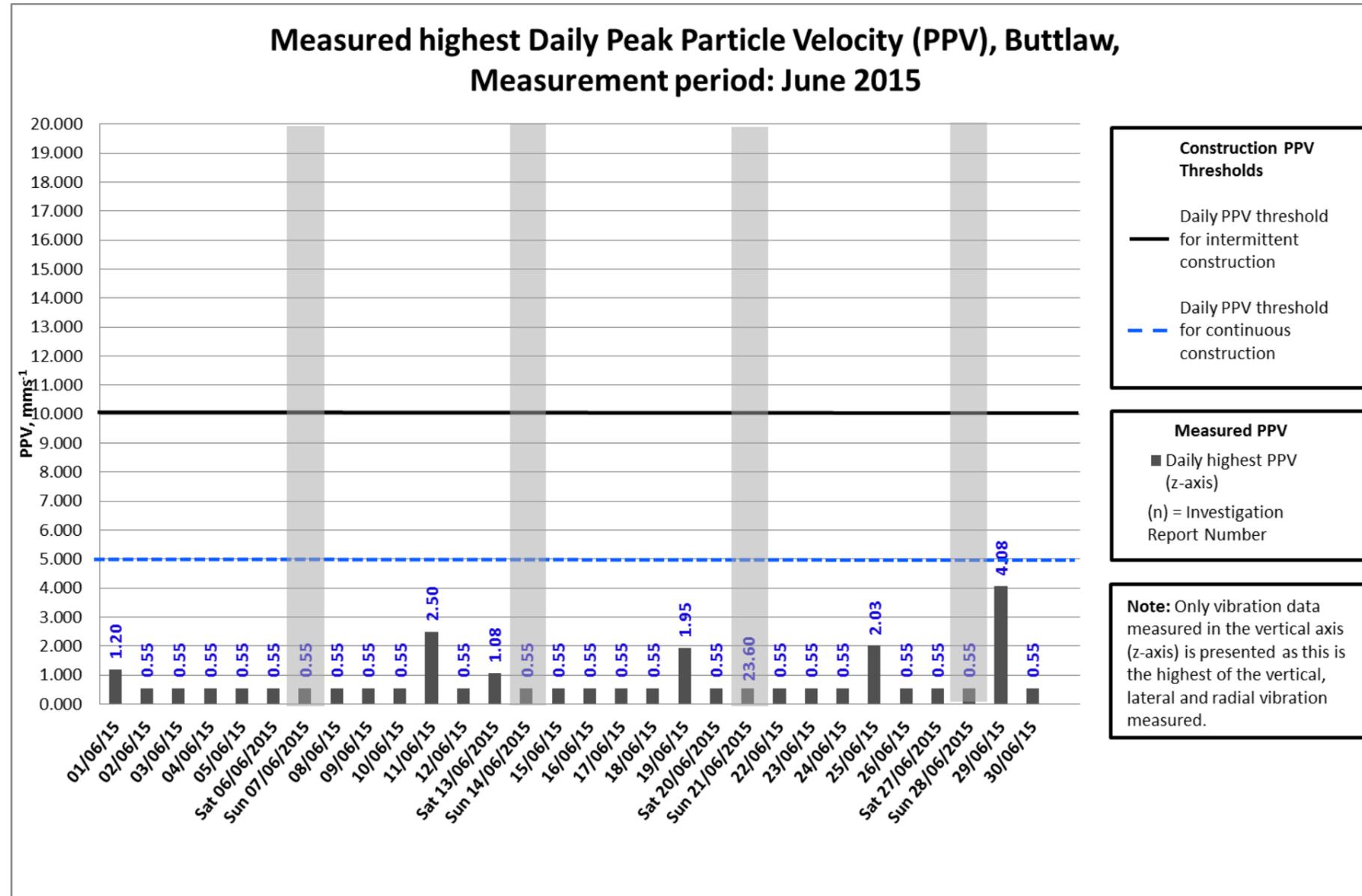
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	2.44	0.37
Dundas	75	2000	Roller/Whacker	0.98	0.33
Echline	40	1000	Roller/Whacker	2.44	0.37
Inchgarvie Lodge	50	40	Roller/Whacker	1.77	0.33
Linn Mill	60	250	Roller/Whacker	1.36	0.33
Scotstoun	40	2000	Roller/Whacker	2.44	0.37
Springfield	50	300	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	180	1800	N/A	-	-

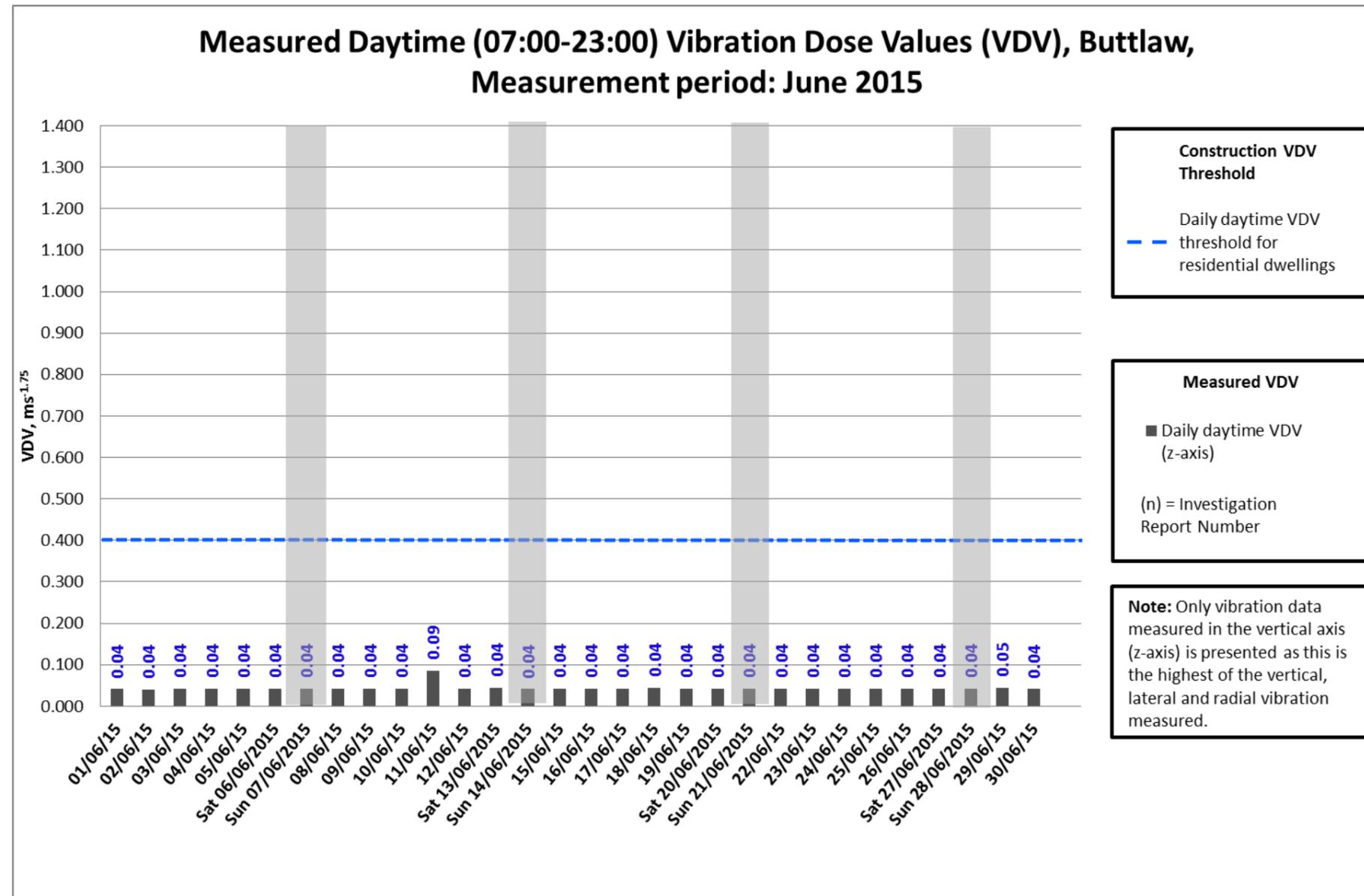
Table 3: The distances from vibration monitors to the closest work areas for both day and night time periods. It also lists worst case PPV and eVDV calculations exhibited at the vibration monitors, resulting from the maximum vibration inducing plant operated at the nearest work areas.

**Notes on Table 3**

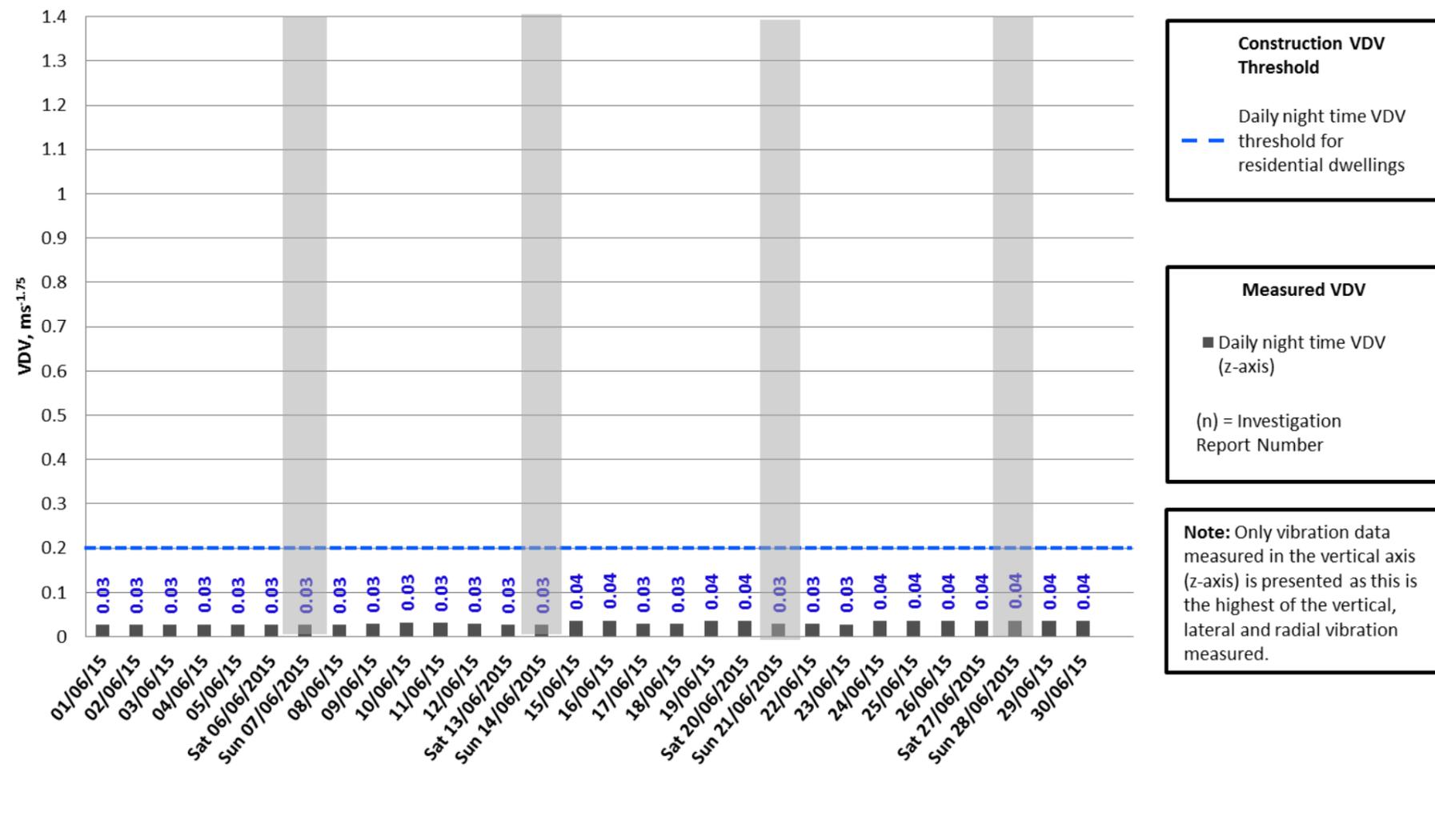
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 5m, 0.4mm/s @ 20m, 0.1mm/s @ 50m have been discounted due to the distances of use from the closest receptors).
- Vibratory rollers were not operated within 20m of any sensitive receptor.
- Whacker plates were not utilised within 40m of any occupied sensitive receptor.
- All roller eVDV values in the table above are based on the worst case scenario of a vibratory roller remaining in continuous operation for 2 hours an average distance (100m) from the nearest occupied receptors.
- All whacker plate eVDV values in the table above are based on the worst case scenario of a whacker plate remaining in continuous operation for 2 hours a minimum distance from the nearest receptor.

## APPENDIX B – VIBRATION GRAPHS





### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Buttlaw, Measurement period: June 2015



**Construction VDV Threshold**

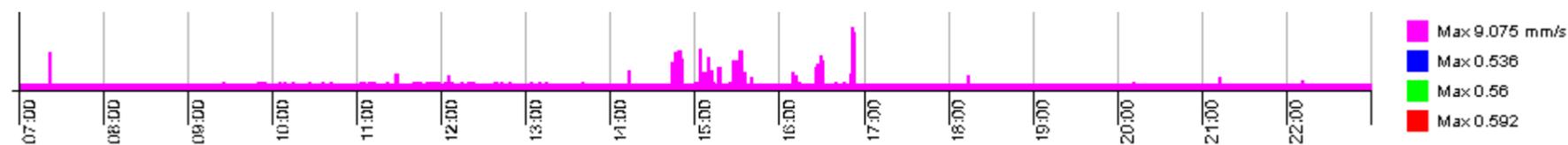
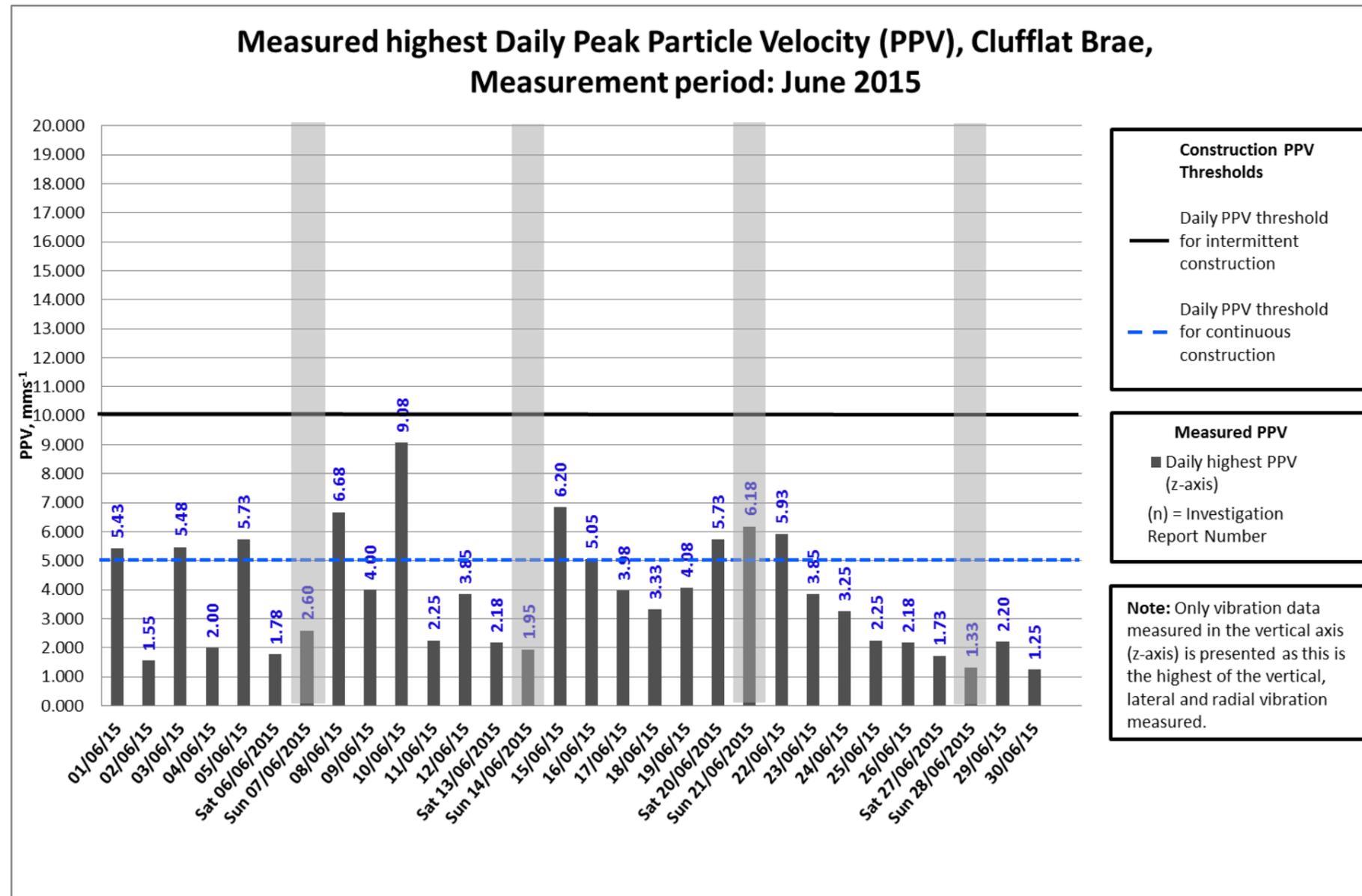
Daily night time VDV threshold for residential dwellings

**Measured VDV**

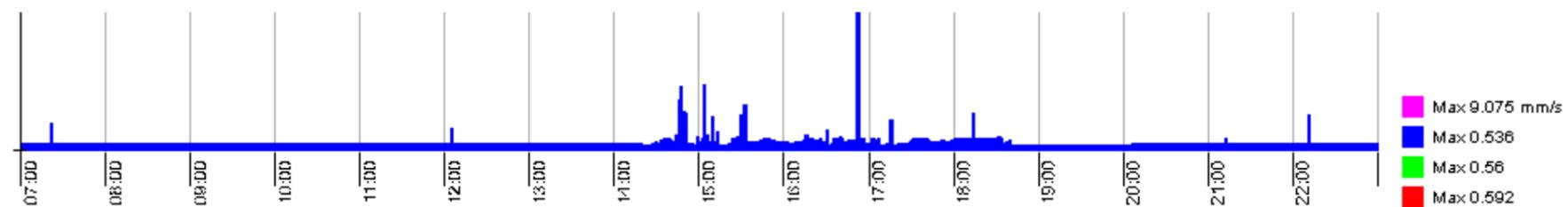
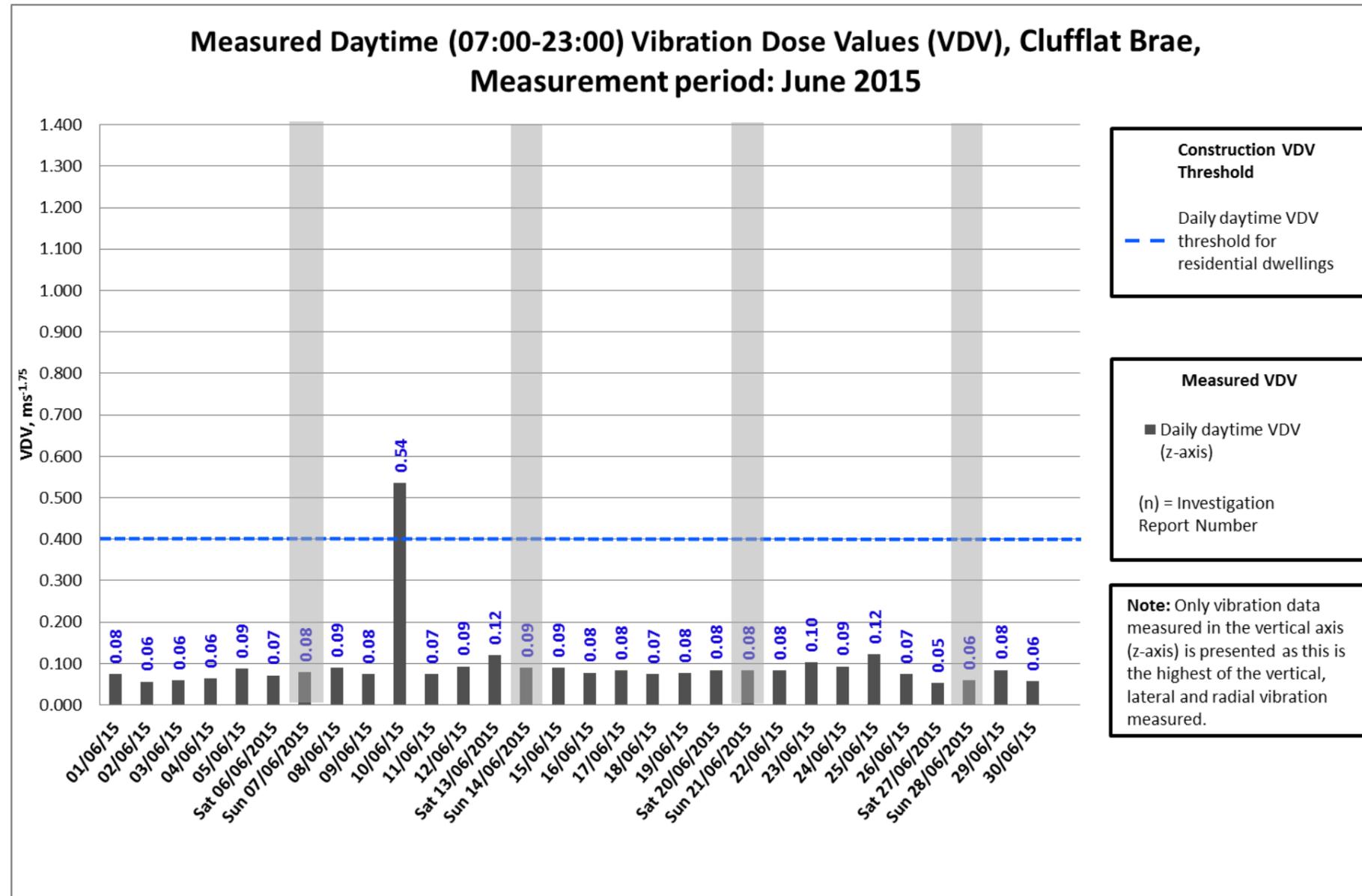
■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

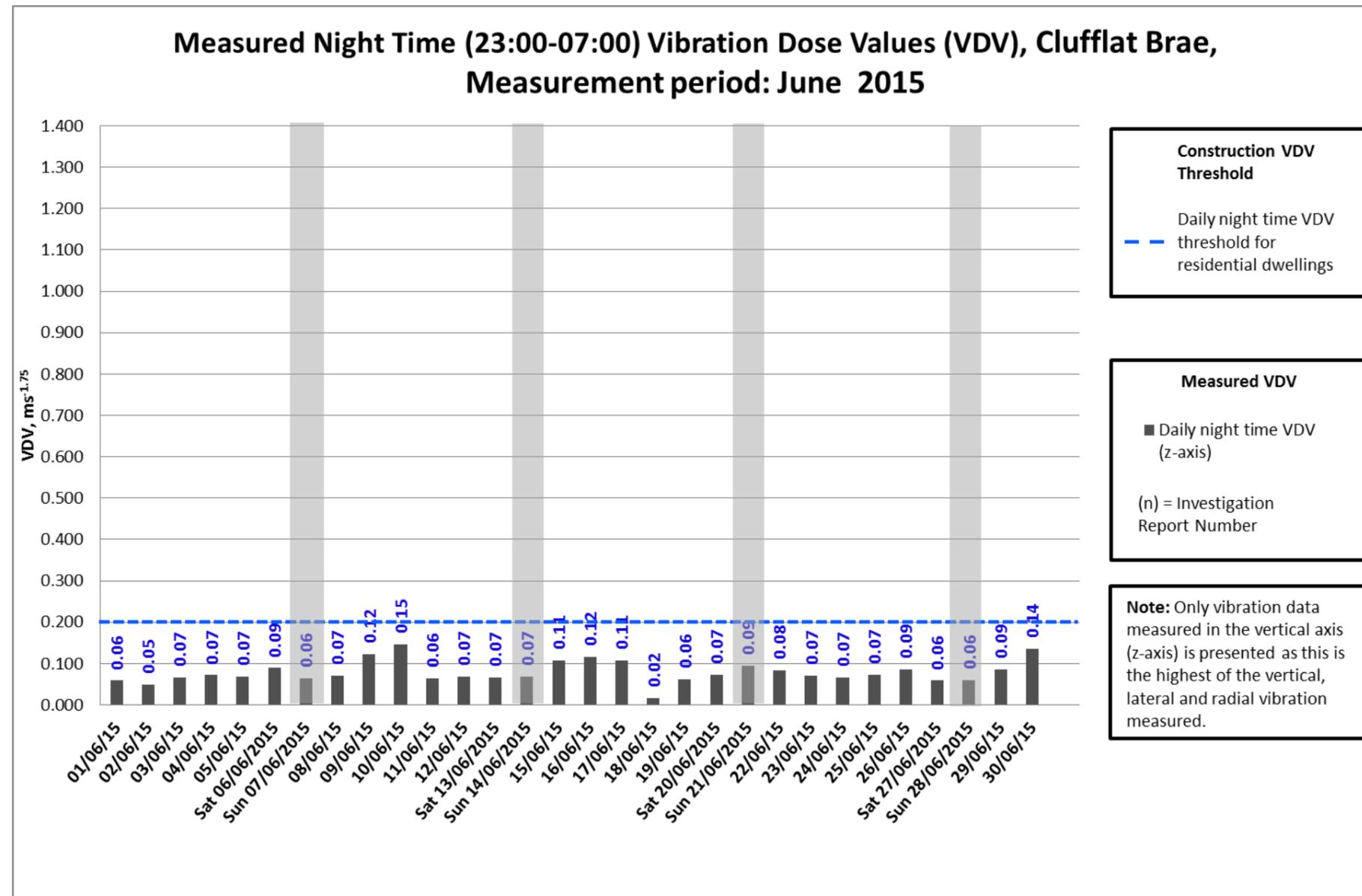
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

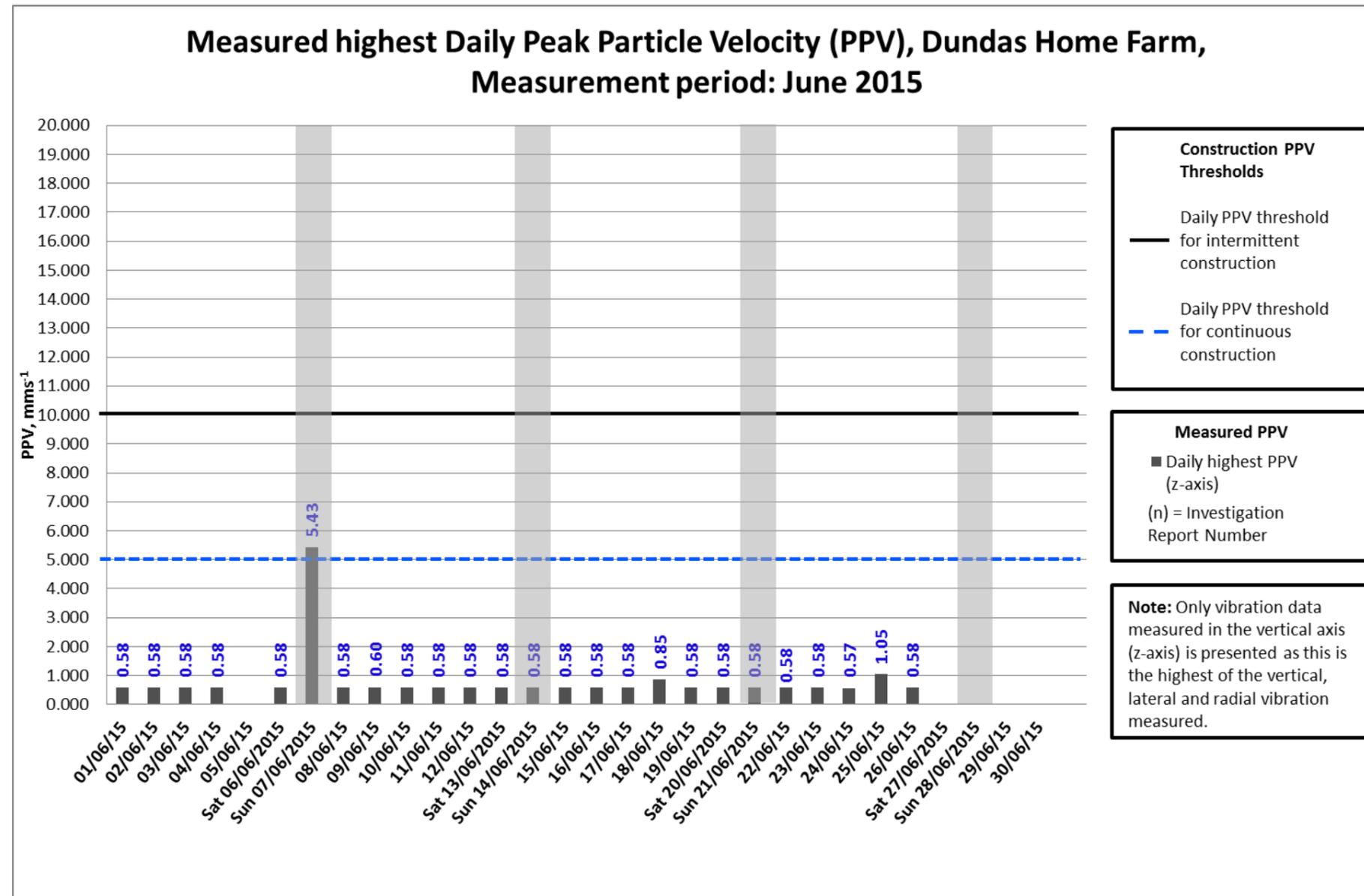


The graph above shows the events on the 10/06/2015, from investigation the nearest works from the monitor was 280m away and the vibration monitor from Linn Mill was only 200m away from the same works. After cross referencing the two graphs there was no similarity's apparent concluding that the vibrations caused on the 10<sup>th</sup> of June were not construction related. Other dates were investigated and found to be individual, isolated events due to external activity near/ directly above the transducers.

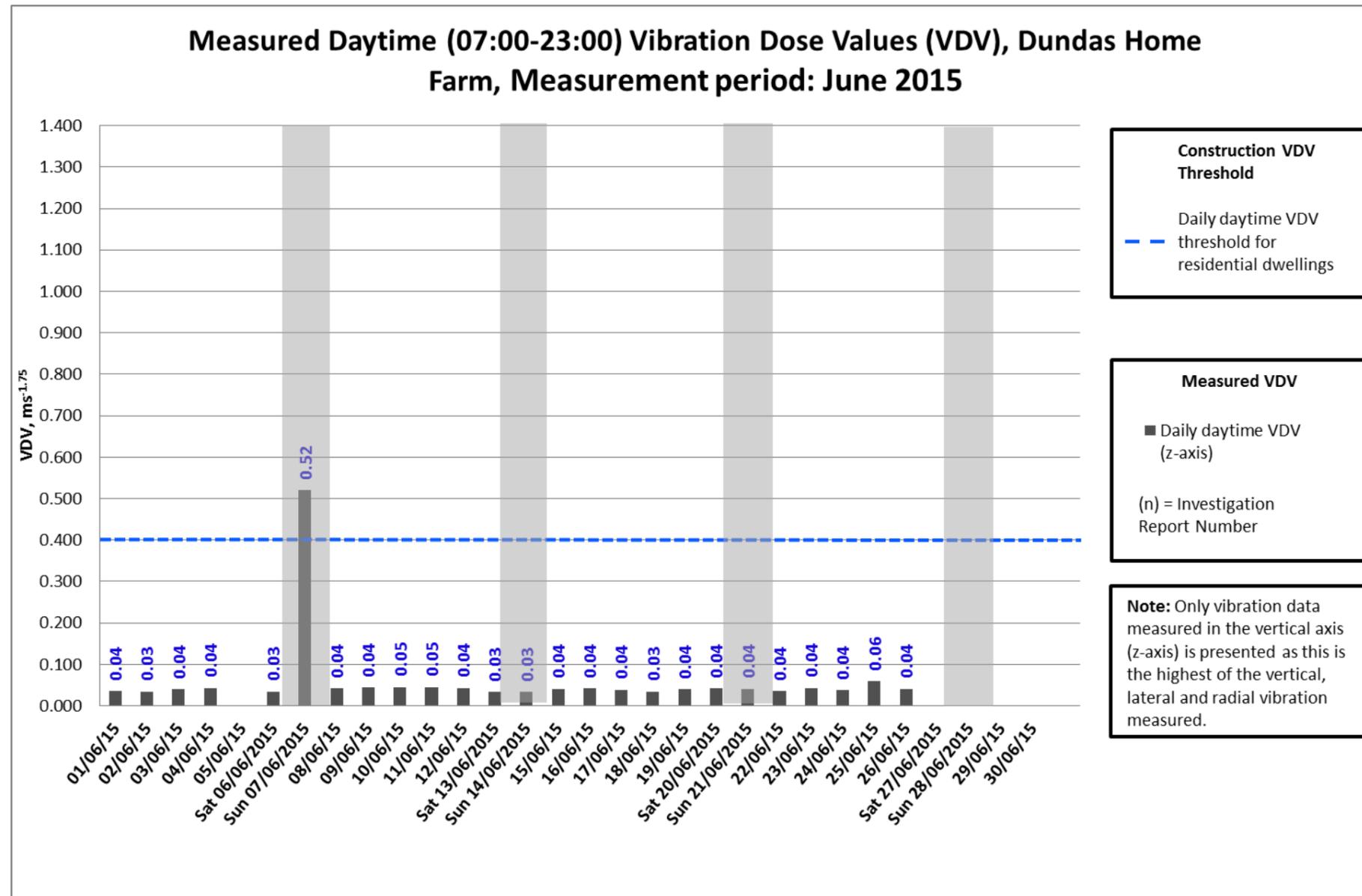


Note: The graph above shows the exceedances on the 10/06/2015. This was on the same day of the exceedance on the PPV Graph. It was investigated and found to be caused by non-Construction related activity.

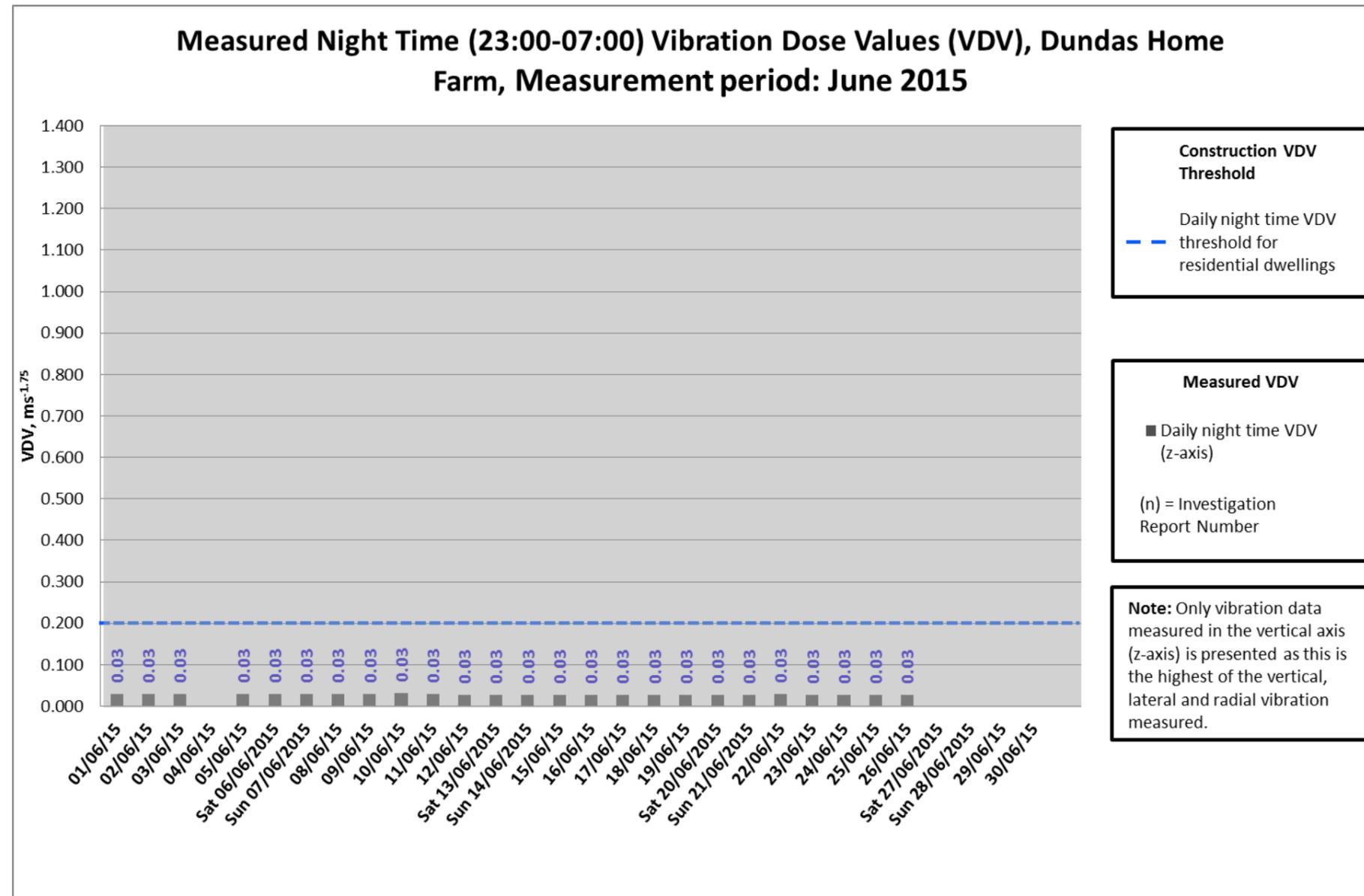




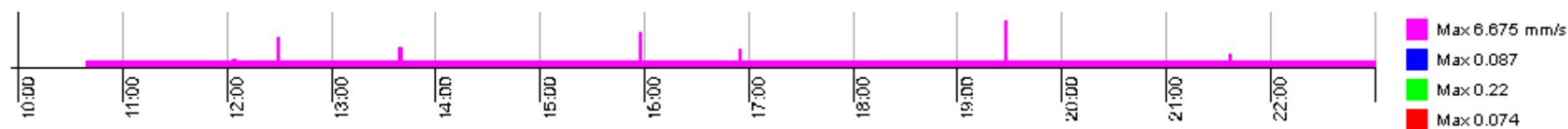
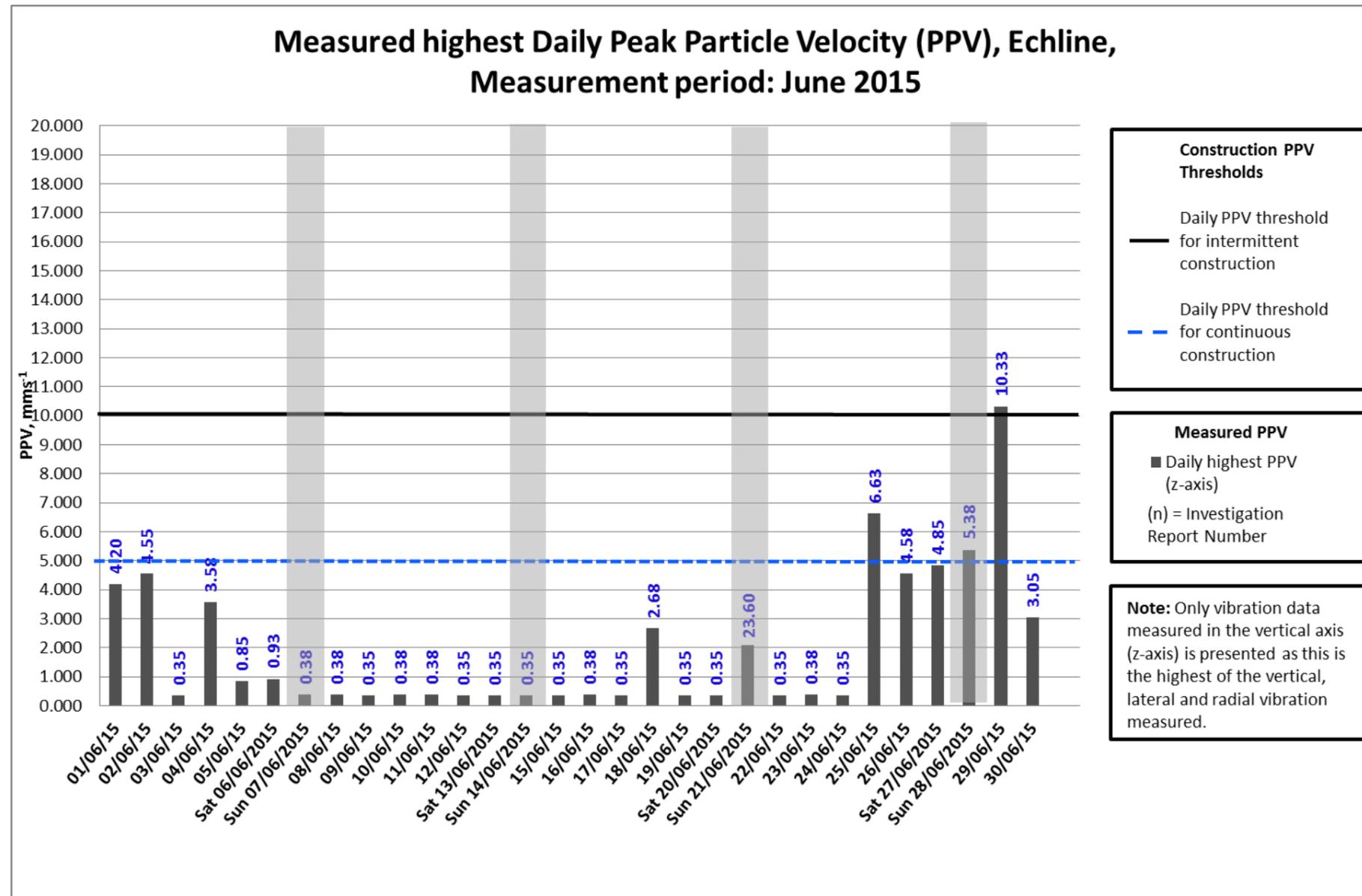
Note: During the 04/06/2015, 05/06/2015, 27/06/2015, 28/06/2015, 29/06/2015 and on the 30/06/2015 there was a power supply problem.



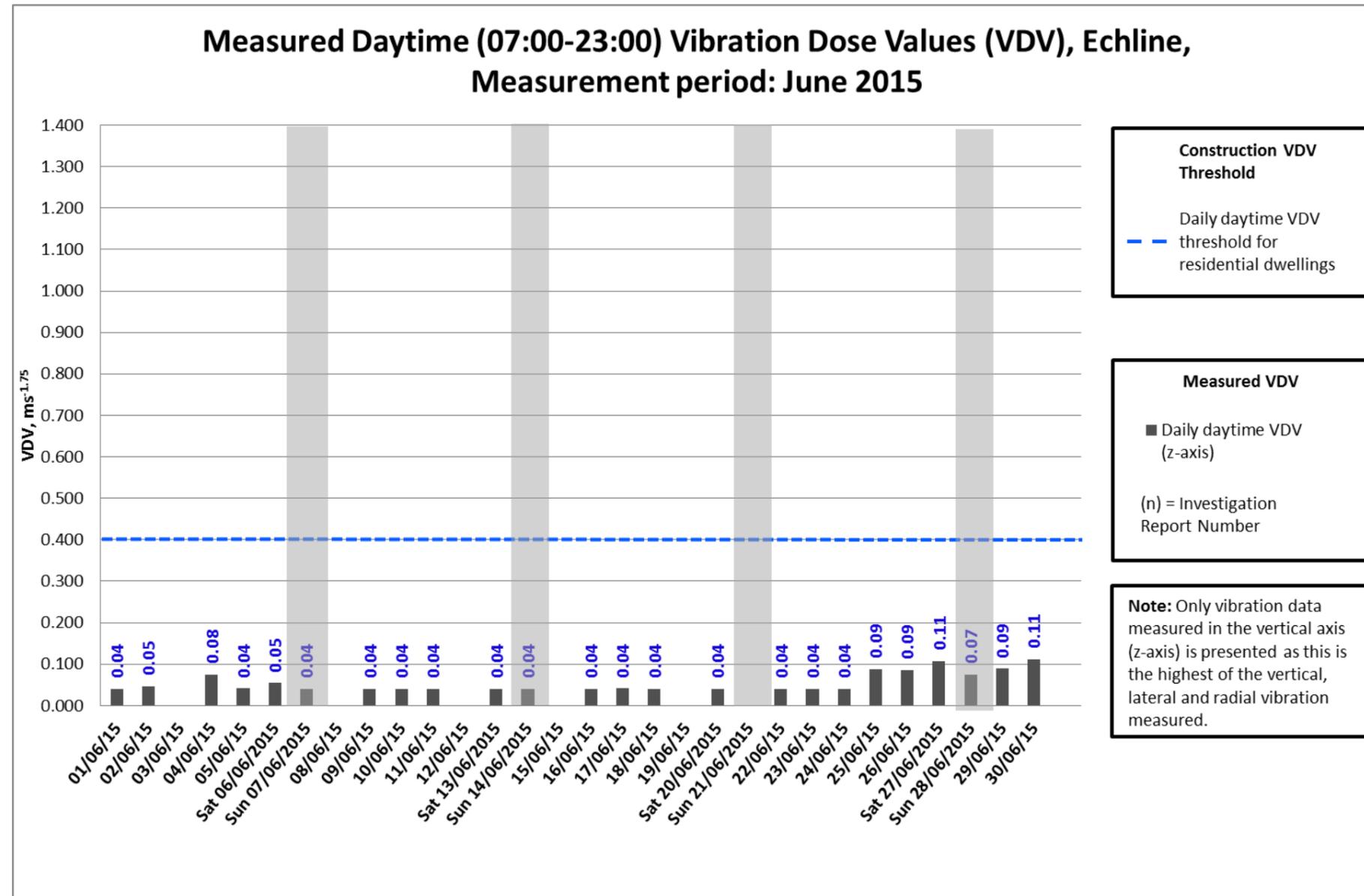
Note: During the 04/06/2015, 05/06/2015, 27/06/2015, 28/06/2015, 29/06/2015 and on the 30/06/2015 there was a power supply problem.

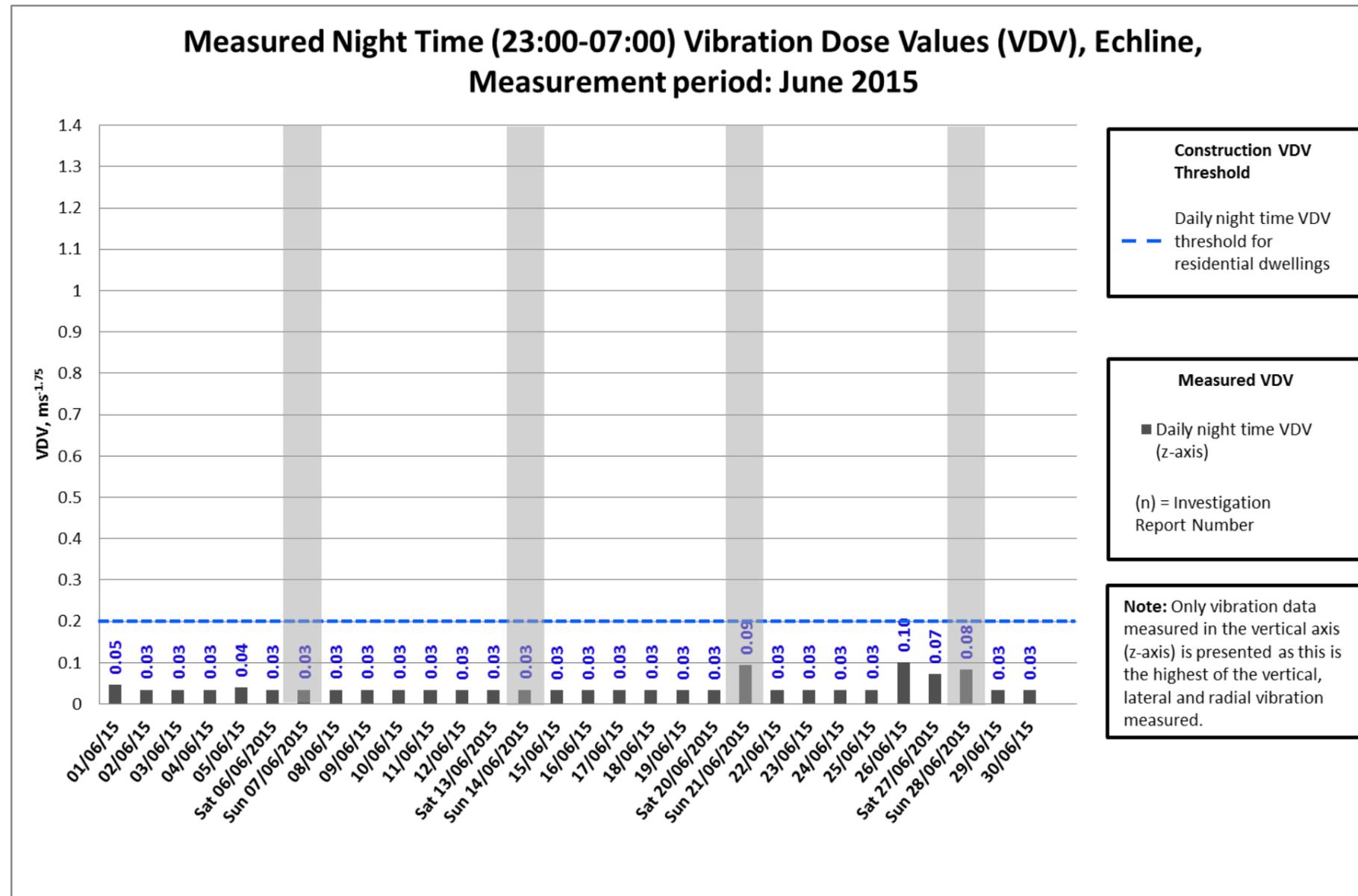


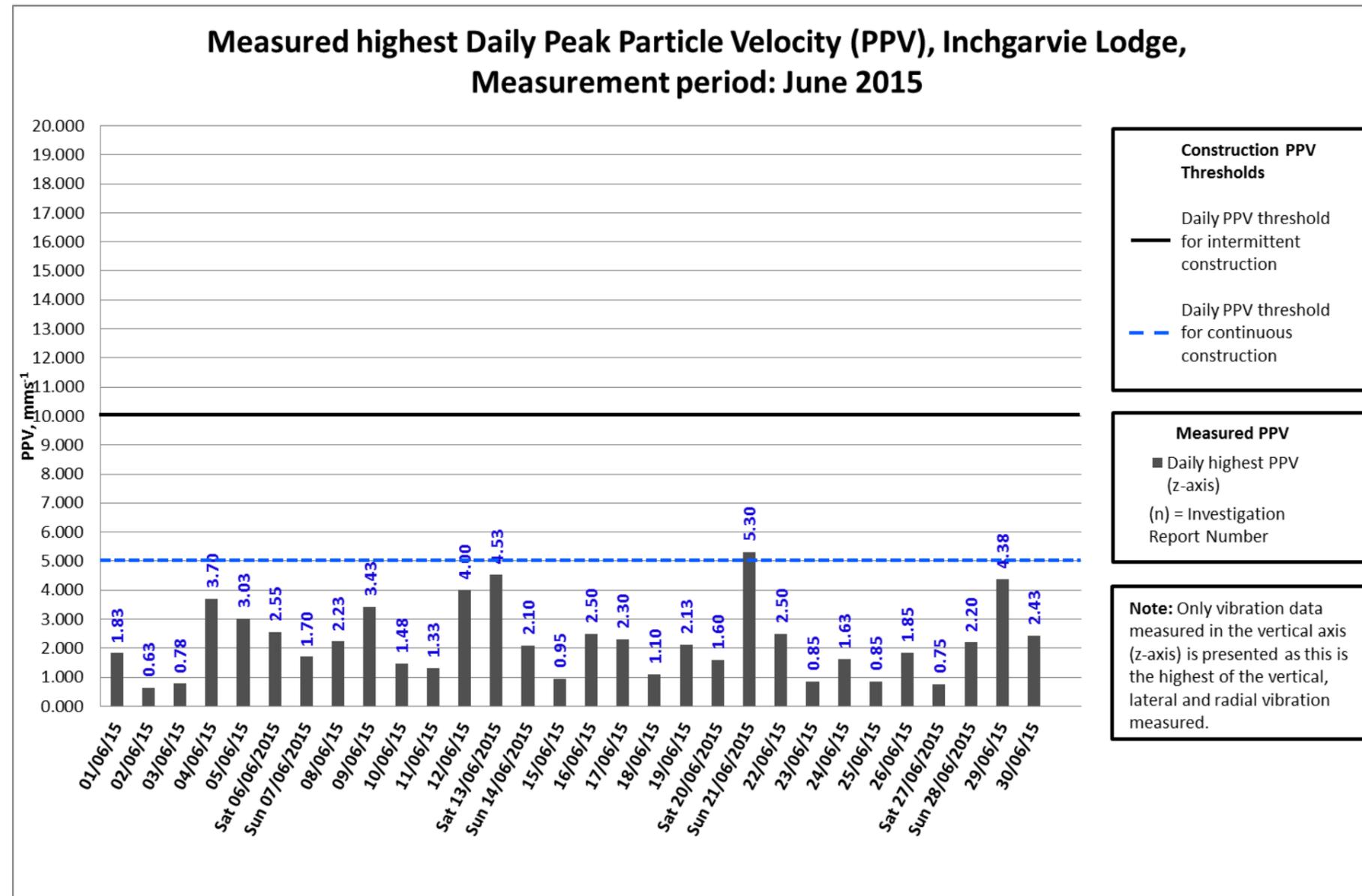
Note: During the 04/06/2015, 05/06/2015, 27/06/2015, 28/06/2015, 29/06/2015 and on the 30/06/2015 there was a power supply problem.



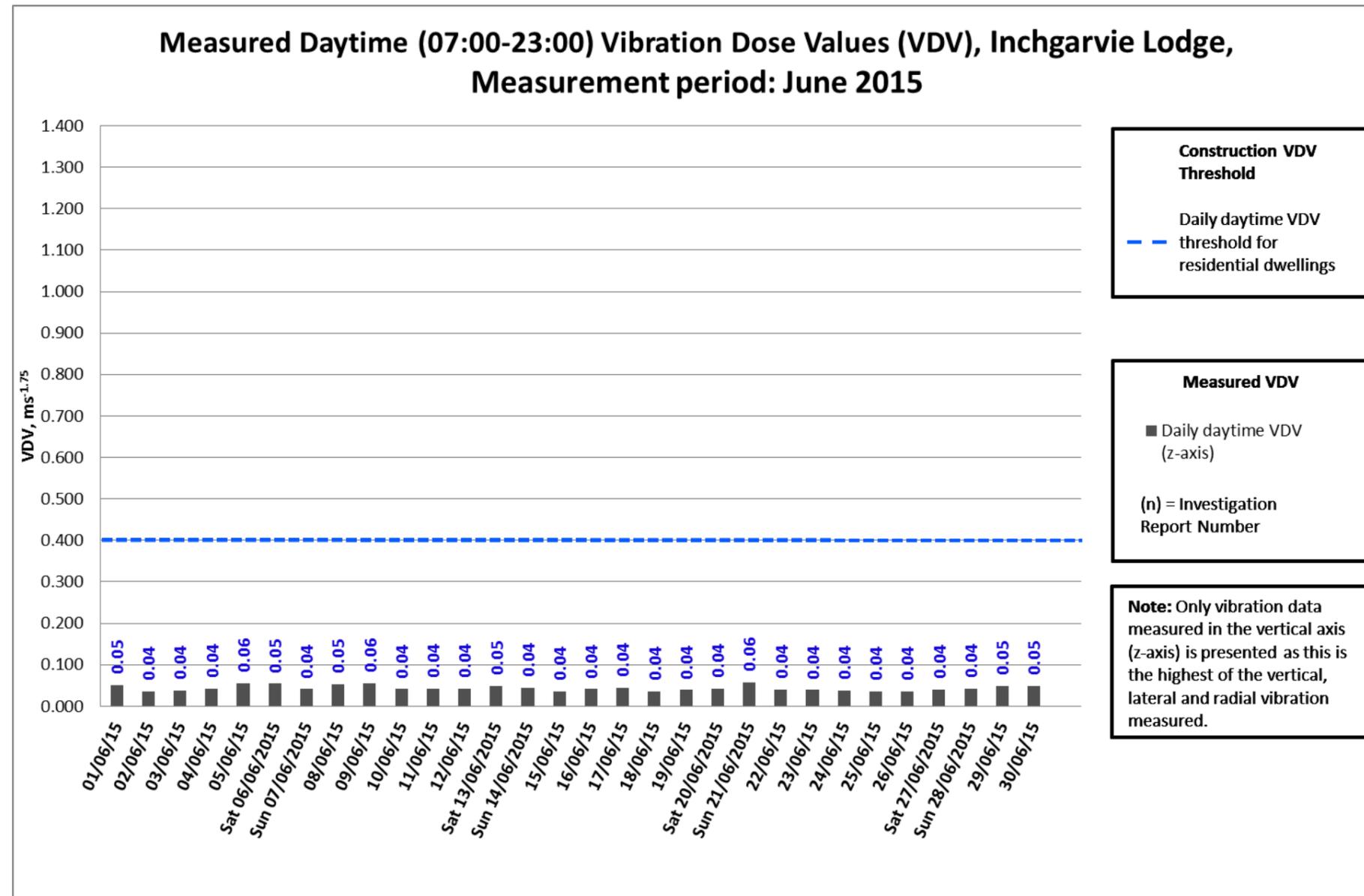
The graph above shows the events on the 25/06/2015, it has been investigated and has been seen to be individual, isolated event not related to construction. This figure is due to external activity near/ directly above the transducers. The exceedance on the 29<sup>th</sup> of June was investigated and found to be the same.



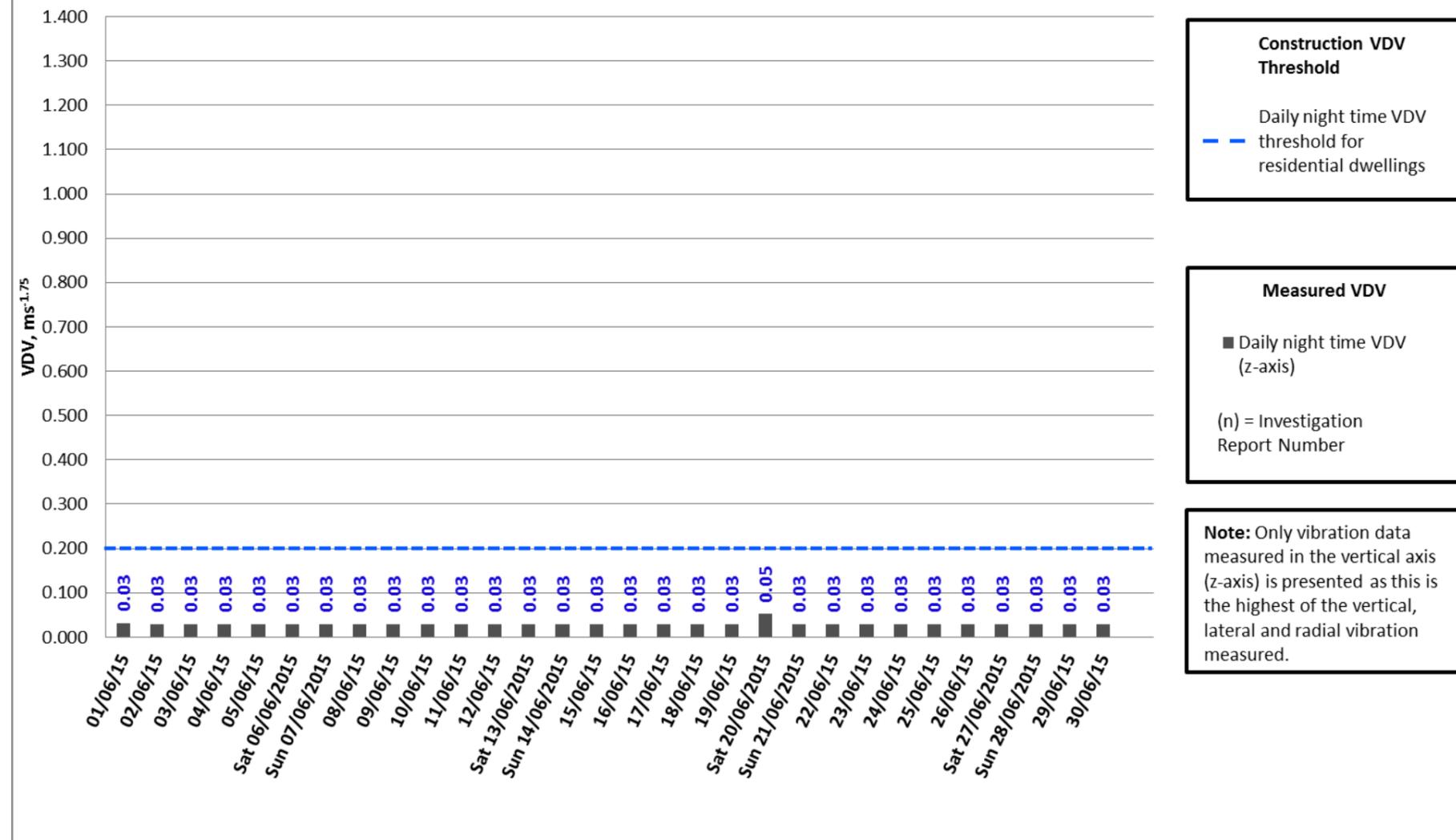


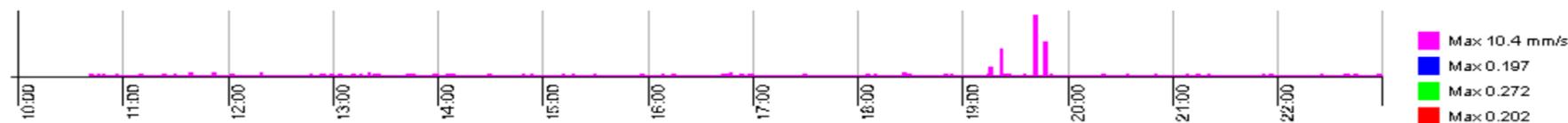
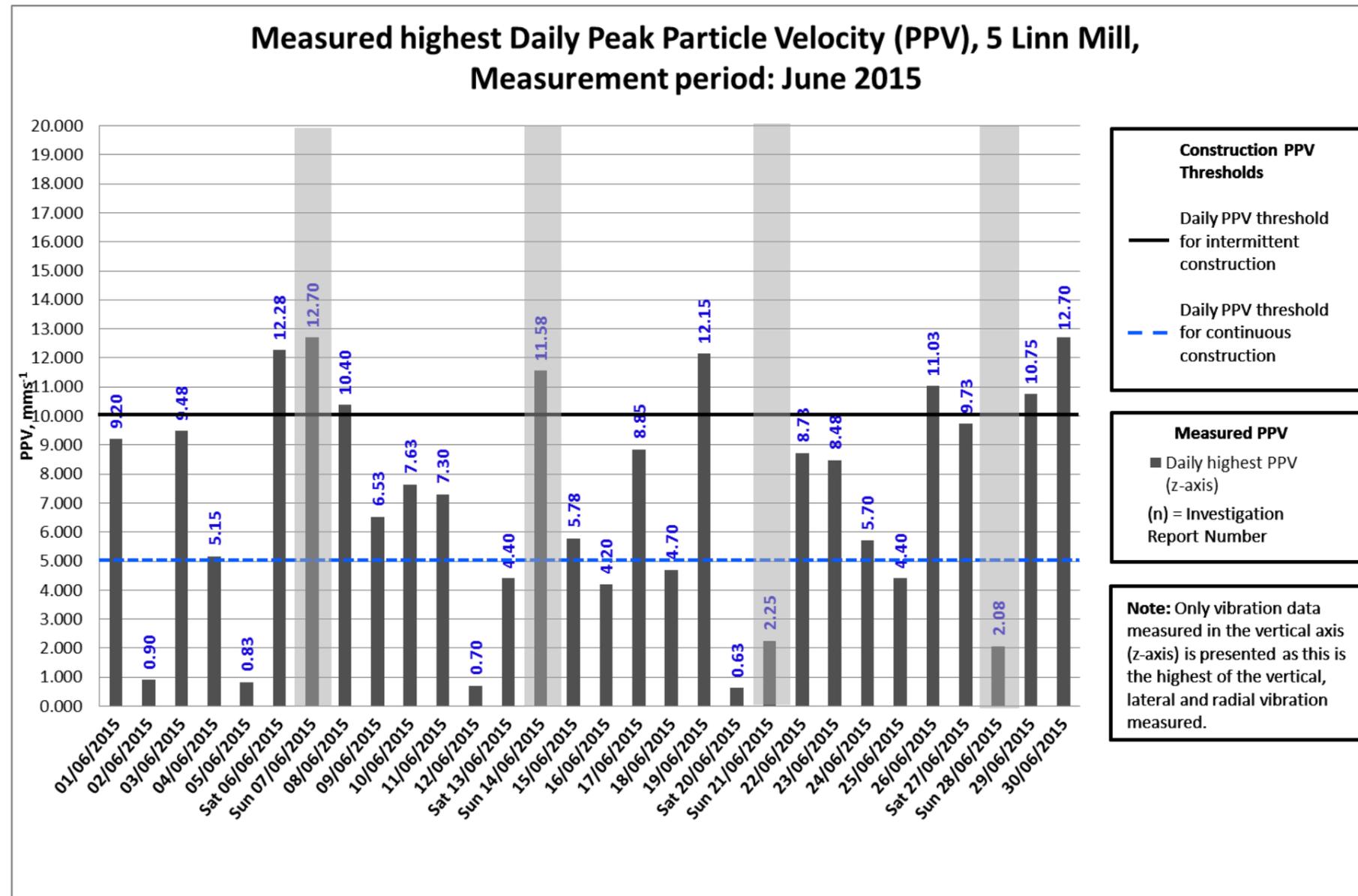


Note: There was no works carried out on Sunday the 21<sup>st</sup> of June in the area.

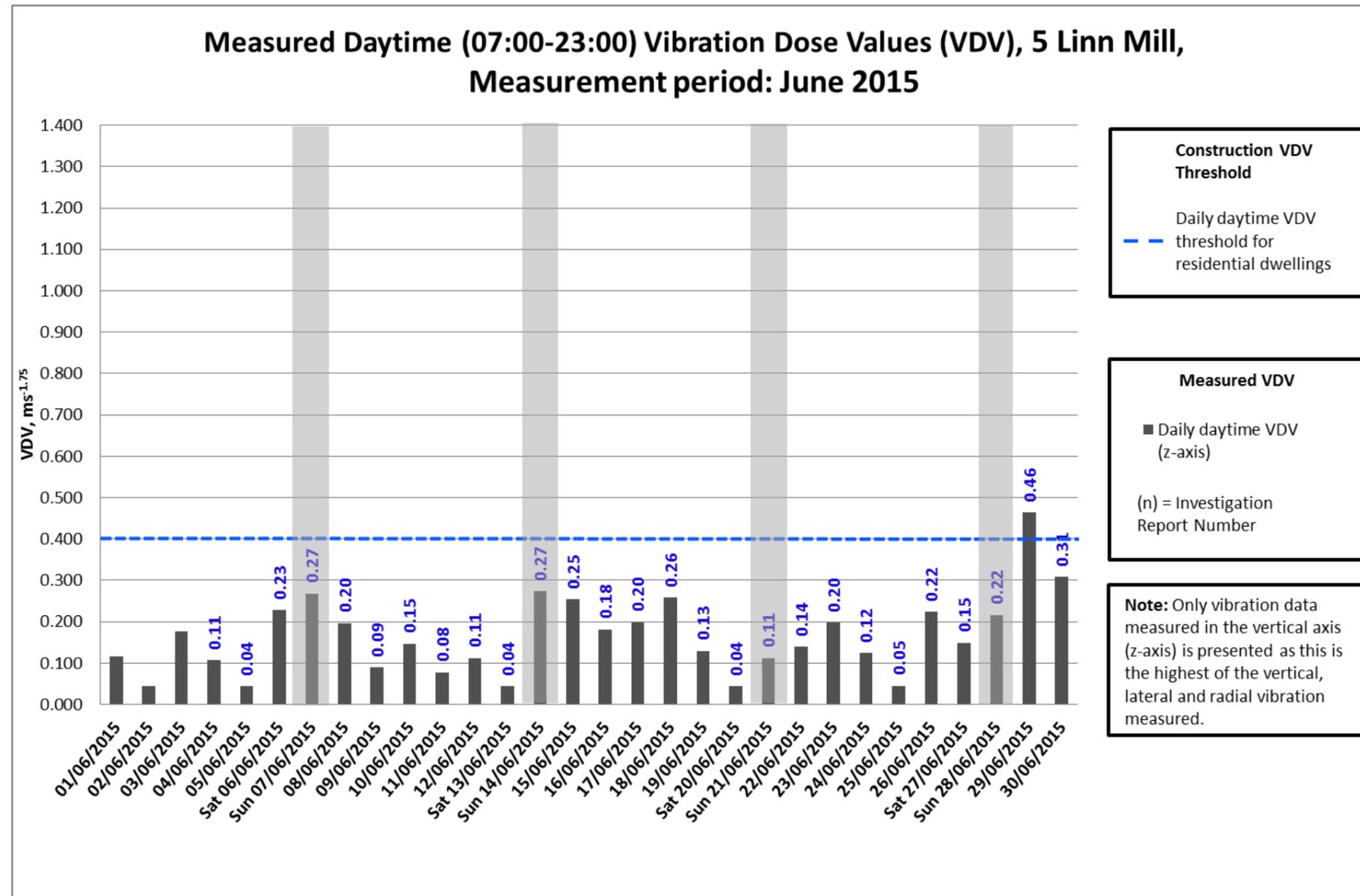


### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: June 2015

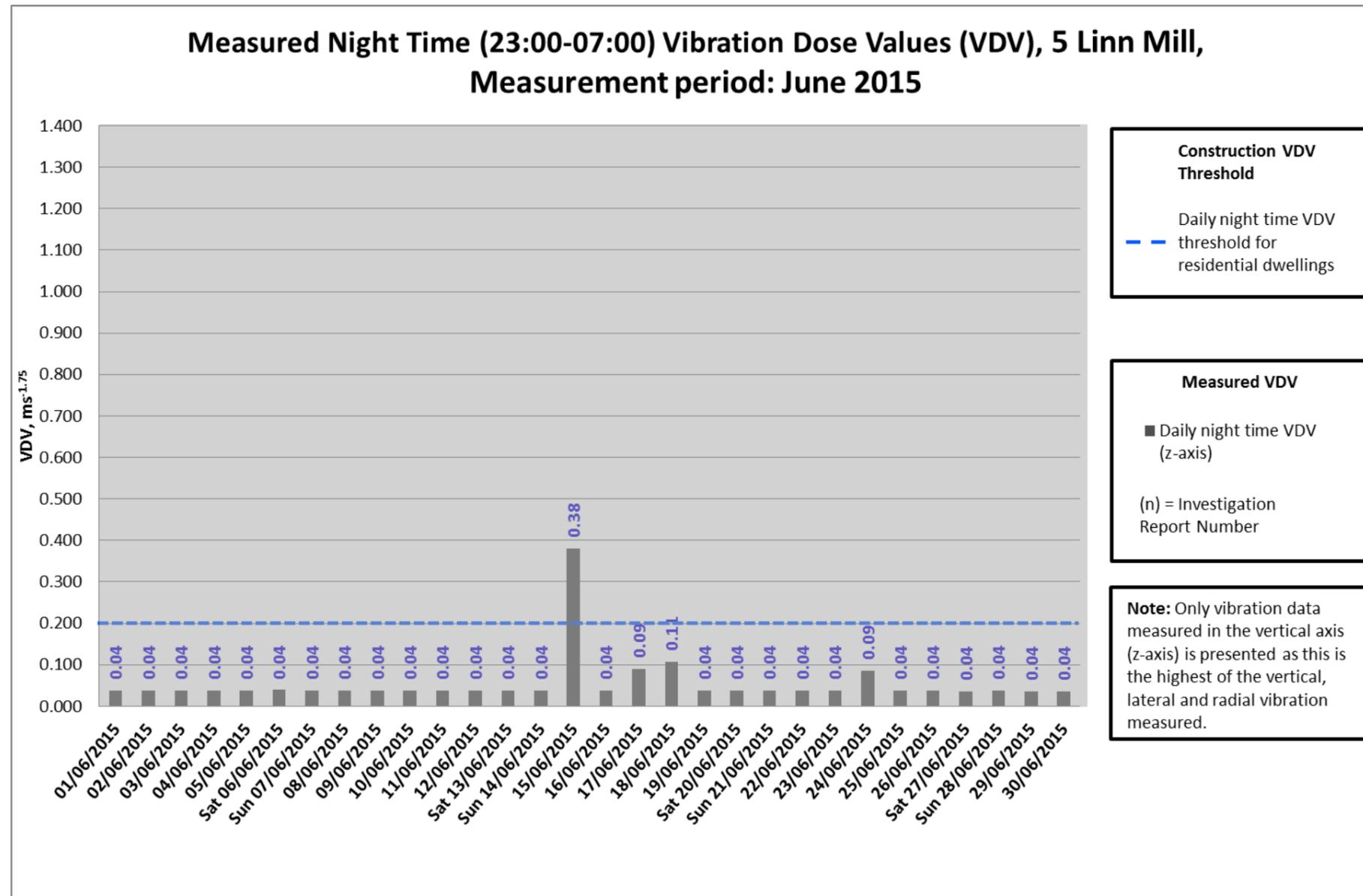




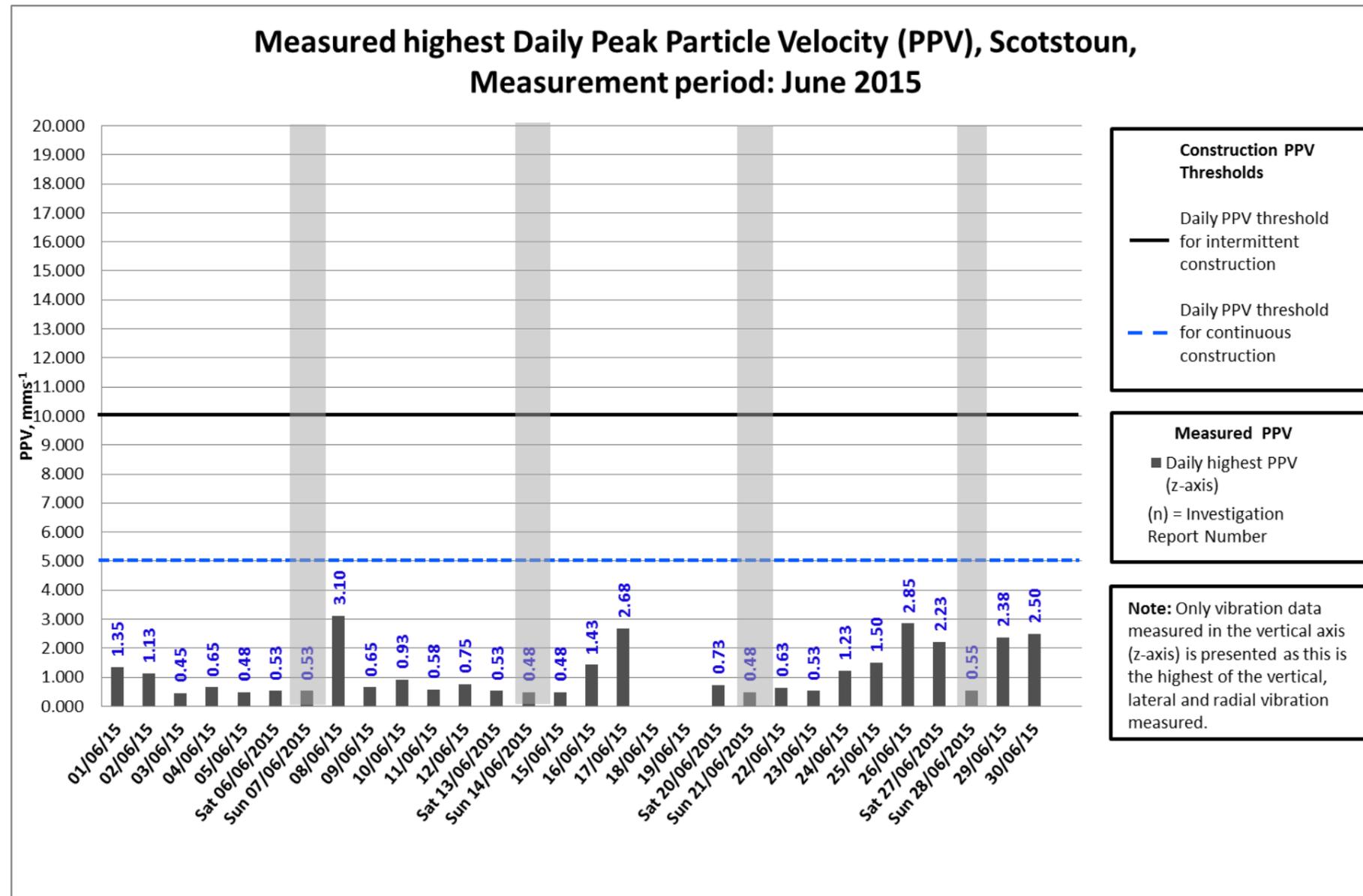
Note: Investigations have found the exceedances in the graph are due to the resident at 5 Linn mill having works done in close proximity of the vibration monitor. Referencing the graph above from the 8<sup>th</sup> of June you can see the exceedances are made at evening Out of construction working hours. This is typical for all exceedances at Linn Mill for the month of June. Furthermore Cross references with other vibration monitors in this location show no vibration similarities, concluding that the exceedances are local not related to construction.



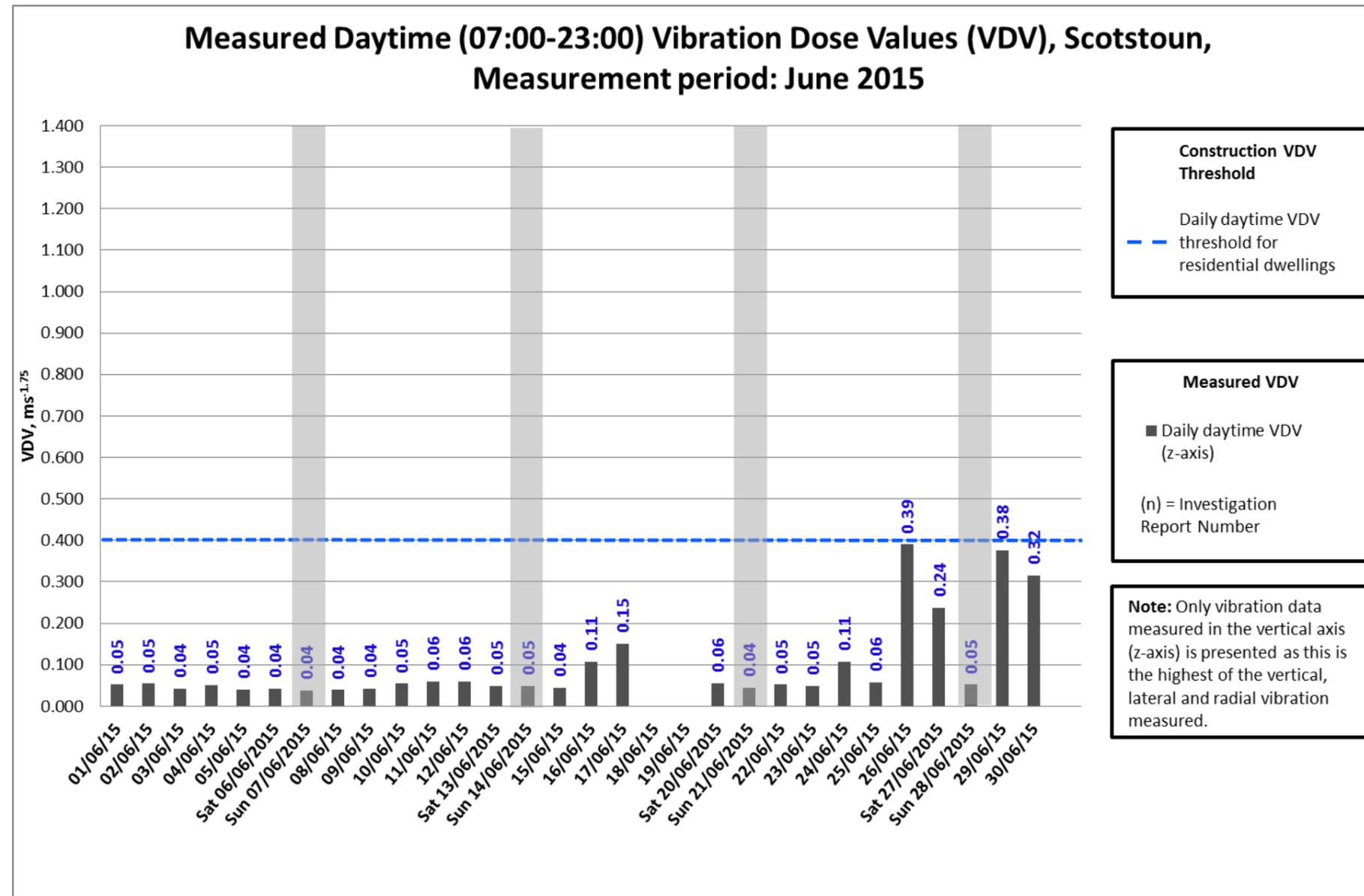
Note: Investigations have found the exceedances in the graph are due to the resident at 5 Linn mill having works done in close proximity of the vibration monitor.



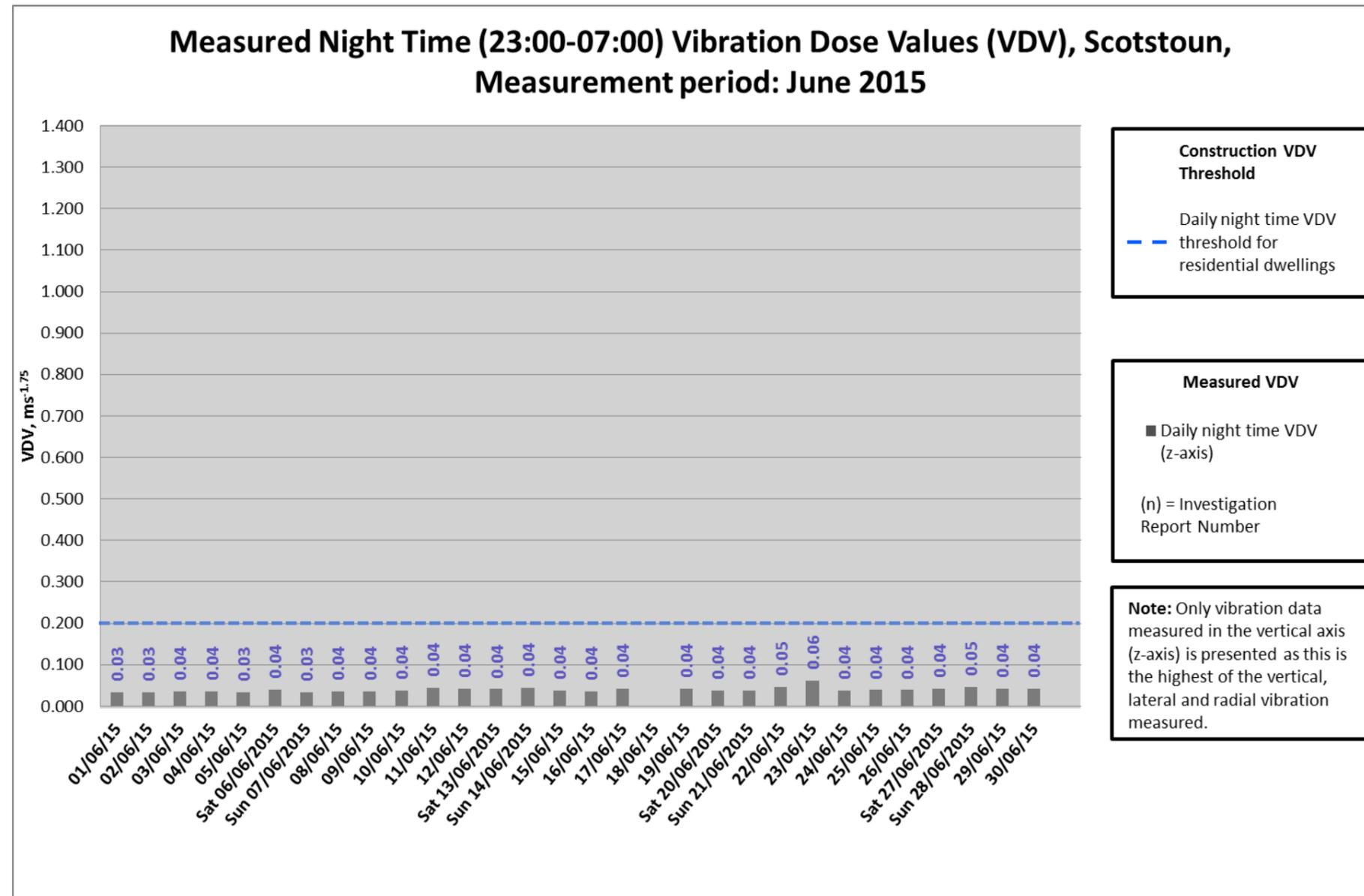
Note: Investigations have found the exceedances in the graph are due to the resident at 5 Linn mill having works done in close proximity of the vibration monitor



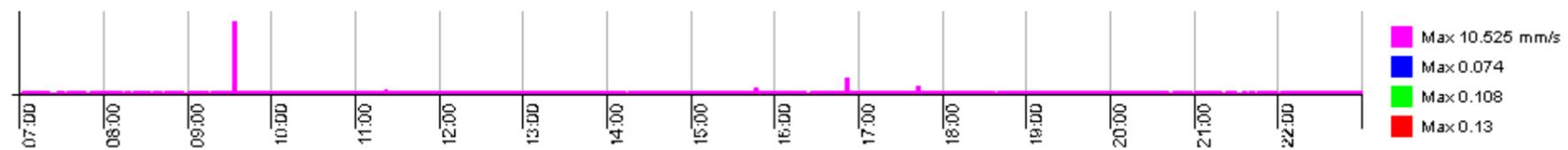
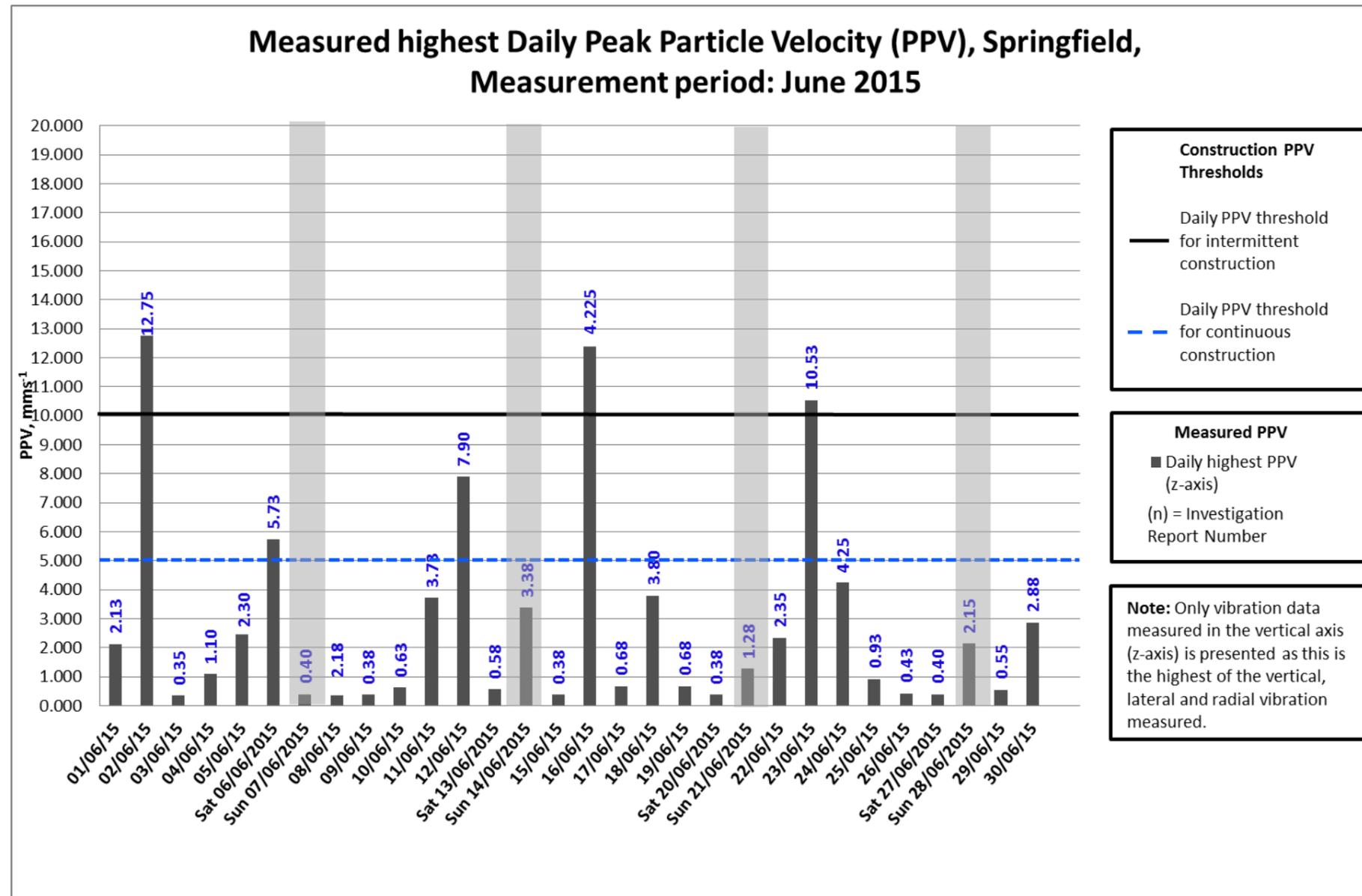
Note: Data missing due to a power problem at the monitor between the 18/06/2015 to the 19/06/2015.



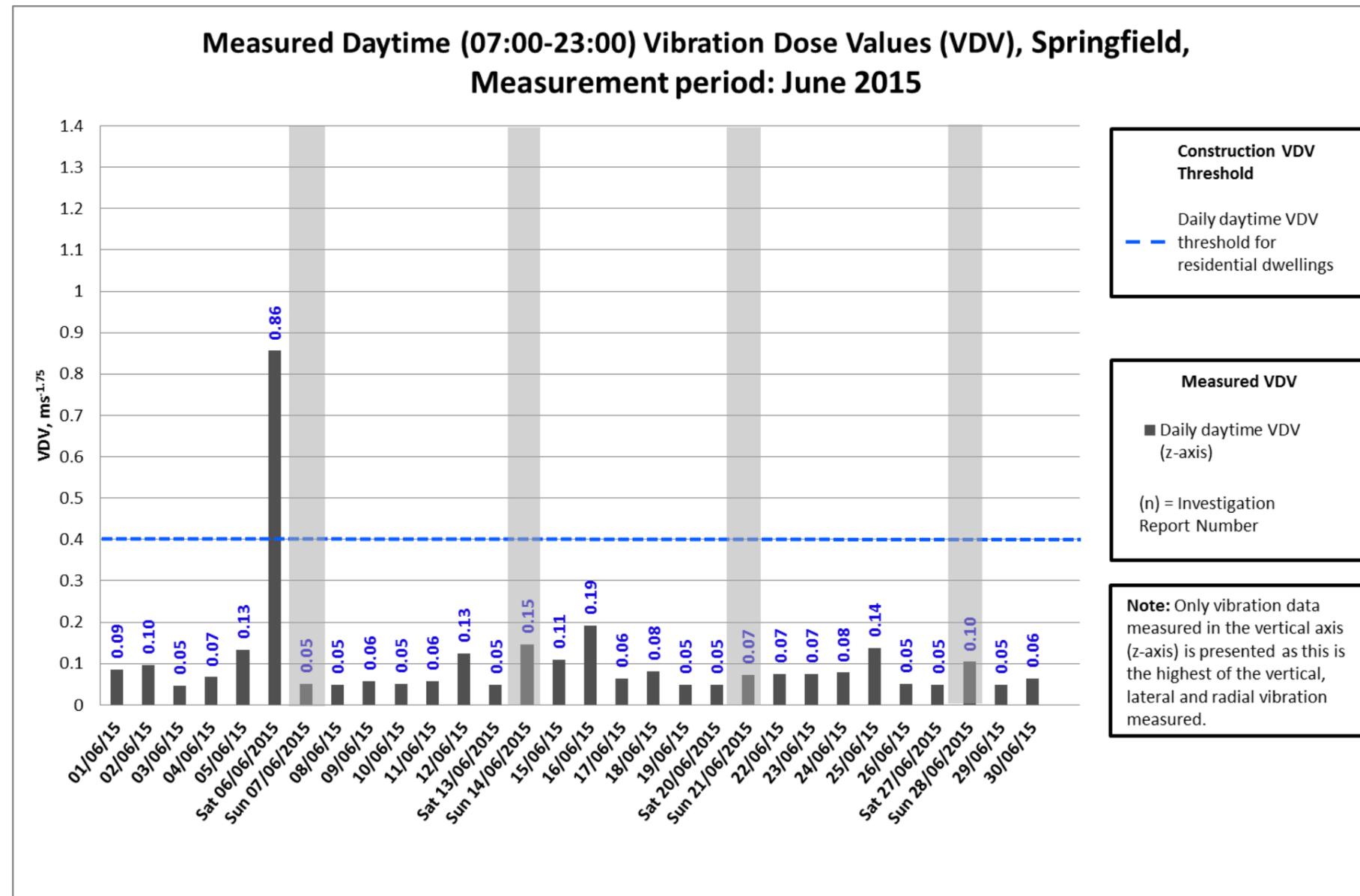
Note: Data missing due to a power problem at the monitor between the 18/06/2015 to the 19/06/2015.



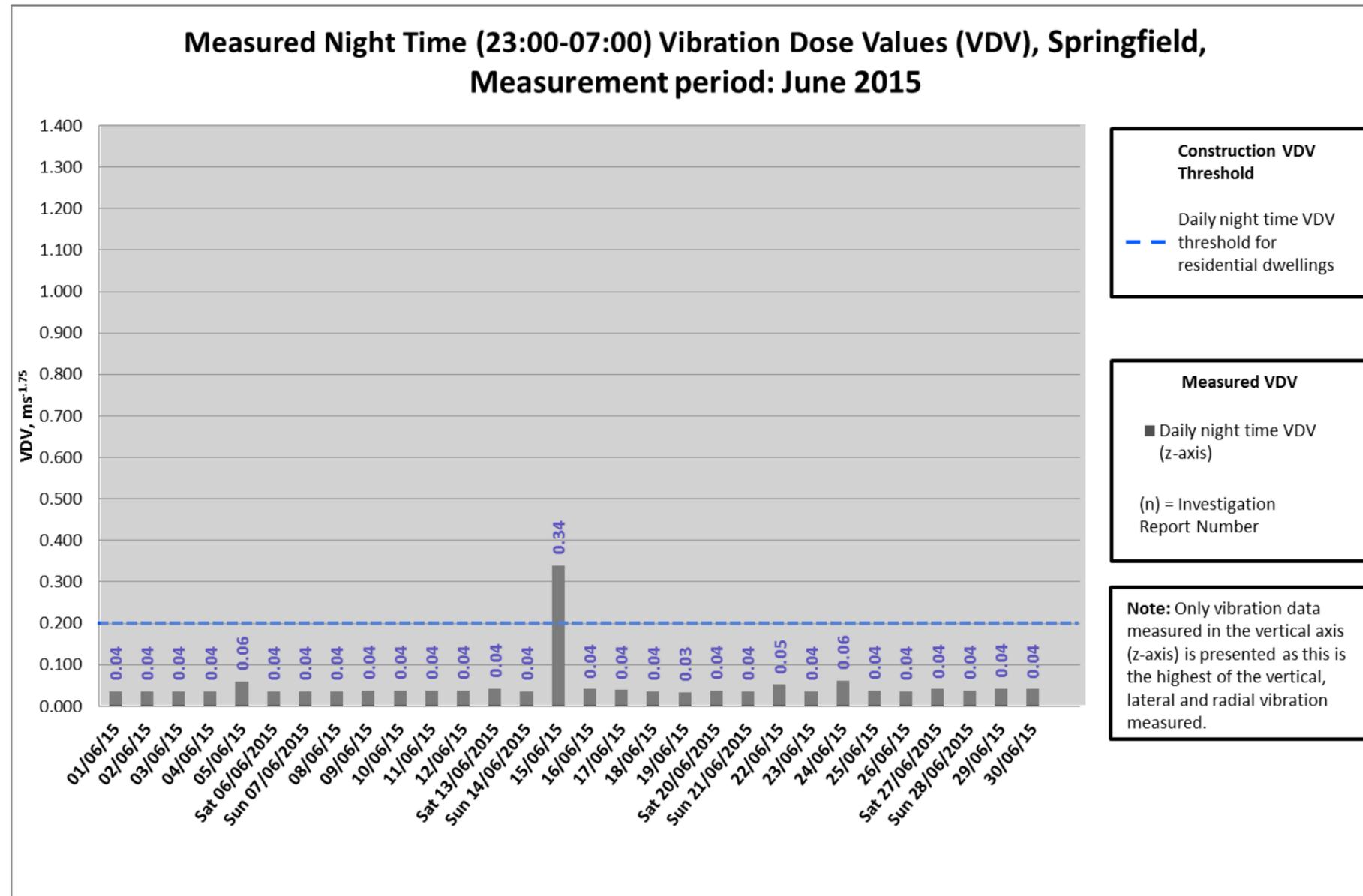
Note: Data missing due to a power problem at the monitor between the 18/06/2015 to the 19/06/2015 they supply was rectified by the evening hence why we have results for VDV evening .



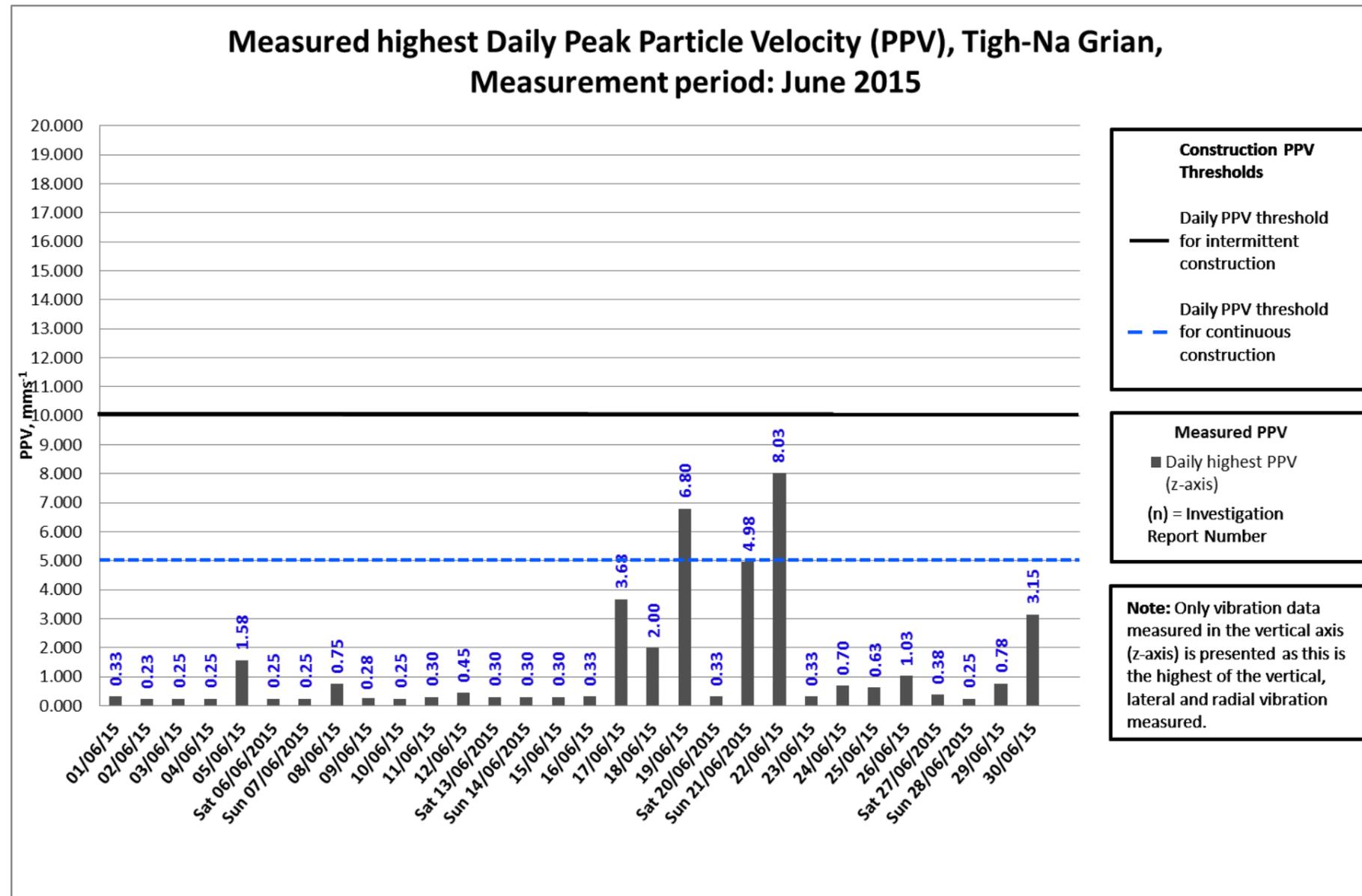
Note: The 02/06/2015 and the 23/06/2015 exceedances were due to monitor maintenance as seen above. Investigations for the 06/06/2015, 12/06/2015 and the 16/06/2015 have found the distance away from the nearest works was 280m away from the monitor. The vibration monitor at Linn mill is only 180m away. Comparing both graphs there was no similarity's found, concluding the vibration isn't related to construction and more than likely to be external activity near/ directly above the transducers.



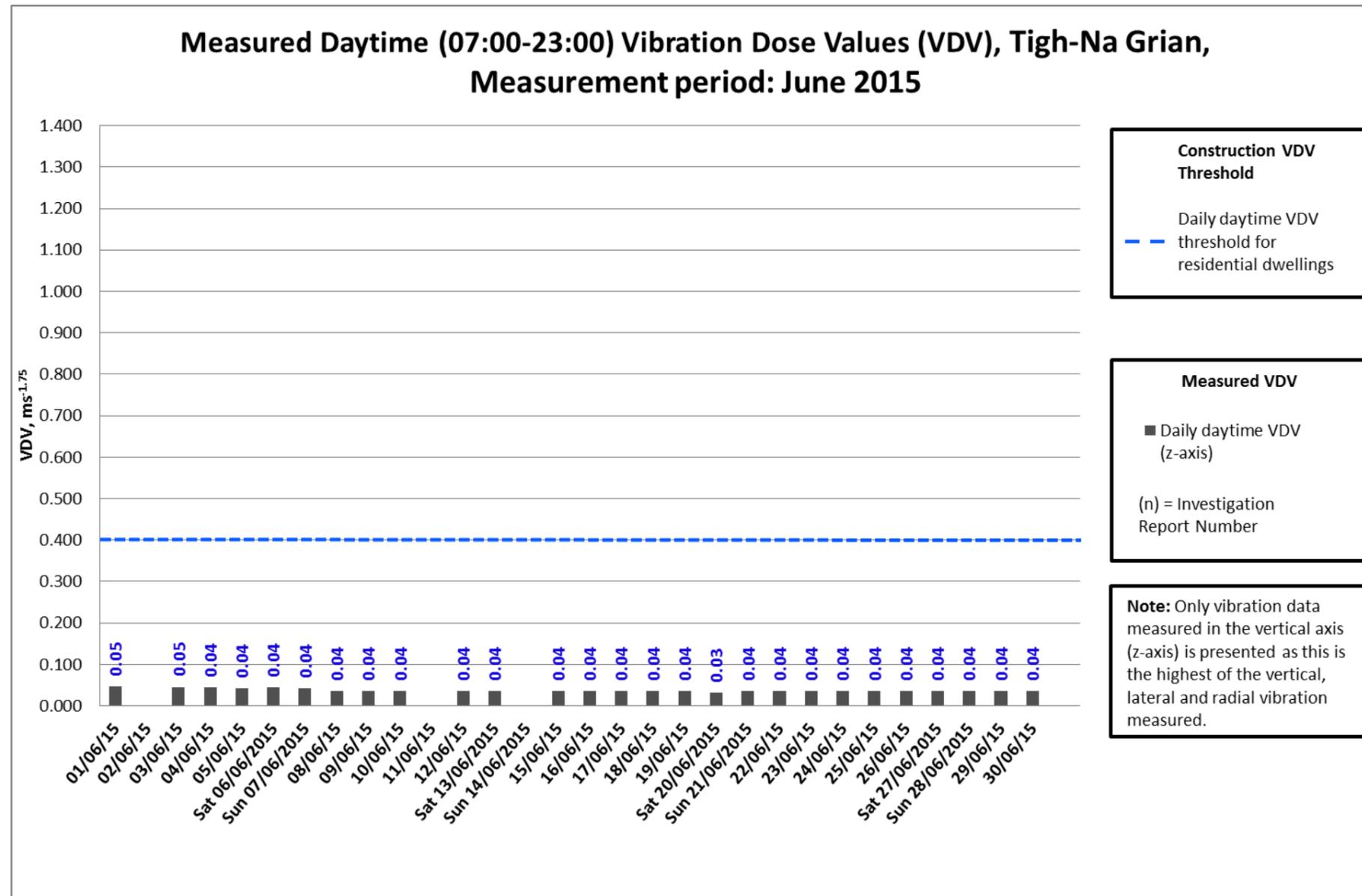
Investigation for the 06/06/2015 has found the distance away from the nearest works was 280m away from the monitor. The vibration monitor at Linn mill is only 180m away. Comparing both graphs there was no similarity's found, concluding the vibration isn't related to construction and more than likely to be external activity near/ directly above the transducers.



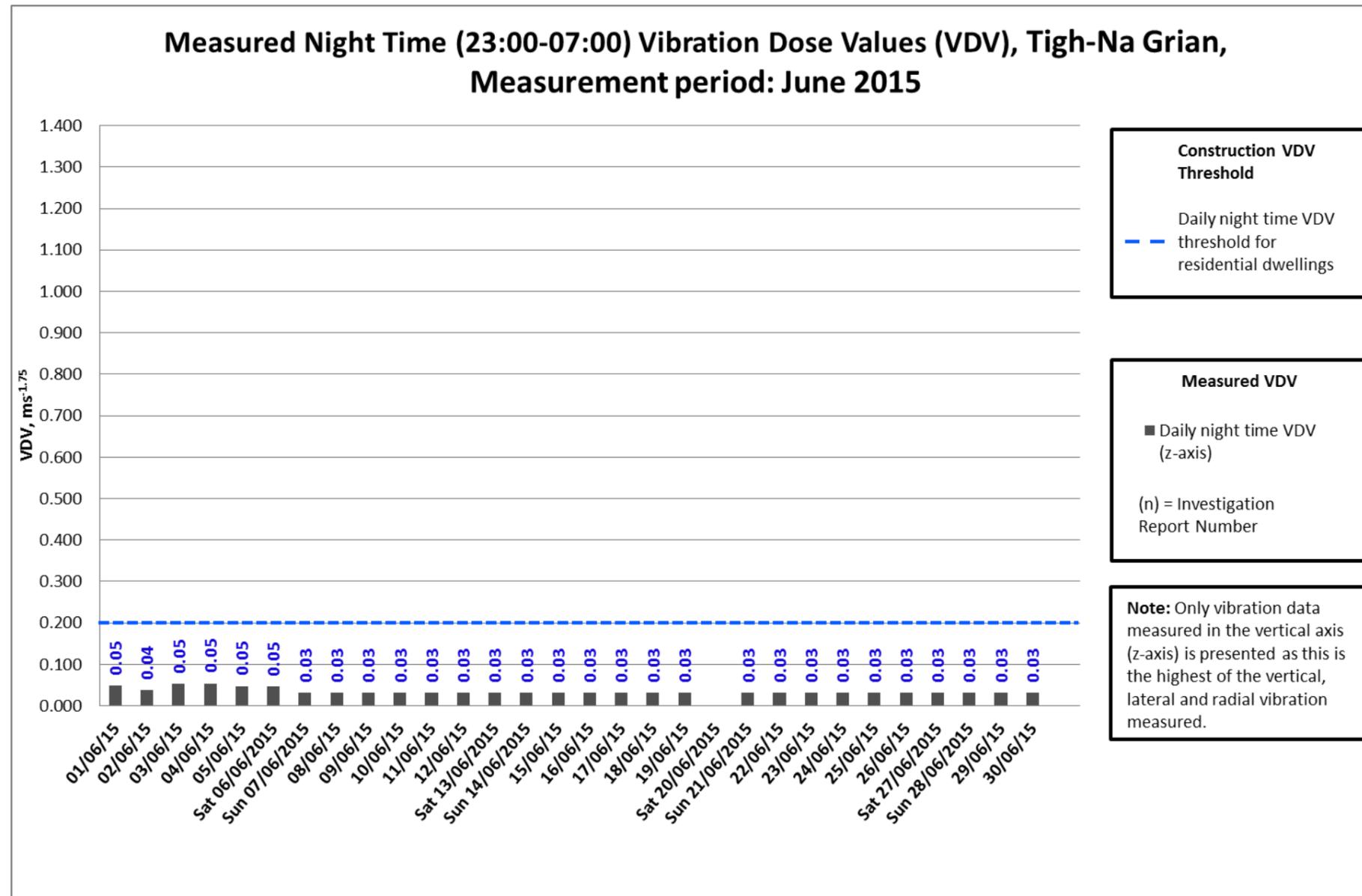
Note: The VDV values on 15/06/15 have been investigated and have seen to be an individual, isolated event within the period. This figure is due to external activity near/ directly above the transducers.



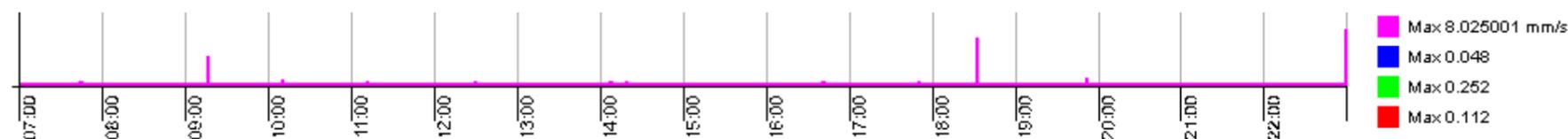
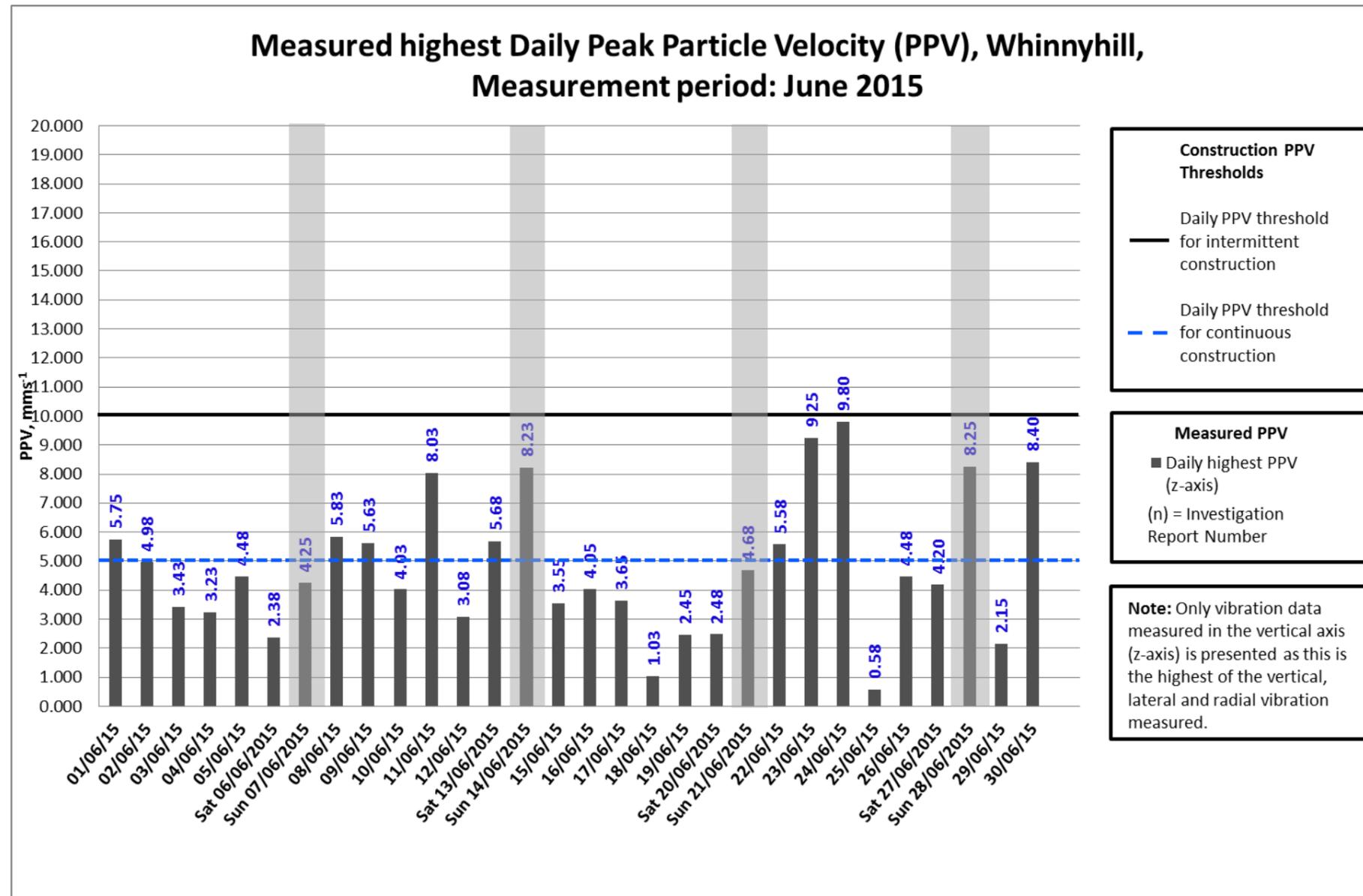
Note: The PPV values on 19/06/15 and 22/06/15 have all been investigated and have been seen to be individual, isolated events within the period. These values are due to monitor maintenance and most likely due to external activity near/ directly above the transducers.



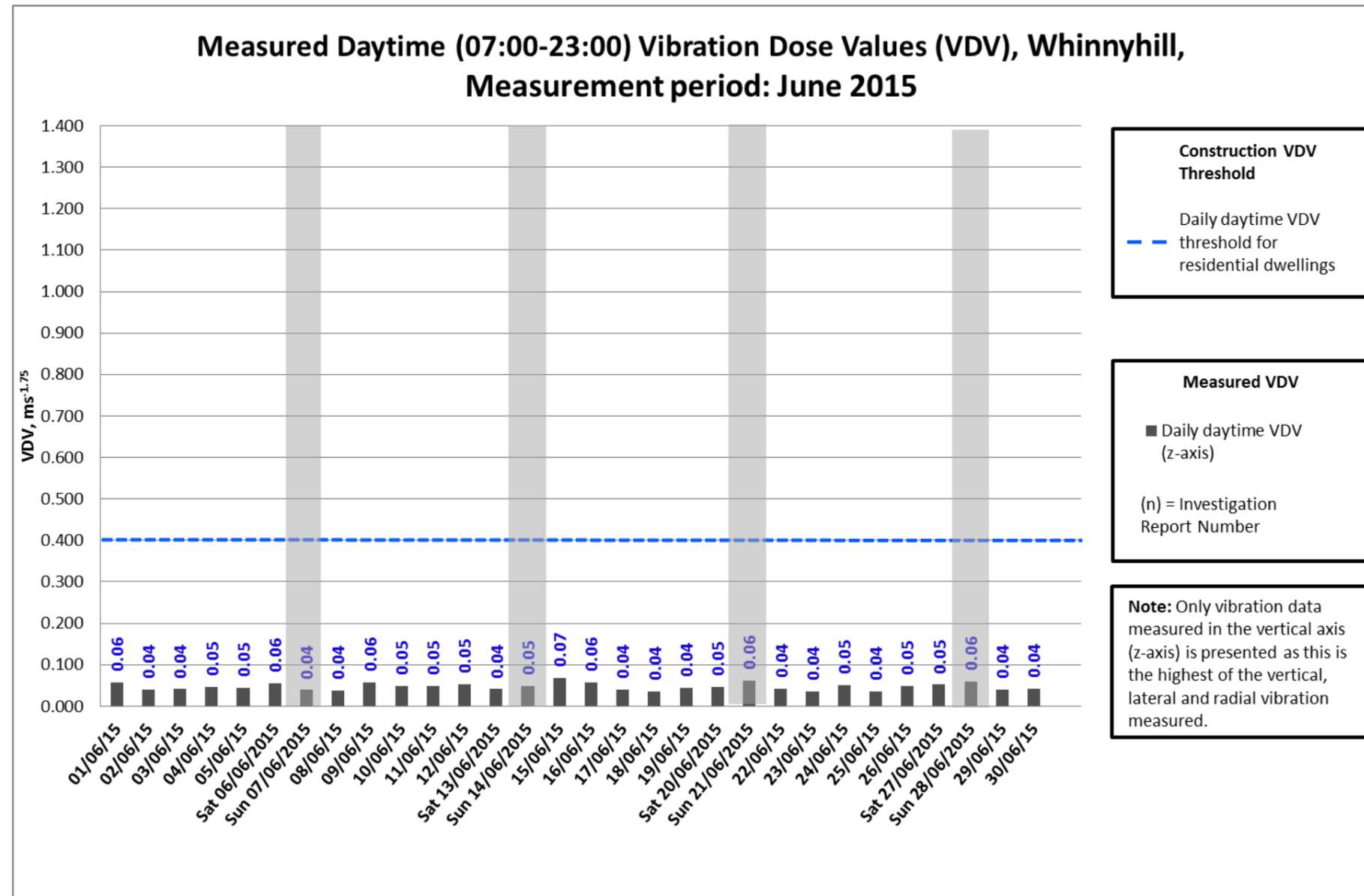
Note: Missing data on the 02/06/2015, 11/06/2015 and 14/06/2015 is due to corrupt files.



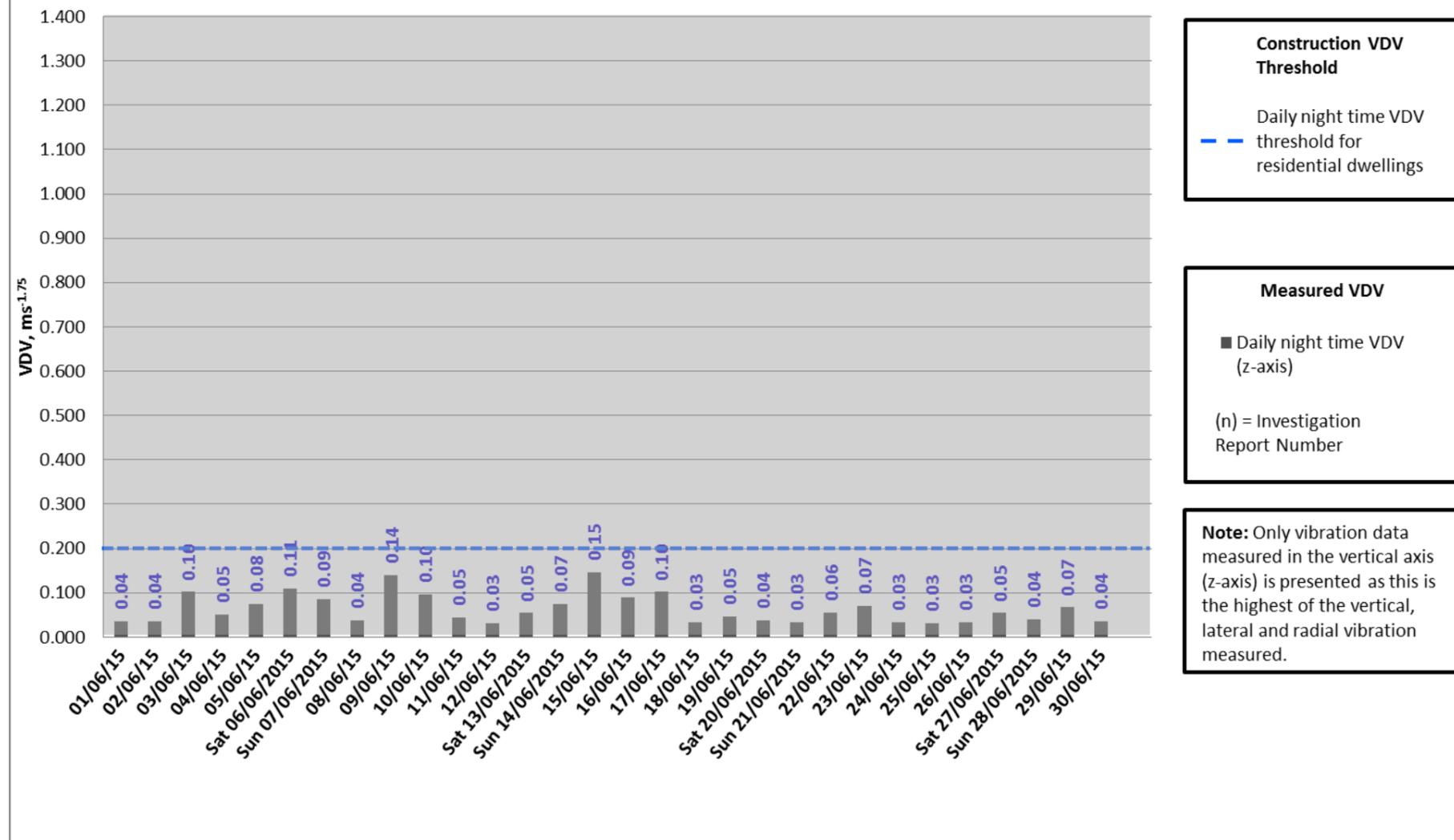
Note: Missing data on the 20/06/2015 is due to corrupt files.



Note: The exceedances on the 08/06/2015, 09/06/2015, 11/06/2015, 13/06/2015, 14/06/2015, 22/06/2015, 23/06/2015, 24/06/2015 and 30/06/2015 have been investigated and have been found to be intermittent vibration that was an isolated incident (reference the graph above on the 11/06/2015 above).



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: June 2015



**Construction VDV Threshold**

Daily night time VDV threshold for residential dwellings

**Measured VDV**

■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.