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Project FORTH REPLACEMENT CROSSING

Document title

VIBRATION MONITORING REPORT  
MAY 2016

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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 May 2016. 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, doors being slammed, 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**

**May 2016**

Location	PPV Exceedance		VDV Exceedance	
	Continuous ( $5 \text{ mm.s}^{-1}$ )	Intermittent ( $10 \text{ mm.s}^{-1}$ )	Day ( $0.4 \text{ m.s}^{-1.75}$ )	Night ( $0.2 \text{ m.s}^{-1.75}$ )
Linn Mill	9	1	0	0
Butlaw Fisheries	0	1	0	0
Clufflat Brae	19	2	0	0
Dundas Home Farm	0	0	0	0
Echline	0	0	0	0
Inchgarvie Lodge	1	3	0	0
Scotstoun	0	0	0	0
Springfield	11	3	0	0
Tigh-Na-Grian	0	0	0	0
Whinnyhill	6	1	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  $5 \text{ mm.s}^{-1}$  for continuous construction (e.g. piling), and  $10 \text{ mm.s}^{-1}$  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 however no exceedances were recorded as a result of the use of this equipment.,.
- 2.12.** Detailed investigation of all other exceedances (i.e. review of PPV levels over 30 seconds periods) has shown that each resulted from isolated, non-construction related events, which occurred close to the monitoring station.
- 2.13.** Within the Appendix B, there are gaps of missing data in the PPV and VDV of Dundas graphs. These occurred due to a power supply issue that was resolved on the 11<sup>th</sup> of May.

### **3. CONCLUSION**

- 3.1.** Considering the distance between FCBC construction works and sensitive receptors, and the methods of working utilised, 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 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 May 2016
M1	Whinny Hill	Network	<ul style="list-style-type: none"> <li>• Earthworks/Fill placement</li> <li>• Hope Street roadworks</li> <li>• FT03 &amp; FT04 works</li> <li>• FT19 Works</li> <li>• Main carriageway Roadworks</li> <li>• Rock breaking / crushing</li> </ul>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• North Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• Pier N1 &amp; N2 works</li> <li>• AVN Rebar and concrete works</li> </ul>
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• South Tower rebar, formwork, concreting works deck section lifts and stay cable installation works</li> <li>• Pier S1 works</li> <li>• Pier S2 works</li> <li>• AVS rebar &amp; concrete deck works</li> </ul>
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation</li> <li>• South Tower rebar, formwork, concreting works deck section lifts and stay cable installation</li> <li>• Pier S1 works</li> <li>• Pier S2 works</li> <li>• AVS rebar &amp; concrete deck works</li> <li>• South Abutment works</li> <li>• Main carriageway roadworks</li> </ul>
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• South Abutment works</li> </ul>
M13	Clufflat Brae	Crossing	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• South Abutment works</li> </ul>
M14	Springfield	Network	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• Main carriageway roadworks</li> <li>• South abutment works</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• AVS rebar &amp; concrete deck works</li> <li>• South abutment works</li> <li>• Main carriageway roadworks</li> </ul>
M16	Scotstoun	Network	<ul style="list-style-type: none"> <li>• Footpath works</li> <li>• Utility works</li> <li>• B800 North and South road works including bridge works</li> <li>• ESQ11 works</li> </ul>



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			<ul style="list-style-type: none"> <li>• Mainline roadworks</li> </ul>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> <li>• Utility works</li> <li>• B800 North and South roadworks including bridge works</li> <li>• ESQ11 works</li> <li>• Mainline roadworks</li> </ul>

Table 2: The main construction activities undertaken in the locality of each of the vibration monitors during the period of May 2016.

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

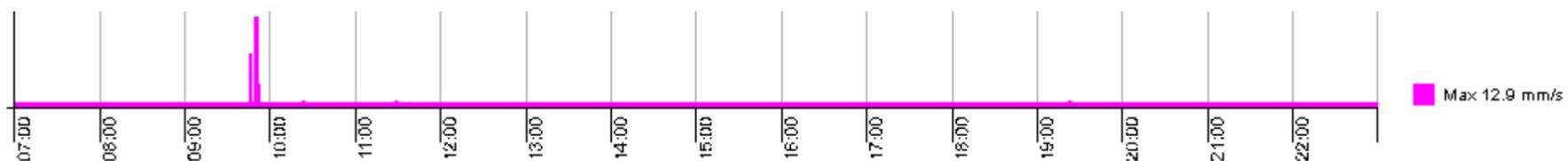
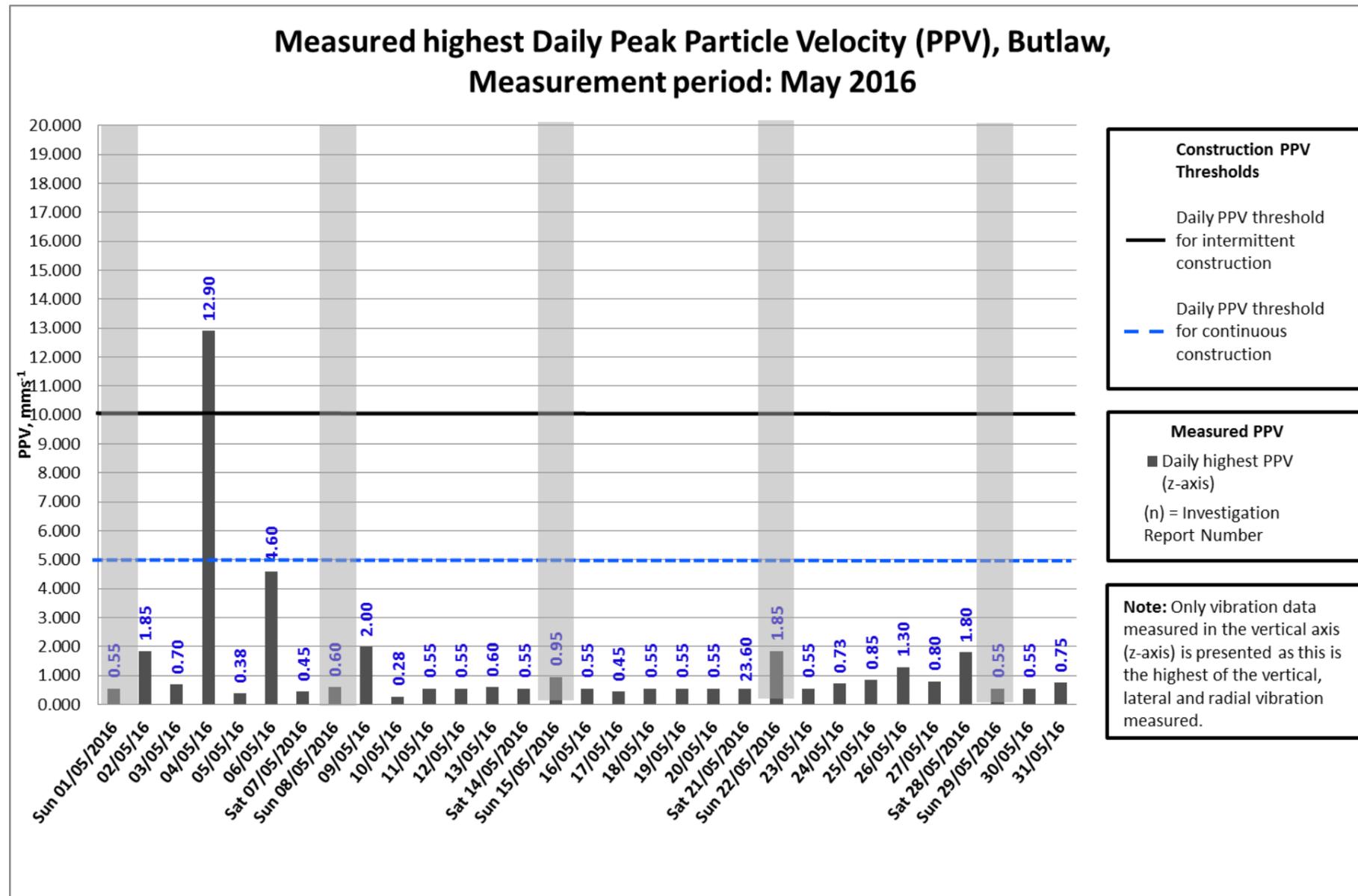
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	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**

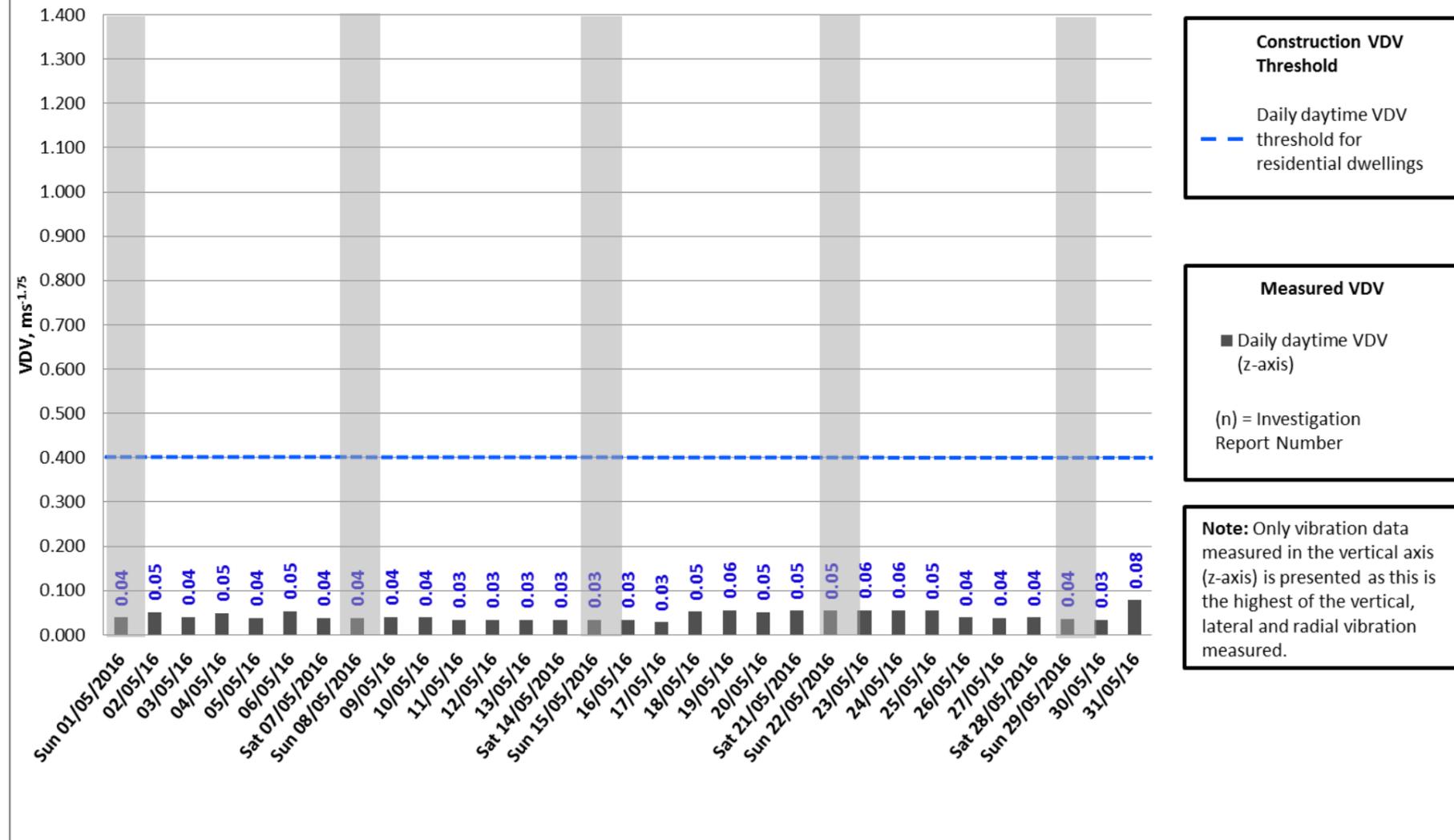
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 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

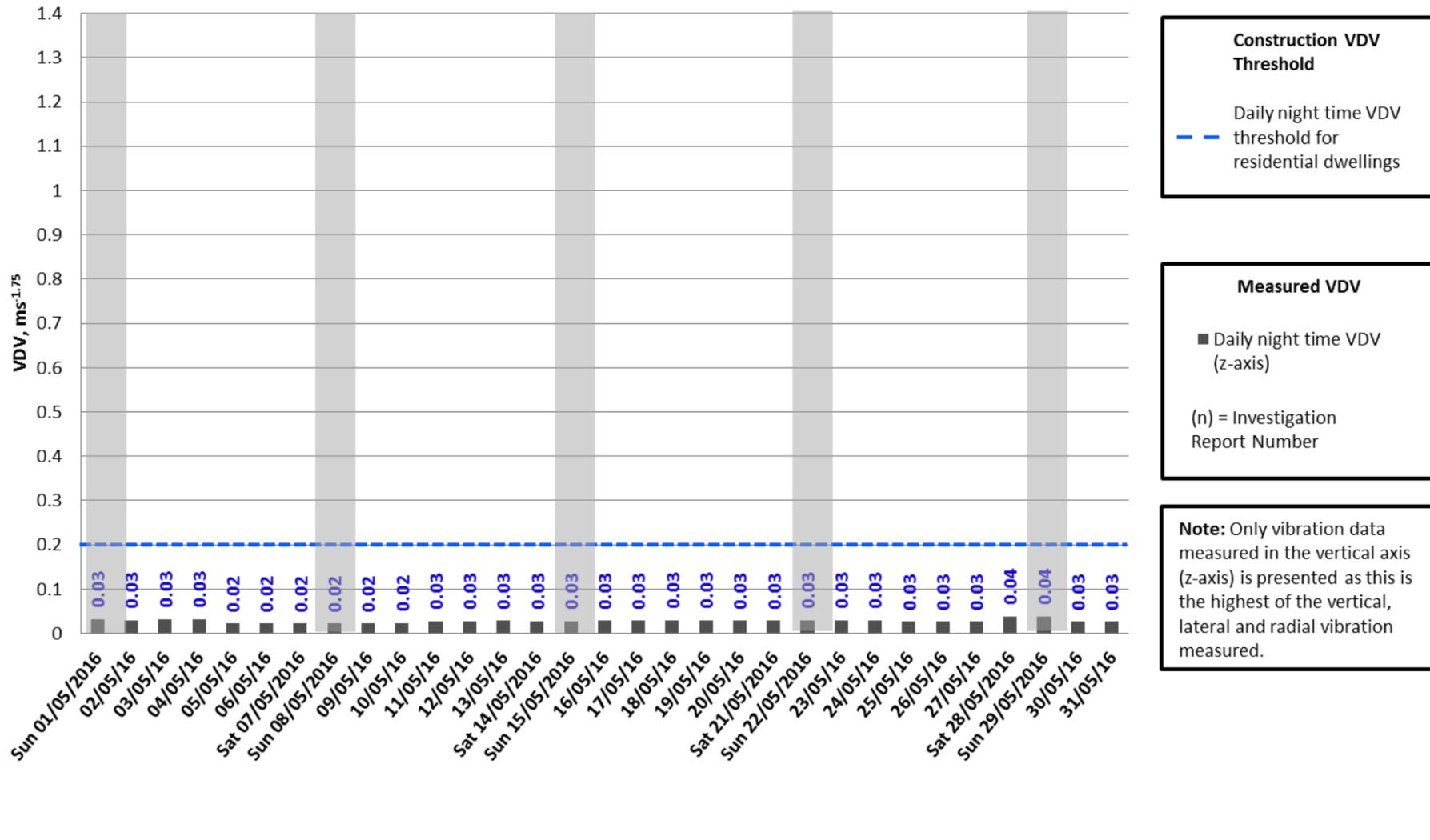


Exceedance on the 4<sup>th</sup> of May has been investigated and found to be caused by the environmental department carrying out maintenance on the noise monitor. Due to the proximity of the noise monitor to the vibration monitor activity from the environmental department was picked up (graph above from the 04/05/2016).

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw, Measurement period: May 2016



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Butlaw, Measurement period: May 2016



**Construction VDV Threshold**

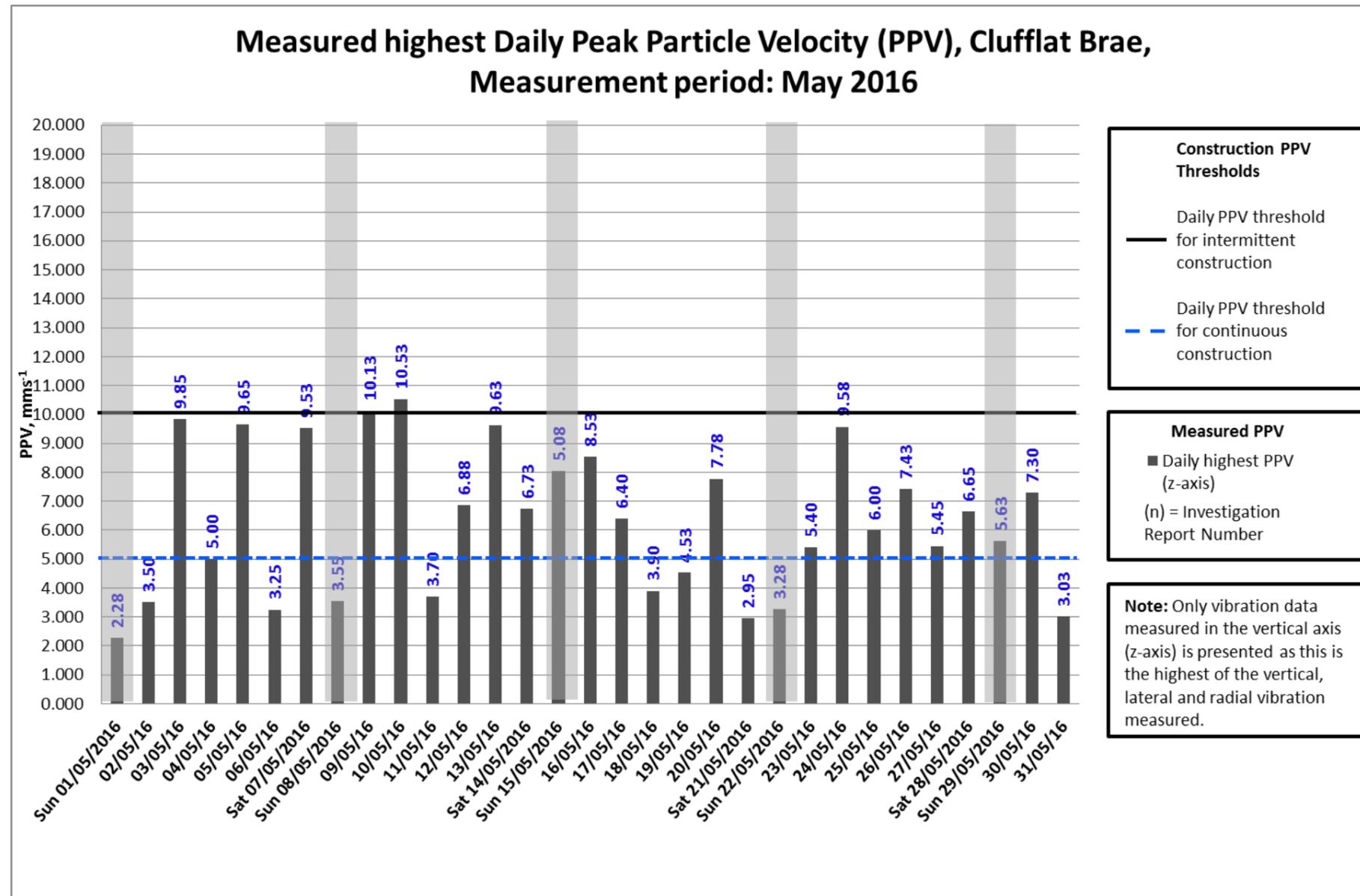
Daily night time VDV threshold for residential dwellings

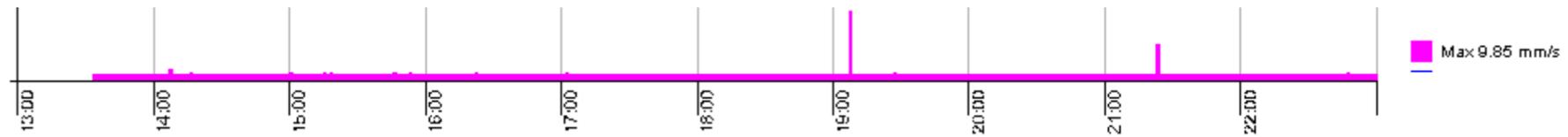
**Measured VDV**

■ Daily night time VDV (z-axis)

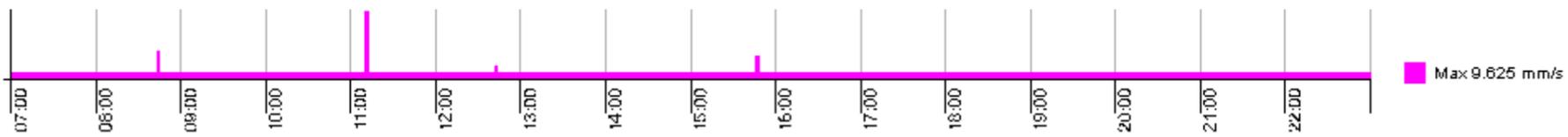
(n) = Investigation Report Number

**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.

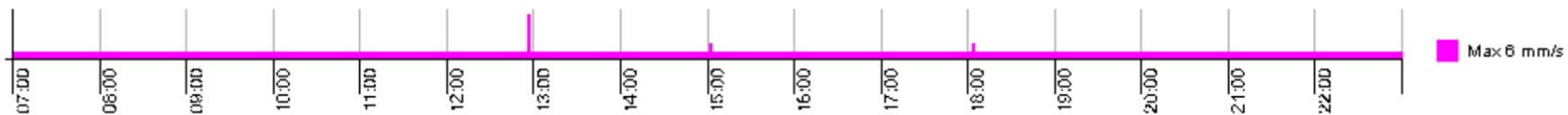




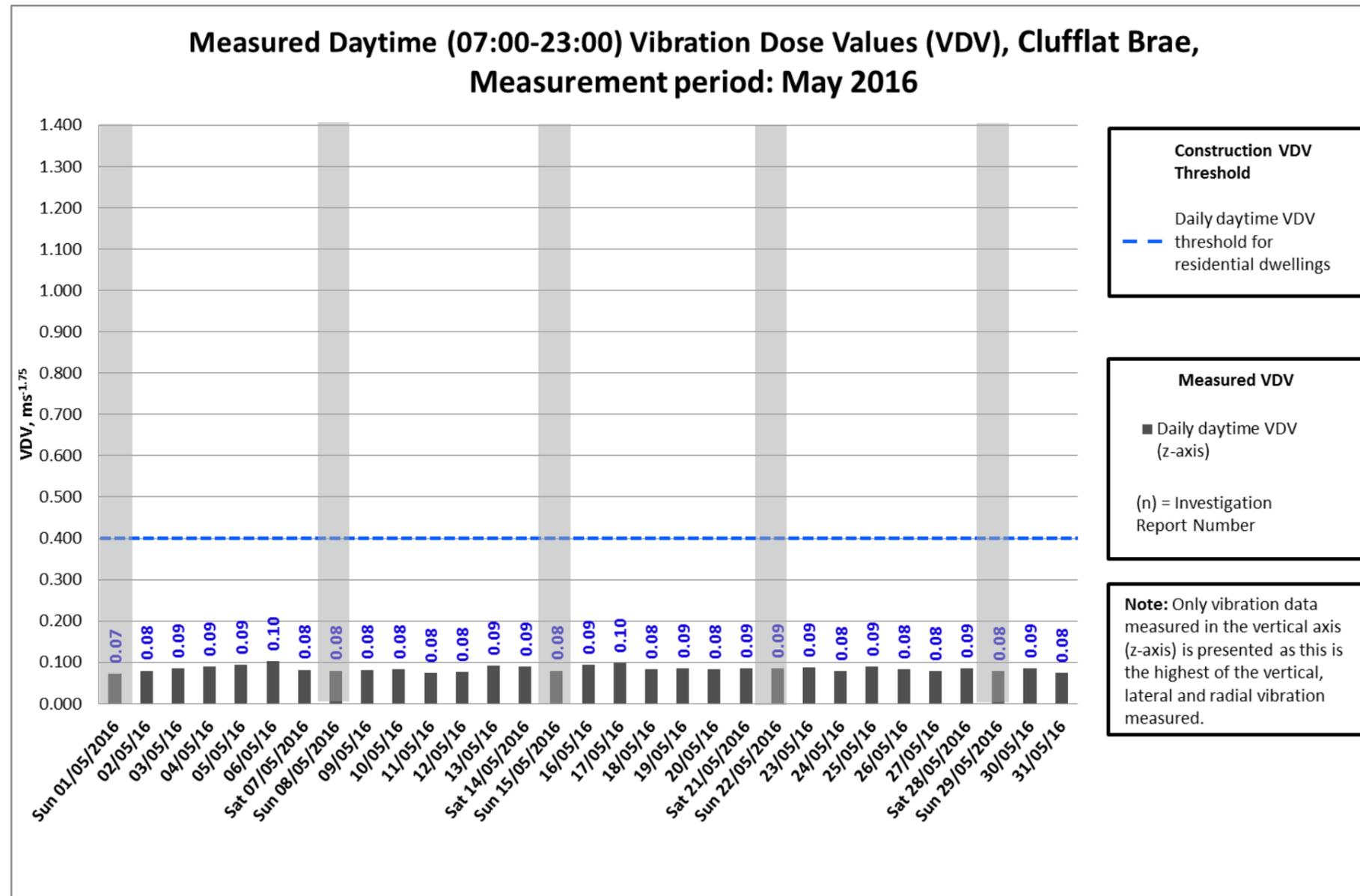
Exceedances on the 3<sup>rd</sup>, 10<sup>th</sup>, 12<sup>th</sup>, 15<sup>th</sup> and 24<sup>th</sup> of May have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 03/05/2016).

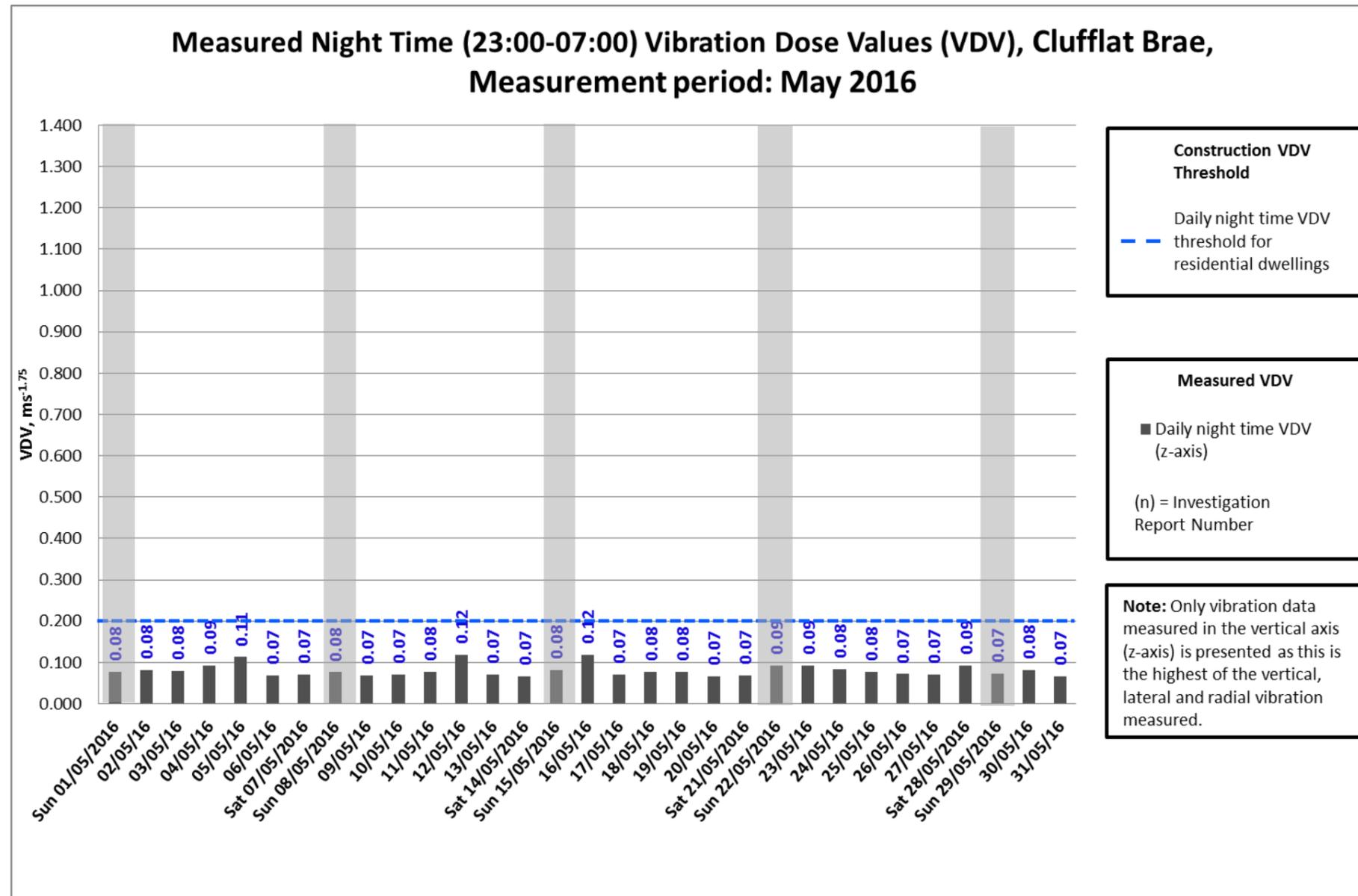


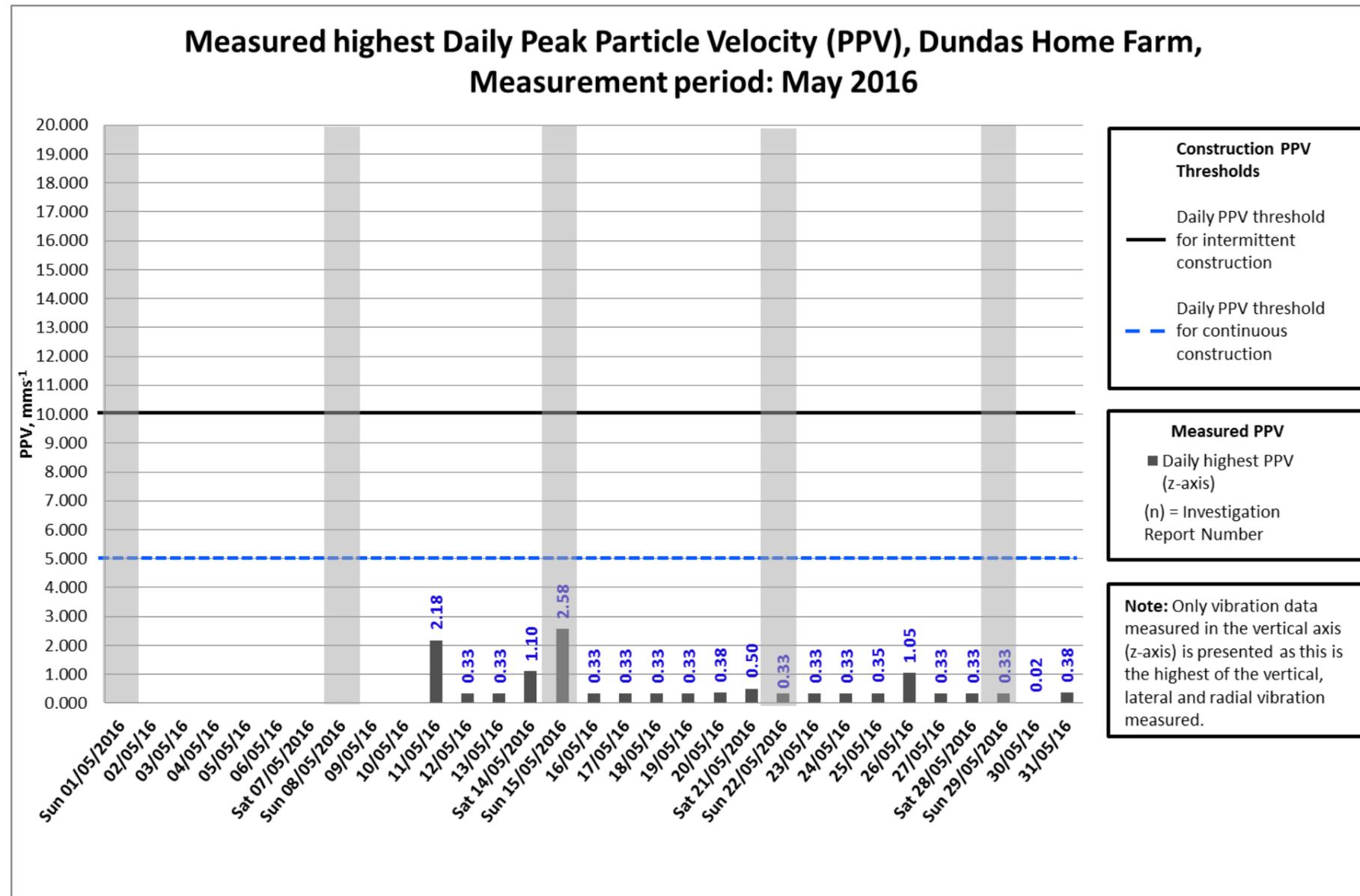
Exceedances on the 4<sup>th</sup>, 5<sup>th</sup>, 7<sup>th</sup>, 9<sup>th</sup>, 13<sup>th</sup>, 14<sup>th</sup>, 16<sup>th</sup>, 17<sup>th</sup>, 20<sup>th</sup>, 23<sup>rd</sup>, 26<sup>th</sup>, 27<sup>th</sup>, 28<sup>th</sup>, 29<sup>th</sup> and 30<sup>th</sup> of May have been investigated and found to be caused by individual isolated events (graph above from the 13/05/2016). Due to the closest works being approximately 220m away with minimal vibration emitting equipment used. Due to the monitor being located on a public path there is a likelihood that the exceedances seen above have been caused by residential movement on the path.



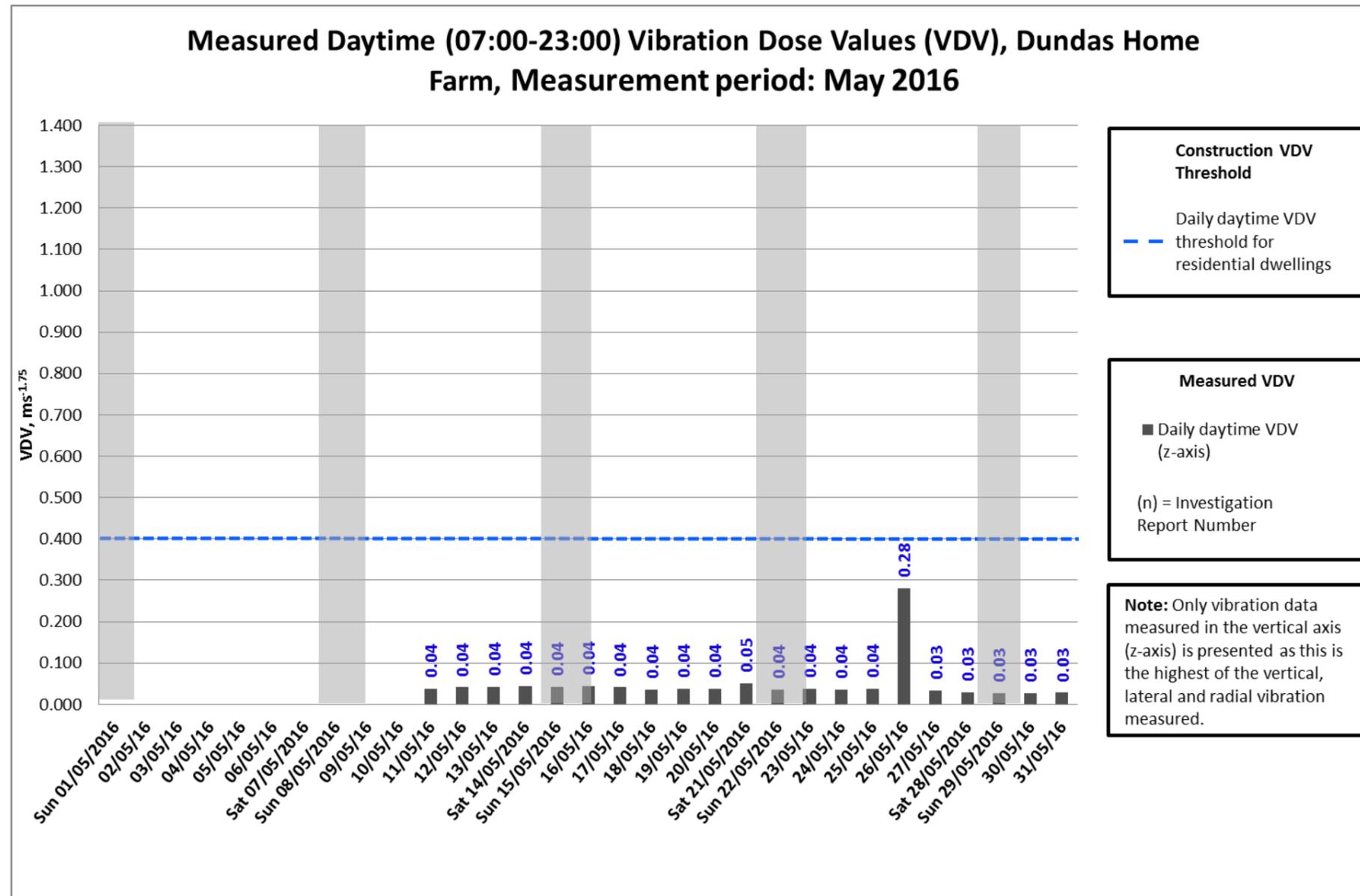
Exceedance on the 25<sup>th</sup> of May has been investigated and found to be caused by the environmental department recovering the Frisbee sample at this location. Due to close proximity of the Vibration monitor to the Frisbee monitor activity was picked up.



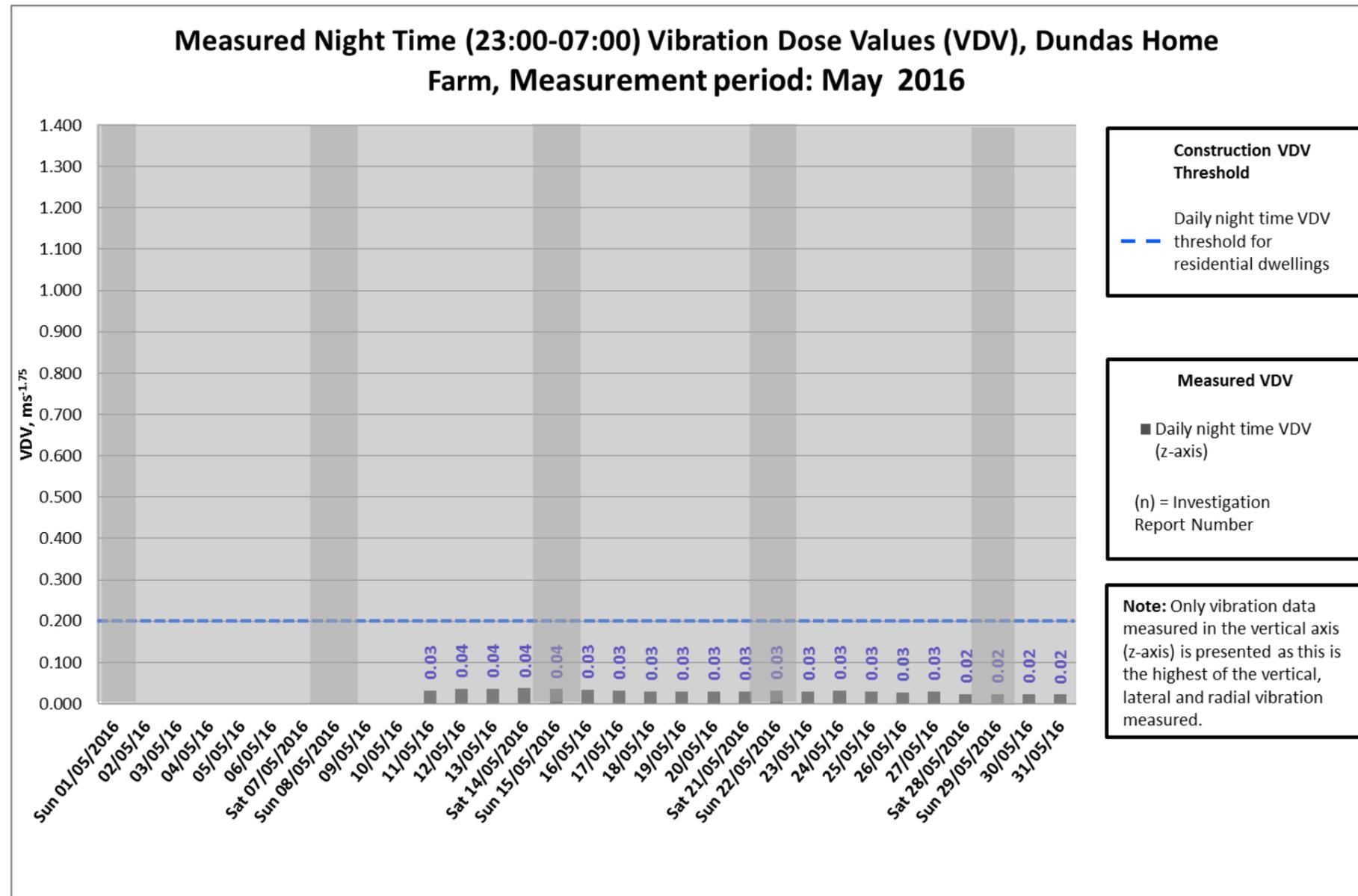




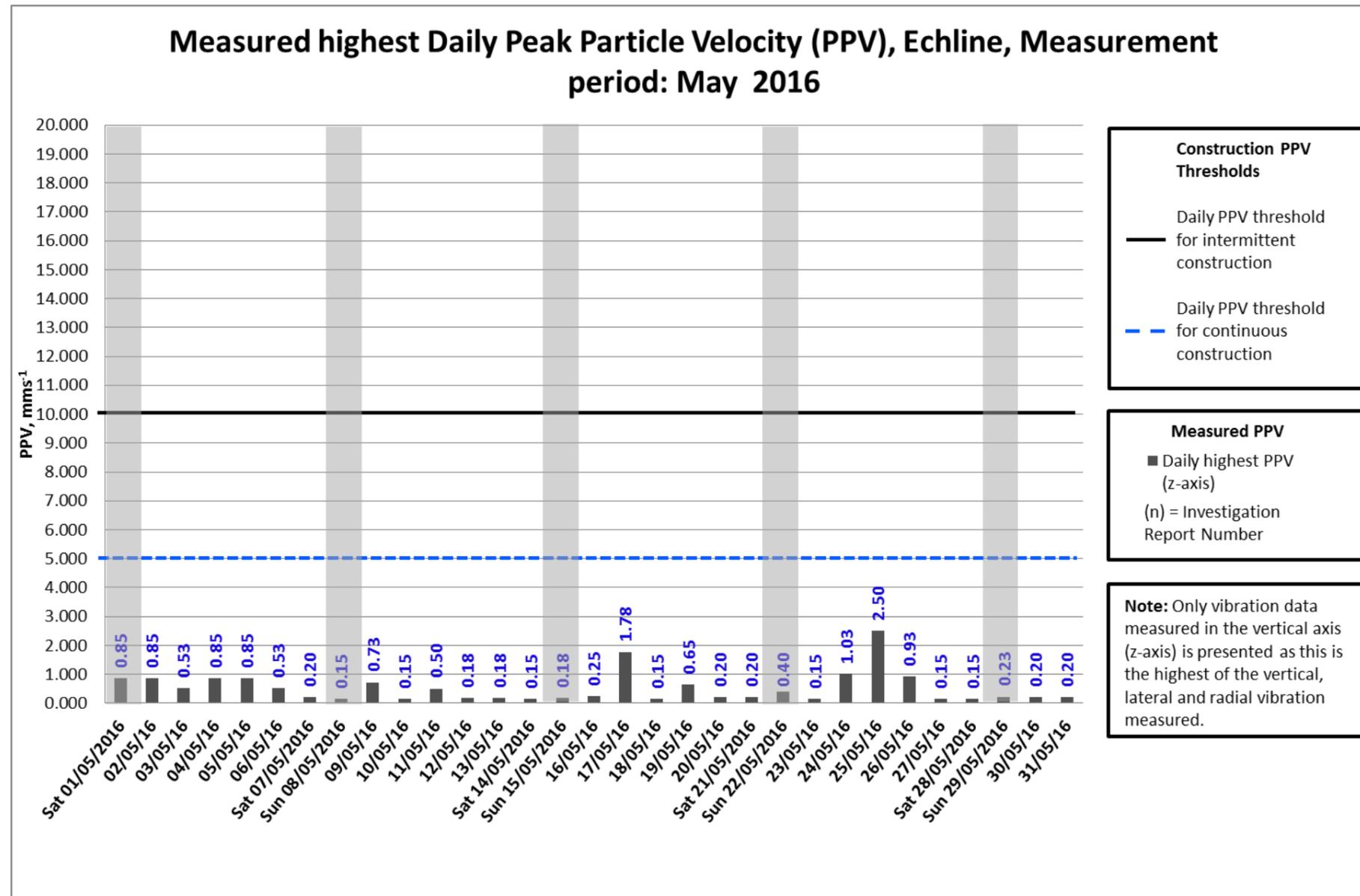
Data missing from the 1<sup>st</sup> to the 10<sup>th</sup> of May was caused by power issue at the monitor location. This has since been resolved on the 11<sup>th</sup> of May.

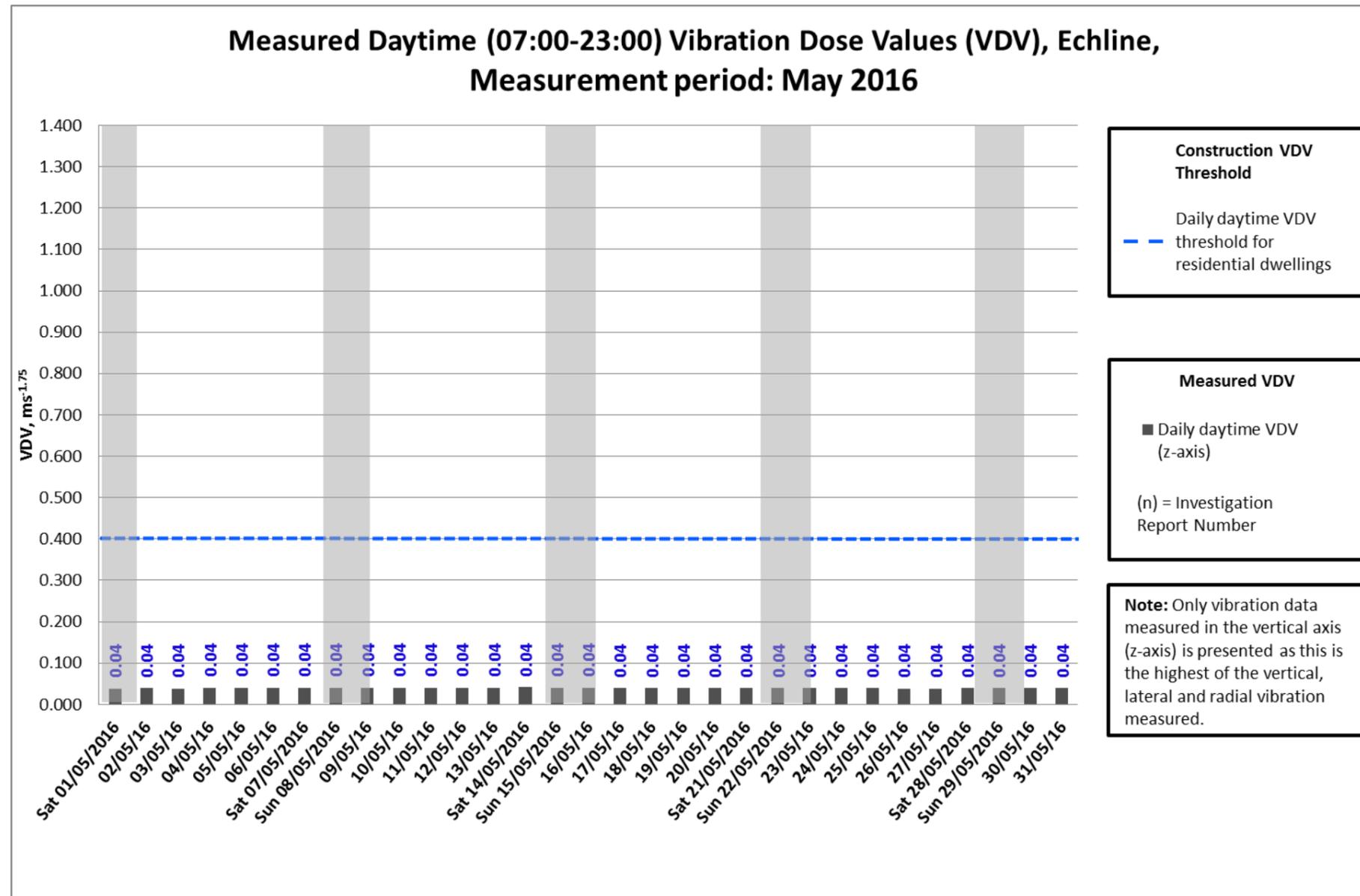


Data missing from the 1<sup>st</sup> to the 10<sup>th</sup> of May was caused by power issue at the monitor location. This has since been resolved on the 11<sup>th</sup> of May.

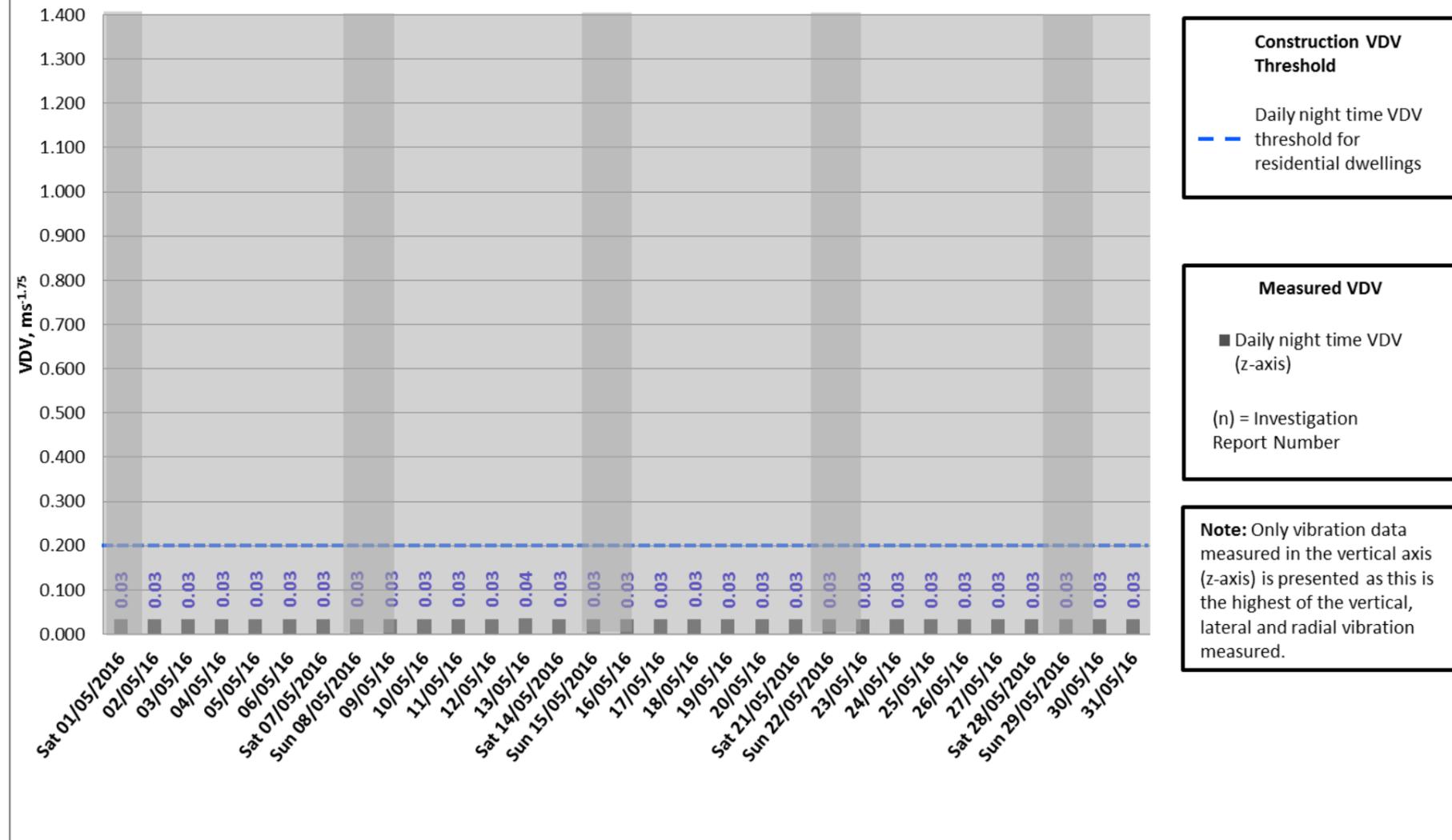


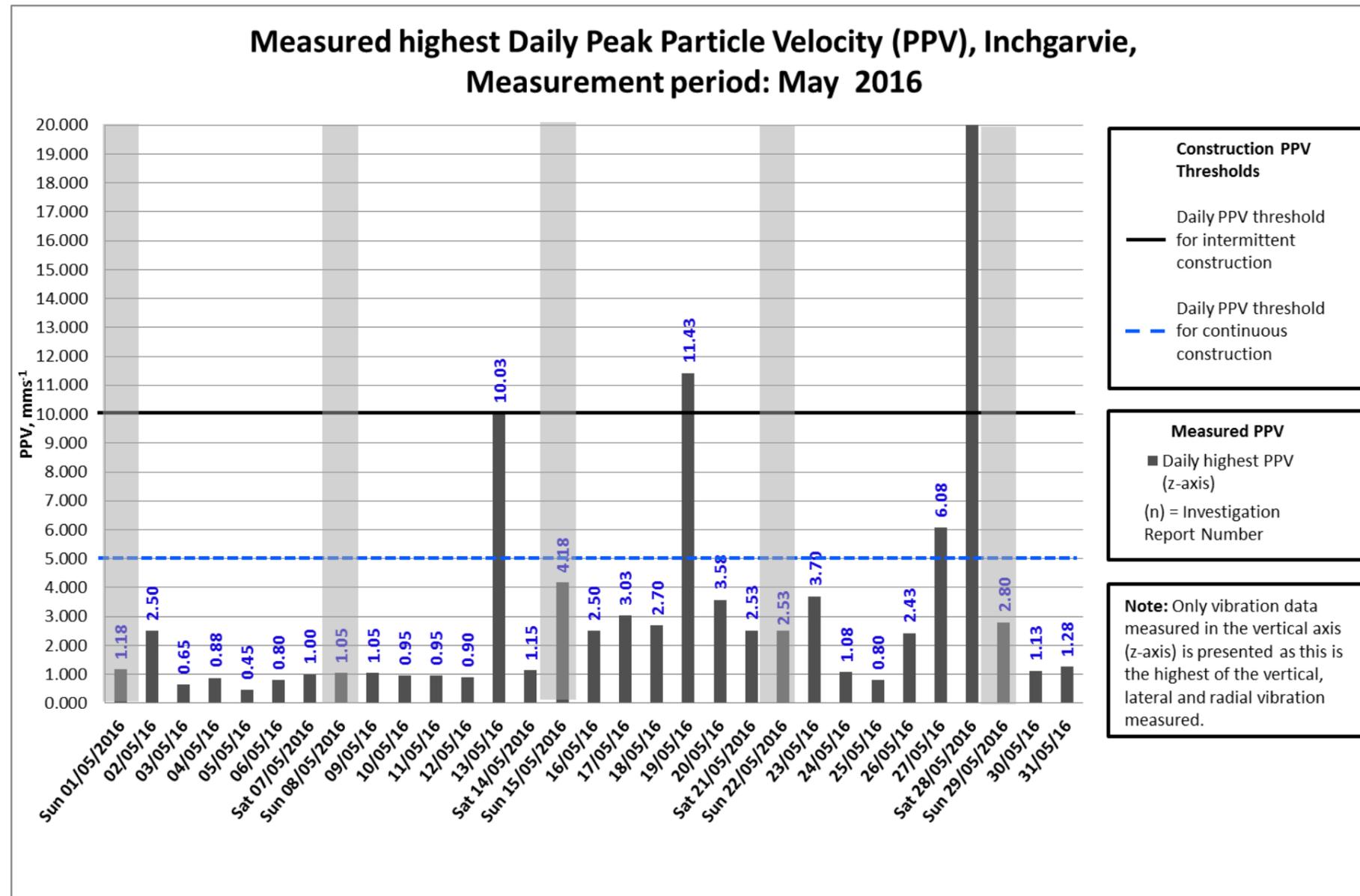
Data missing from the 1<sup>st</sup> to the 10<sup>th</sup> of May was caused by power issue at the monitor location. This has since been resolved on the 11<sup>th</sup> of May.

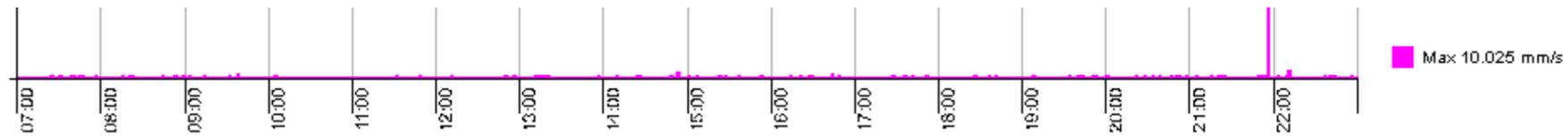




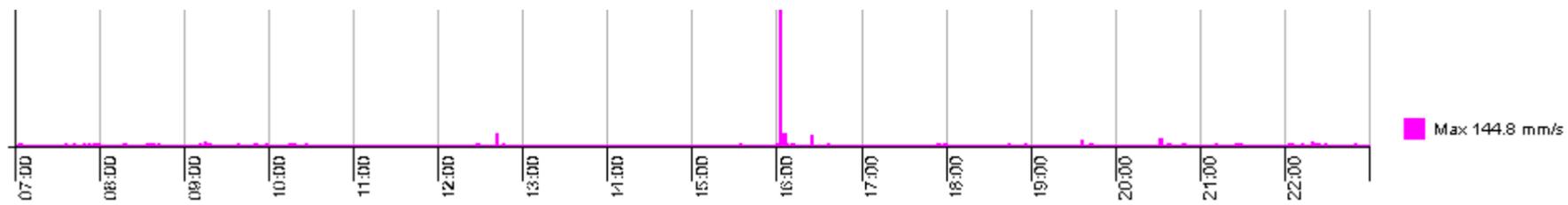
### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Echline, Measurement period: May 2016







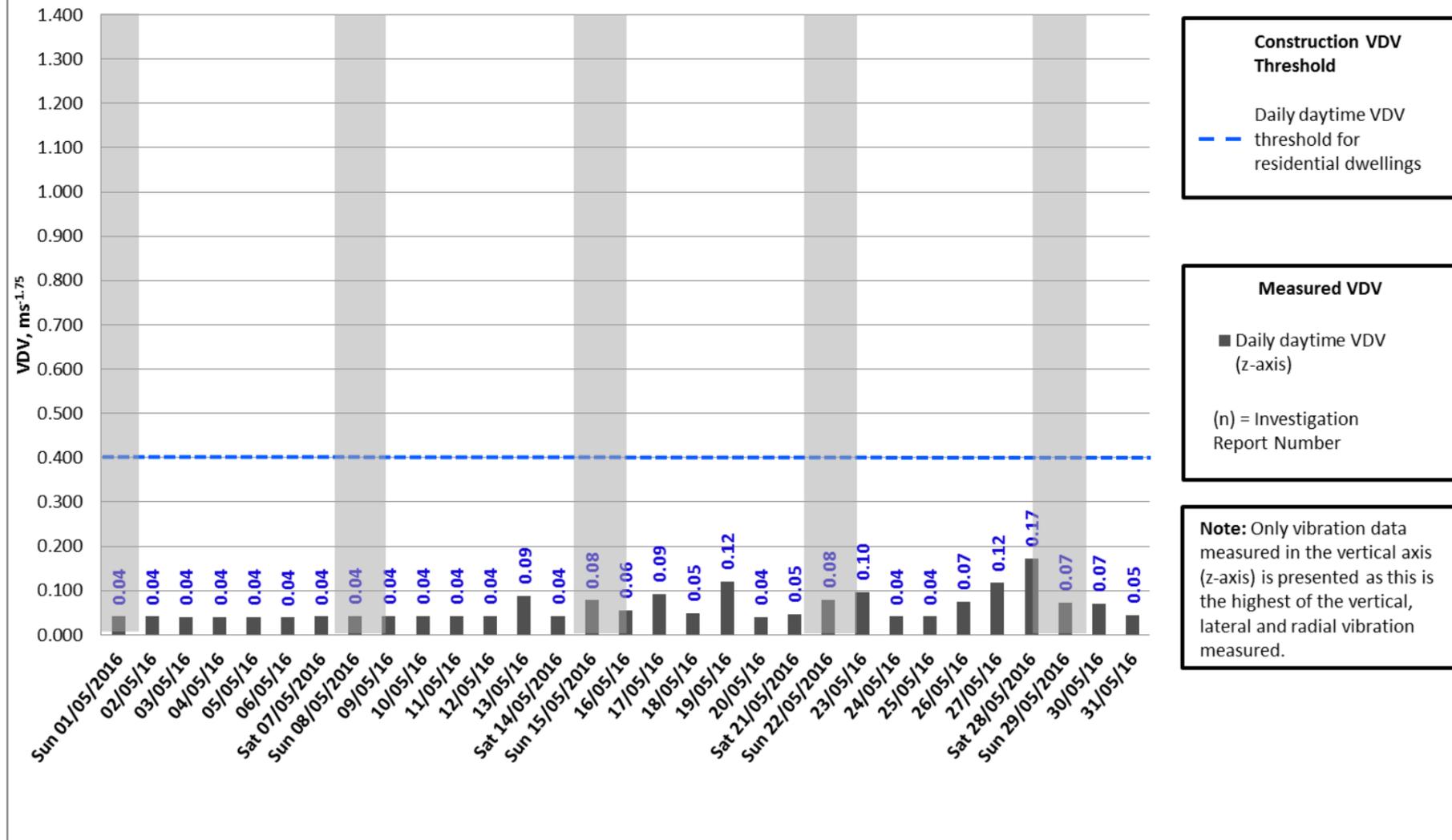
Exceedances on the 13<sup>th</sup> and 19<sup>th</sup> of May have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 13/05/2016).



Exceedances on the 27<sup>th</sup> and 28<sup>th</sup> of May have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 28/05/2016).

During this period the resident at the property, where the monitor is situated, has ongoing private construction works. It is likely that exceedances within the graph above were caused by the works on the property rather than the construction of the new crossing and supporting infrastructure.

### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Inchgarvie, Measurement period: May 2016



**Construction VDV Threshold**

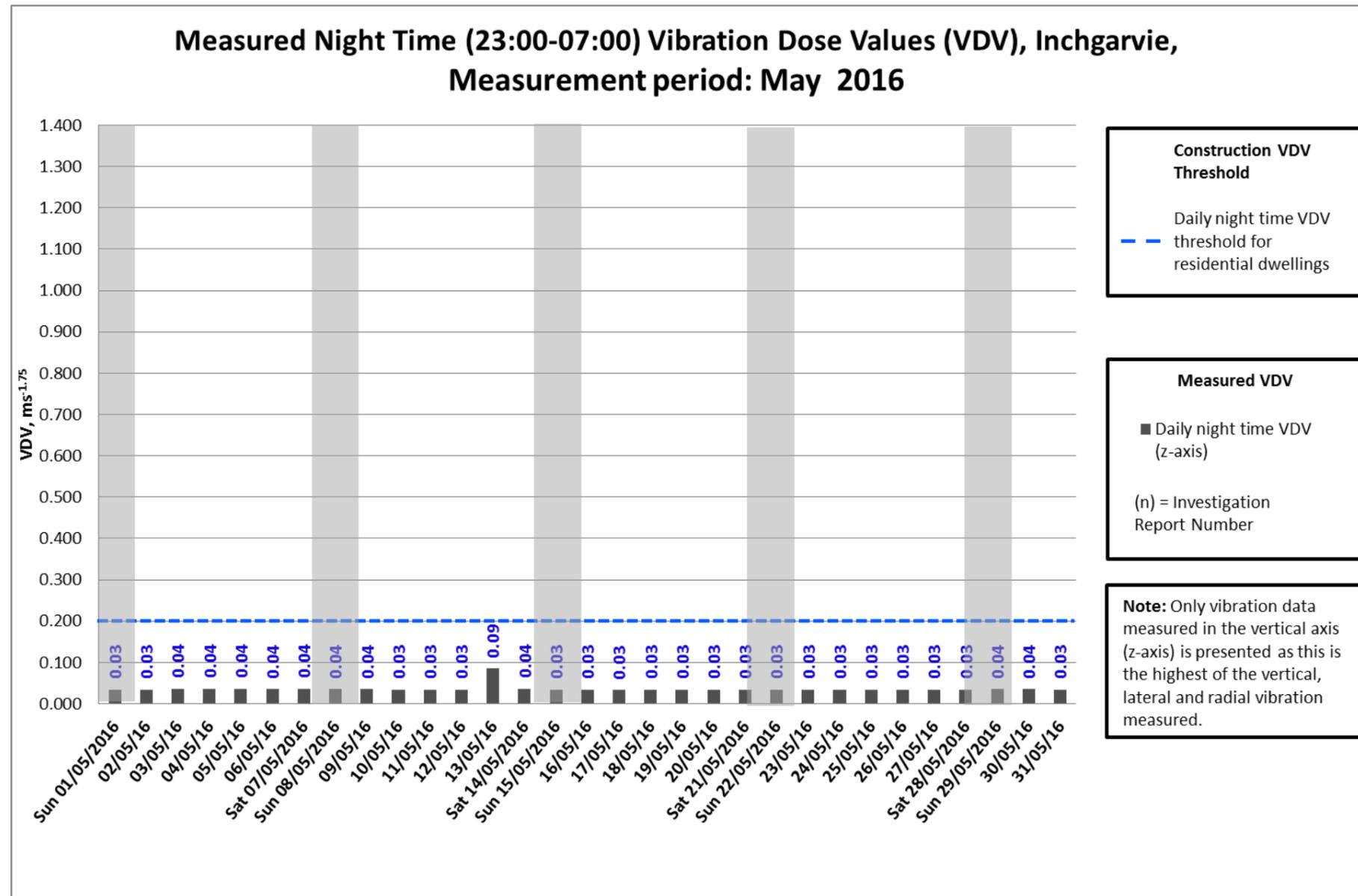
Daily daytime VDV threshold for residential dwellings

**Measured VDV**

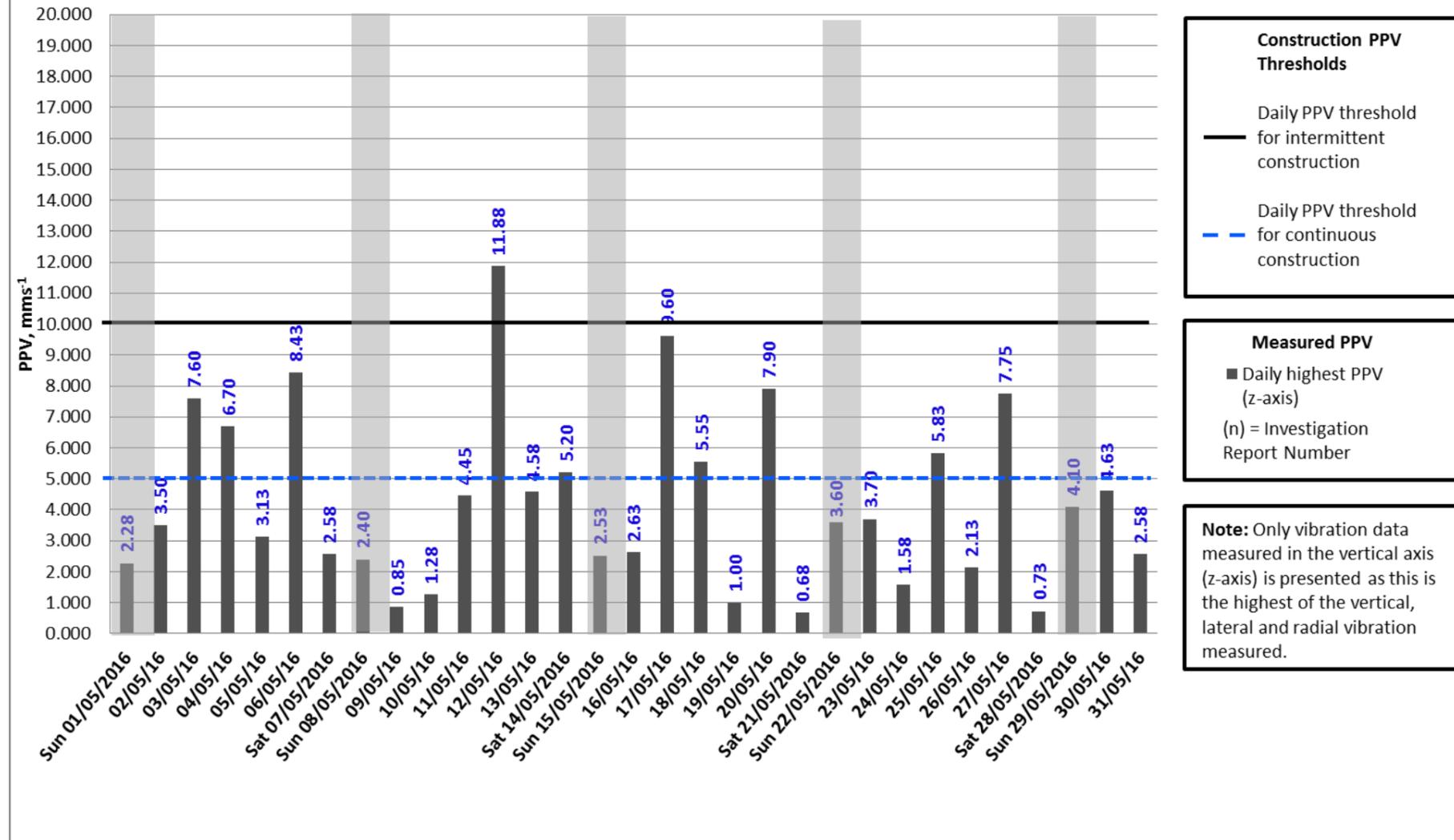
■ Daily daytime VDV (z-axis)

(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.



### Measured highest Daily Peak Particle Velocity (PPV), Linn Mill, Measurement period: May 2016



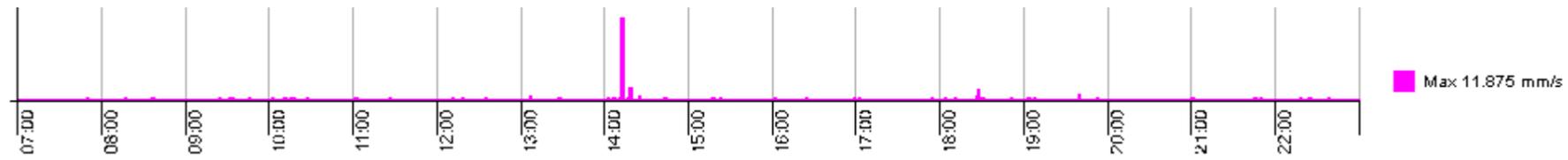
**Construction PPV Thresholds**

- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

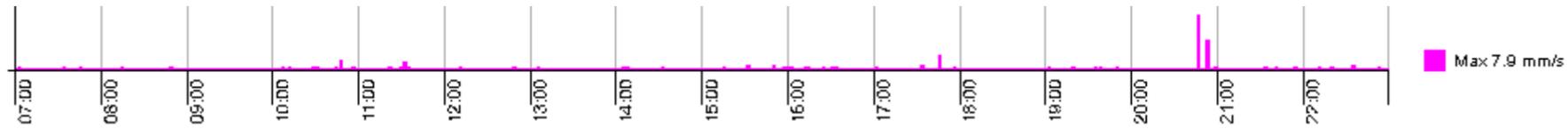
**Measured PPV**

- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

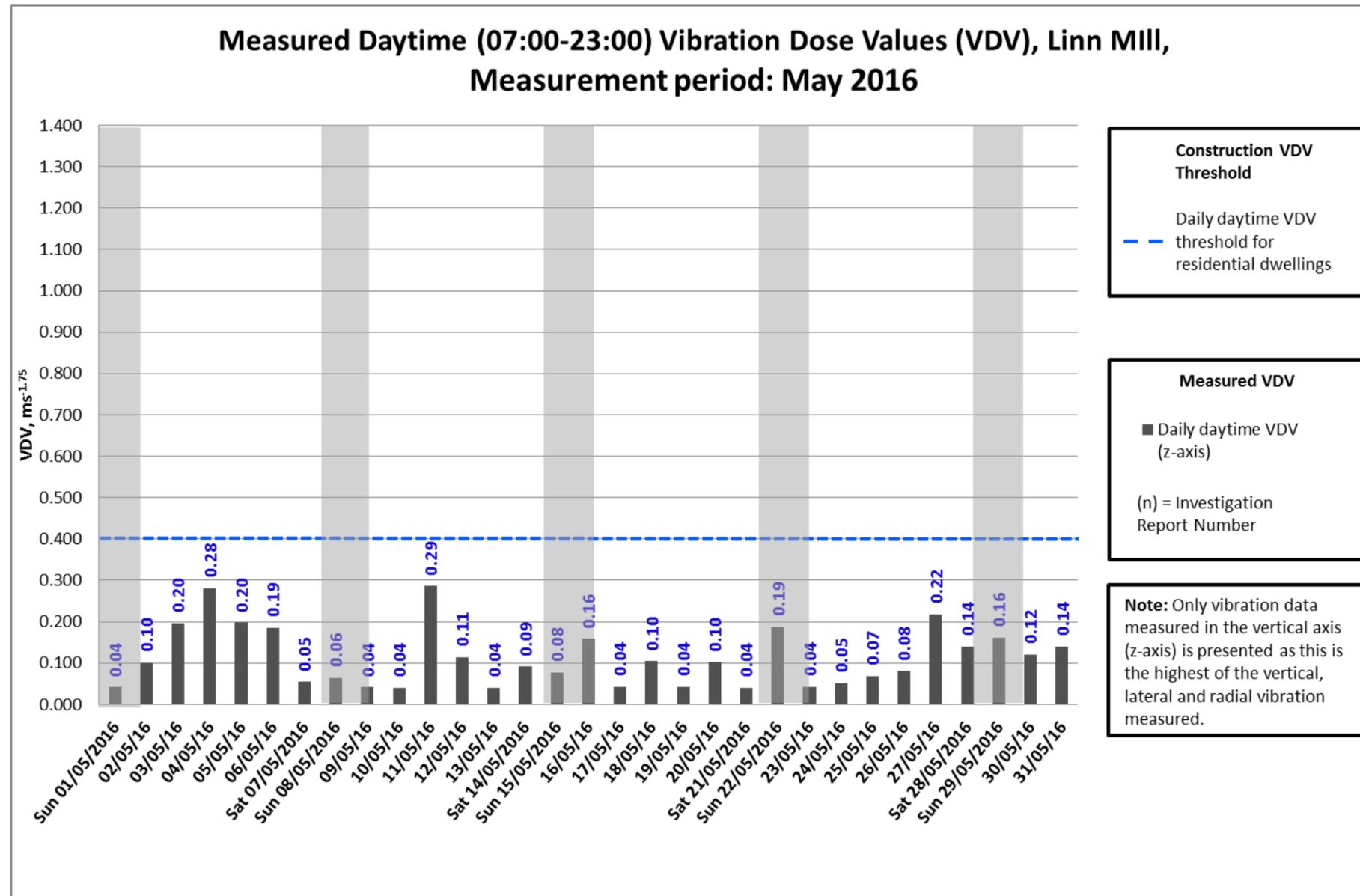
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



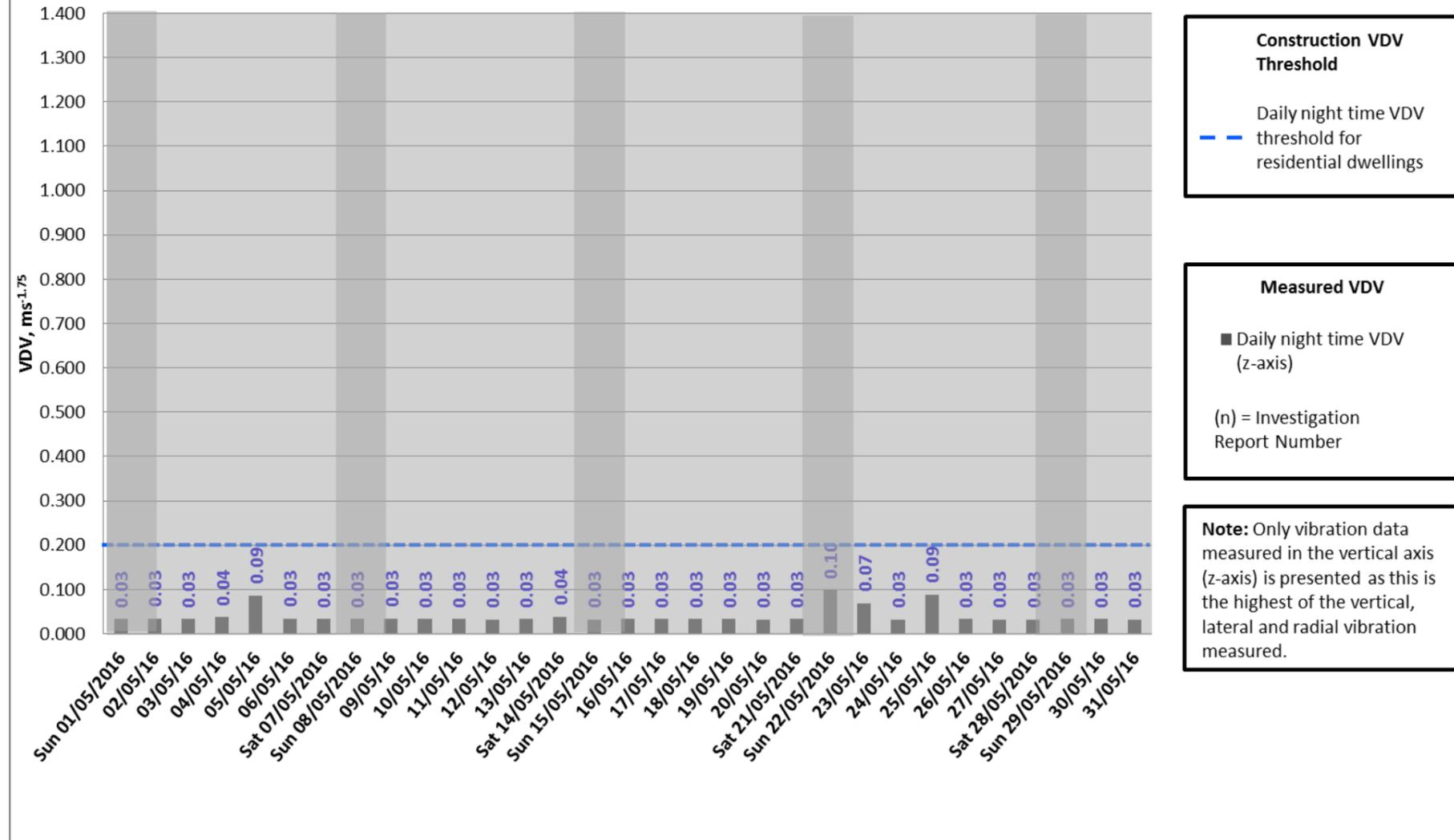
Exceedances on the 3<sup>rd</sup>, 4<sup>th</sup>, 12<sup>th</sup>, 14<sup>th</sup>, 17<sup>th</sup>, 18<sup>th</sup> and 27<sup>th</sup> of May have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 12/05/2016).



Exceedances on the 20<sup>th</sup> and 25<sup>th</sup> of May have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 20/05/2016).



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Linn Mill, Measurement period: May 2016



**Construction VDV Threshold**

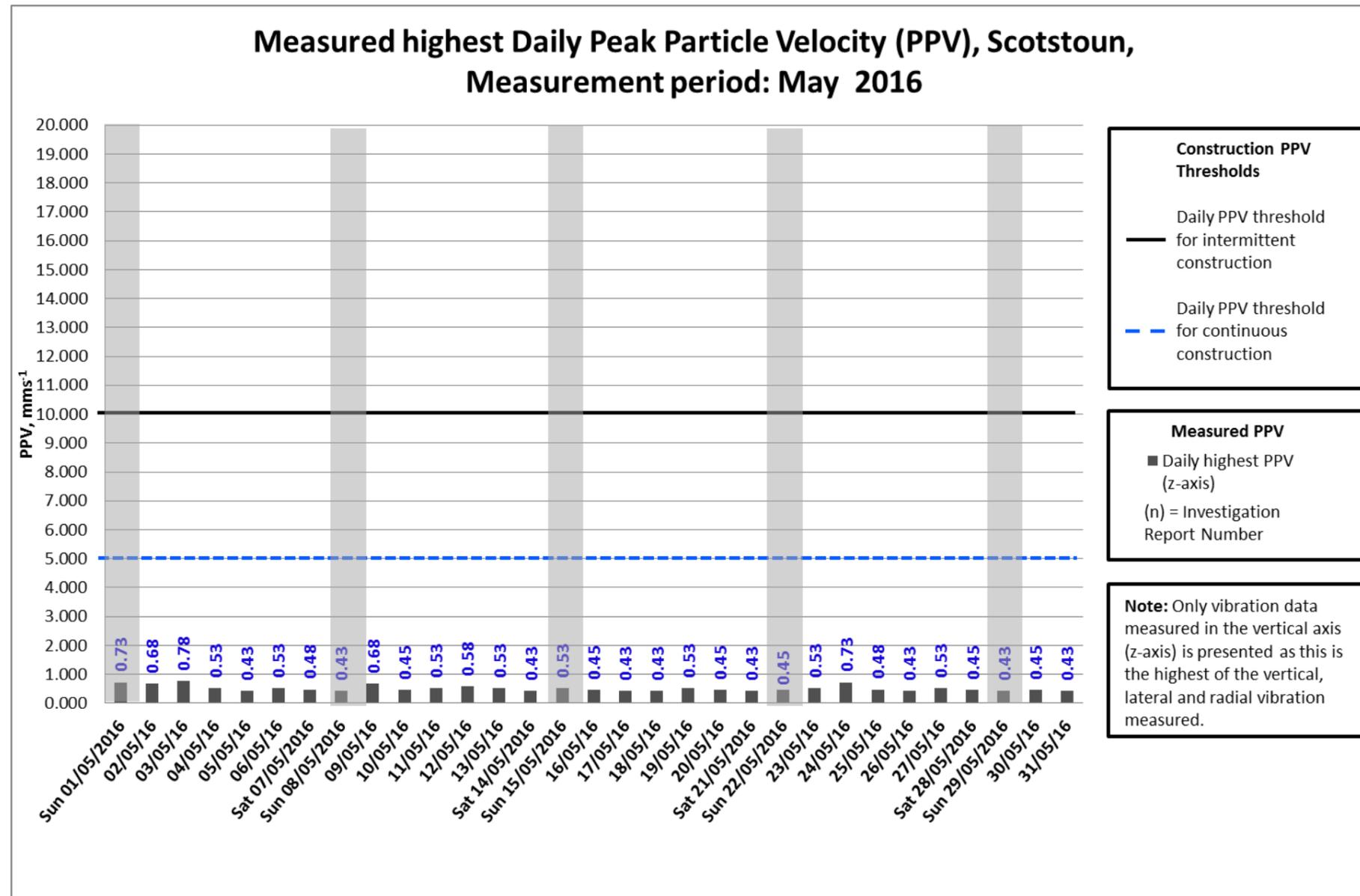
Daily night time VDV threshold for residential dwellings

**Measured VDV**

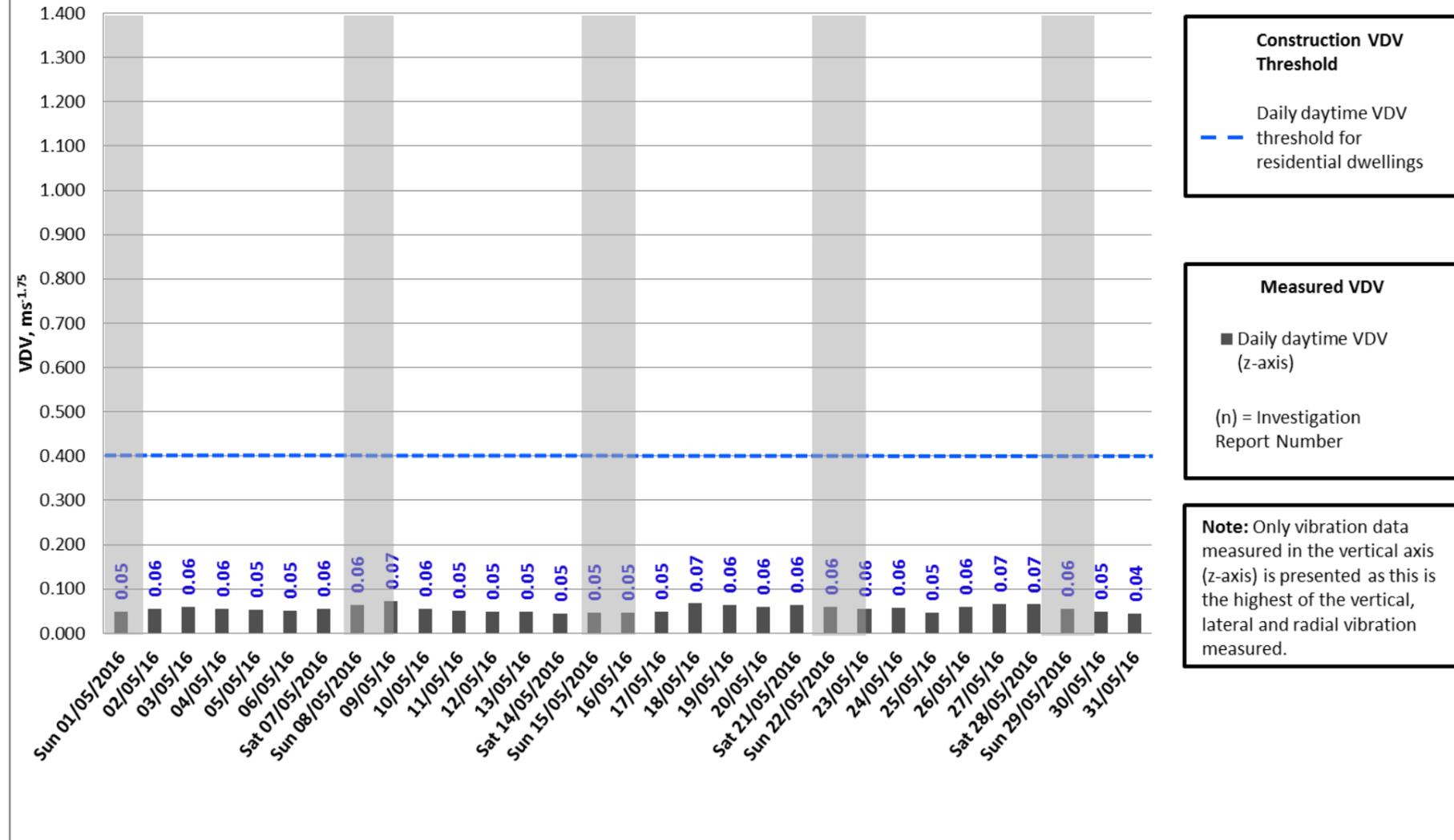
■ Daily night time VDV (z-axis)

(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.



### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: May 2016



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

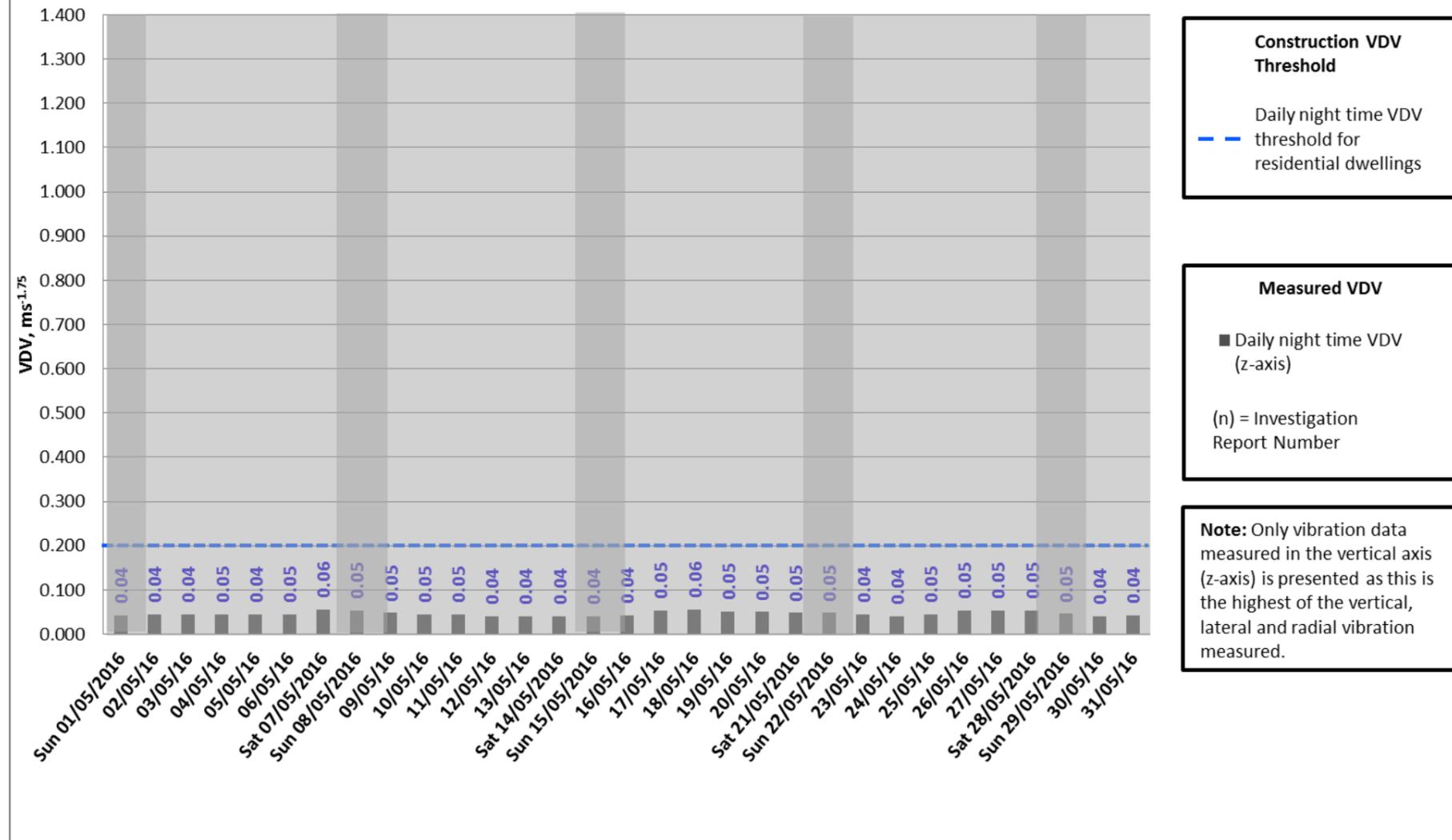
**Measured VDV**

■ Daily daytime 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.

### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: May 2016



**Construction VDV Threshold**

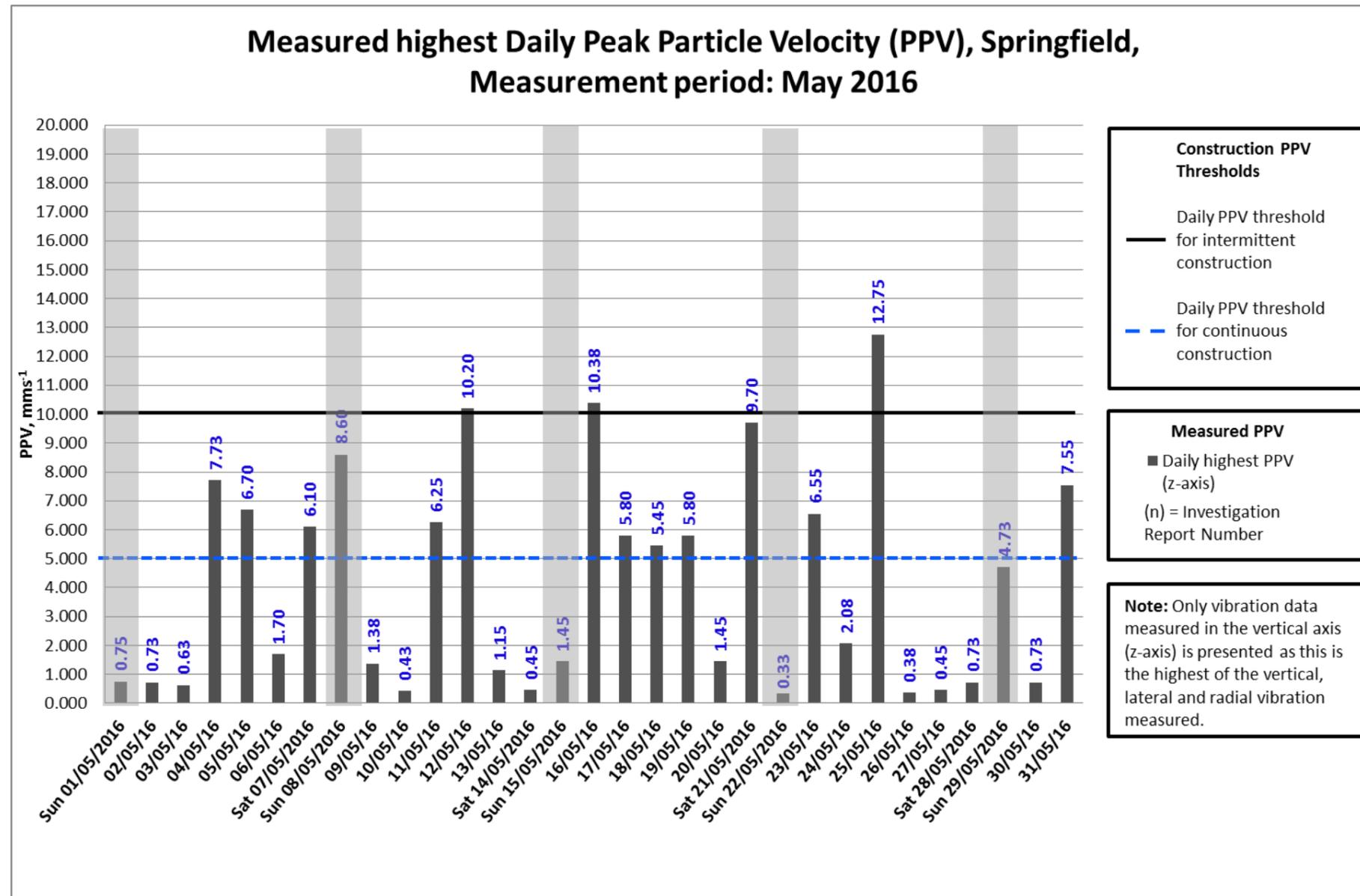
Daily night time VDV threshold for residential dwellings

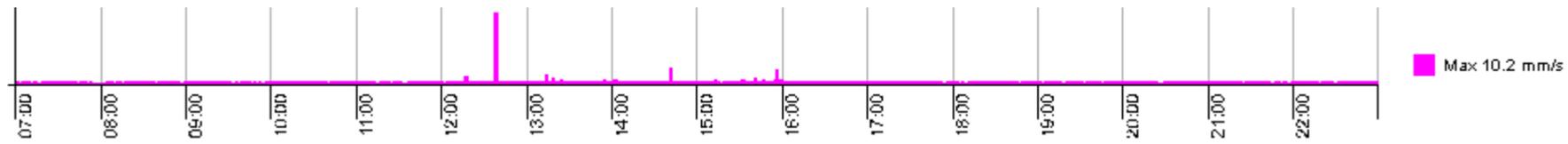
**Measured VDV**

■ Daily night time VDV (z-axis)

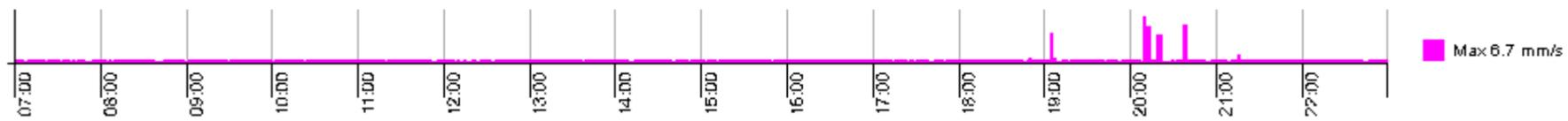
(n) = Investigation Report Number

**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.



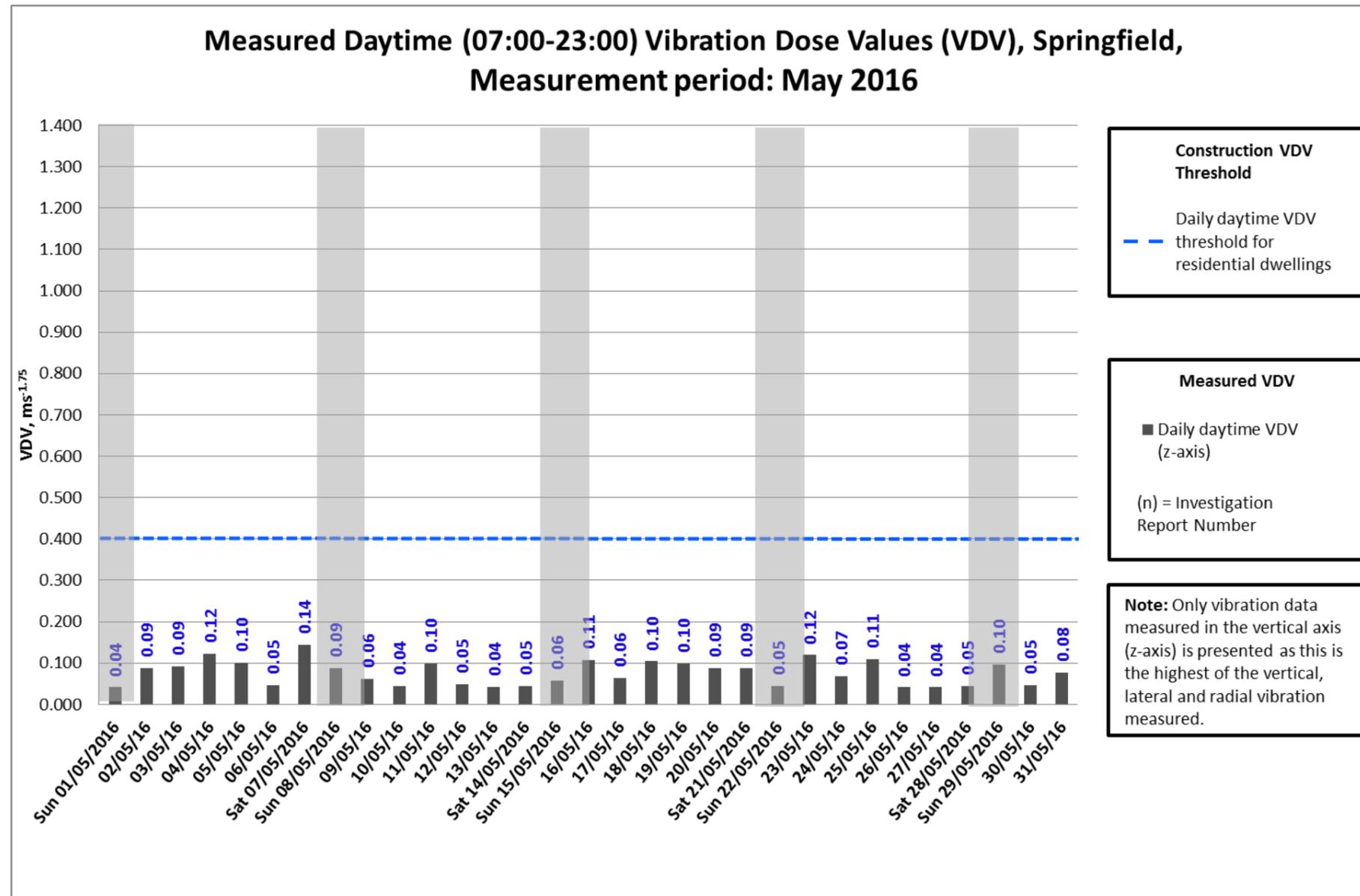


Exceedances on the 4<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup>, 12<sup>th</sup>, 17<sup>th</sup>, 21<sup>st</sup>, 23<sup>rd</sup>, 25<sup>th</sup> and 31<sup>st</sup> of May have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 12/05/2016) .

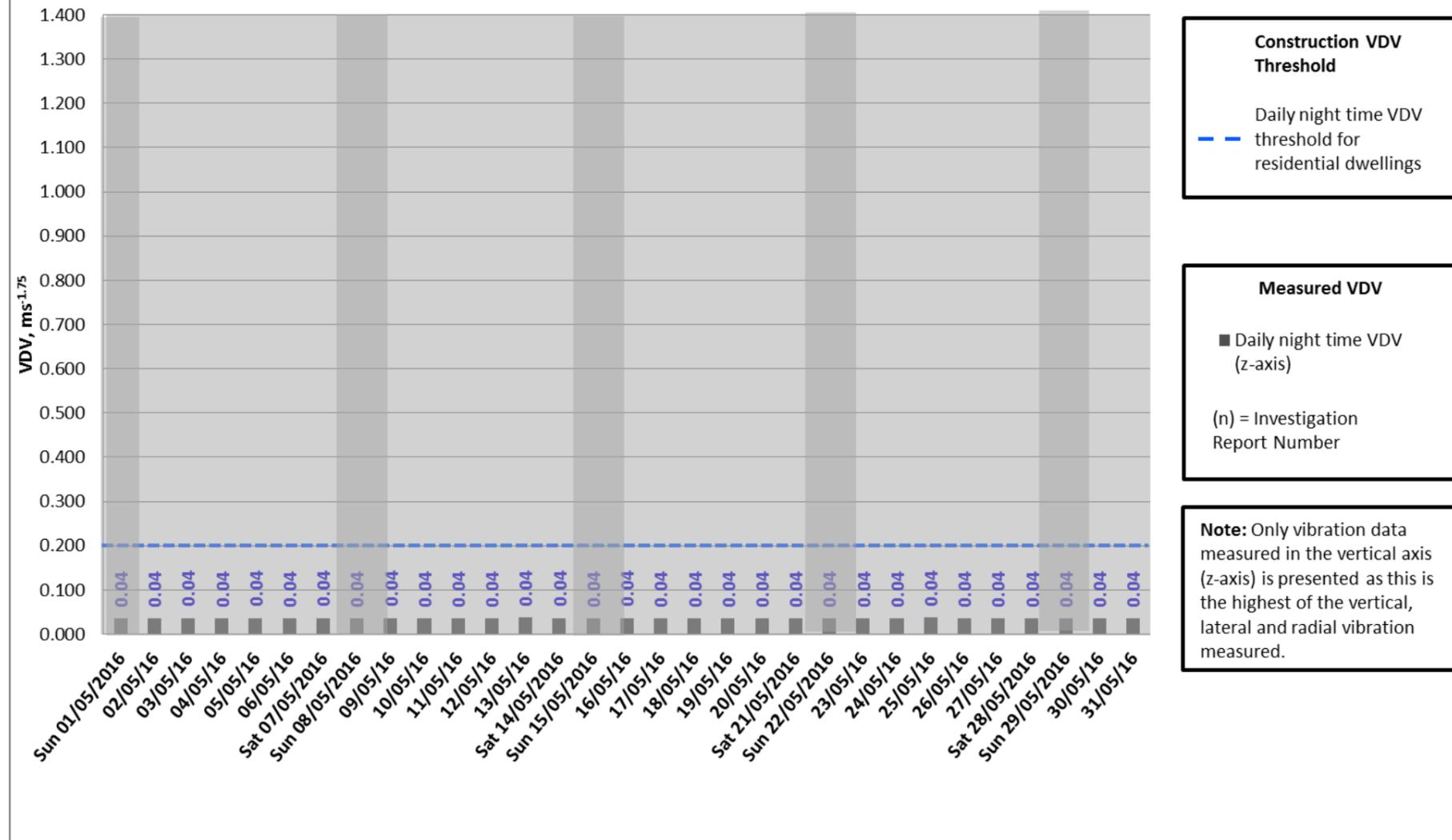


Exceedances on the 5<sup>th</sup>, 8<sup>th</sup>, 16<sup>th</sup>, 18<sup>th</sup> and 19<sup>th</sup> of May have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 05/05/2016).

During the reported period there has been significant activity from the local residents picked up on the noise monitor from which the vibration monitor is situated at. Due to this there is a likelihood that the exceedances portrayed in the graph above have been caused by this close proximity movement.



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Springfield, Measurement period: May 2016



**Construction VDV Threshold**

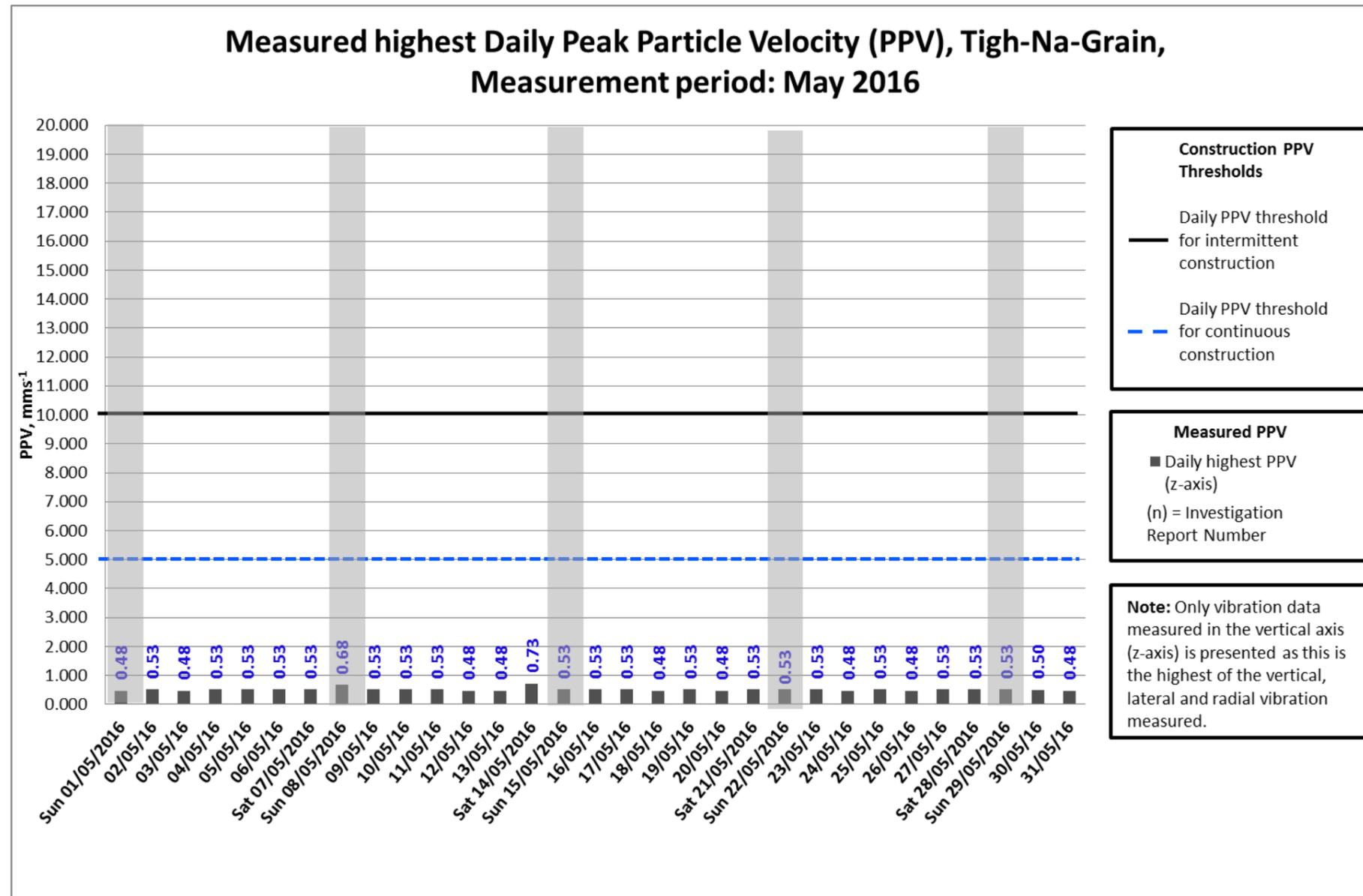
Daily night time VDV threshold for residential dwellings

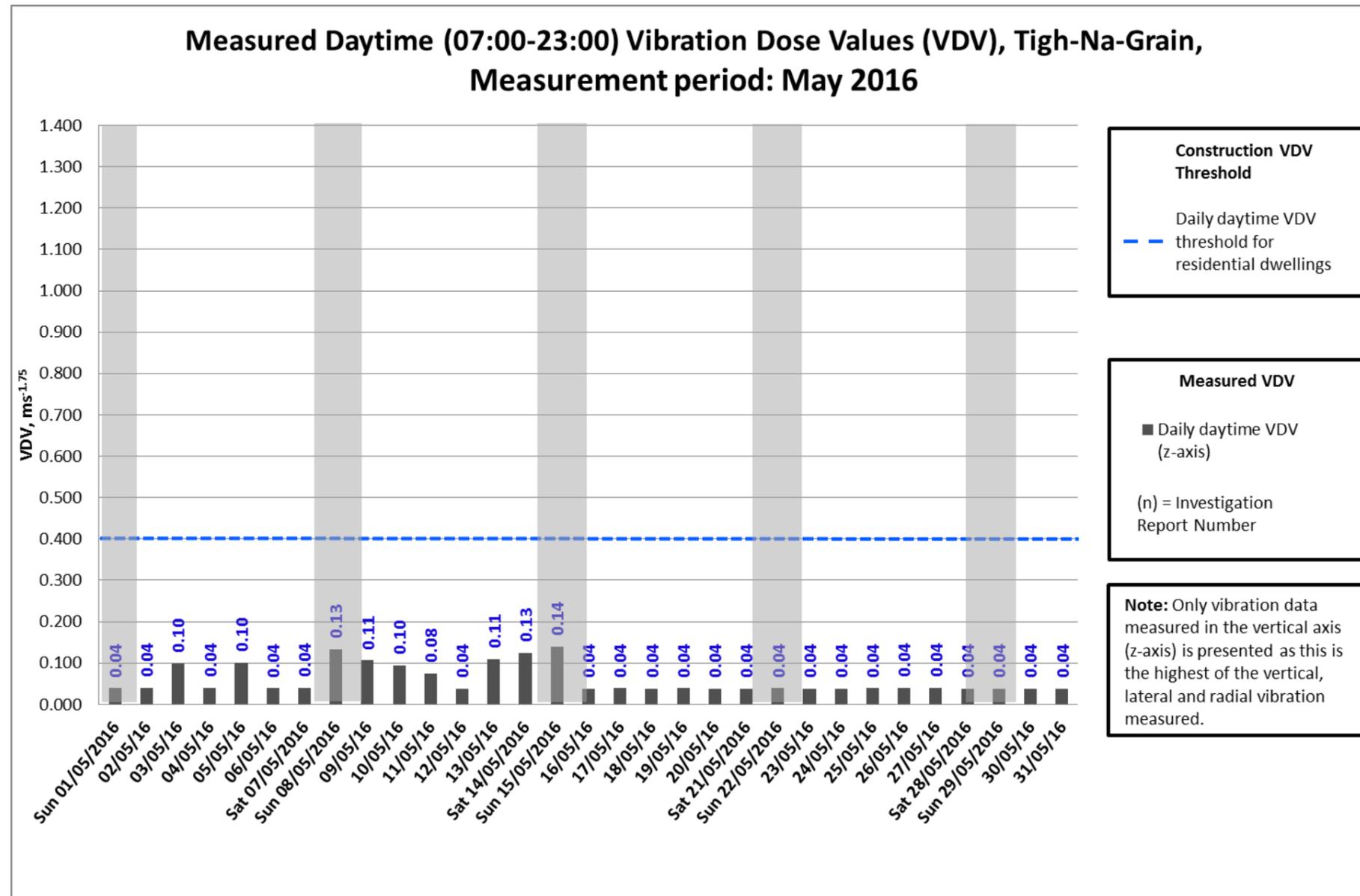
**Measured VDV**

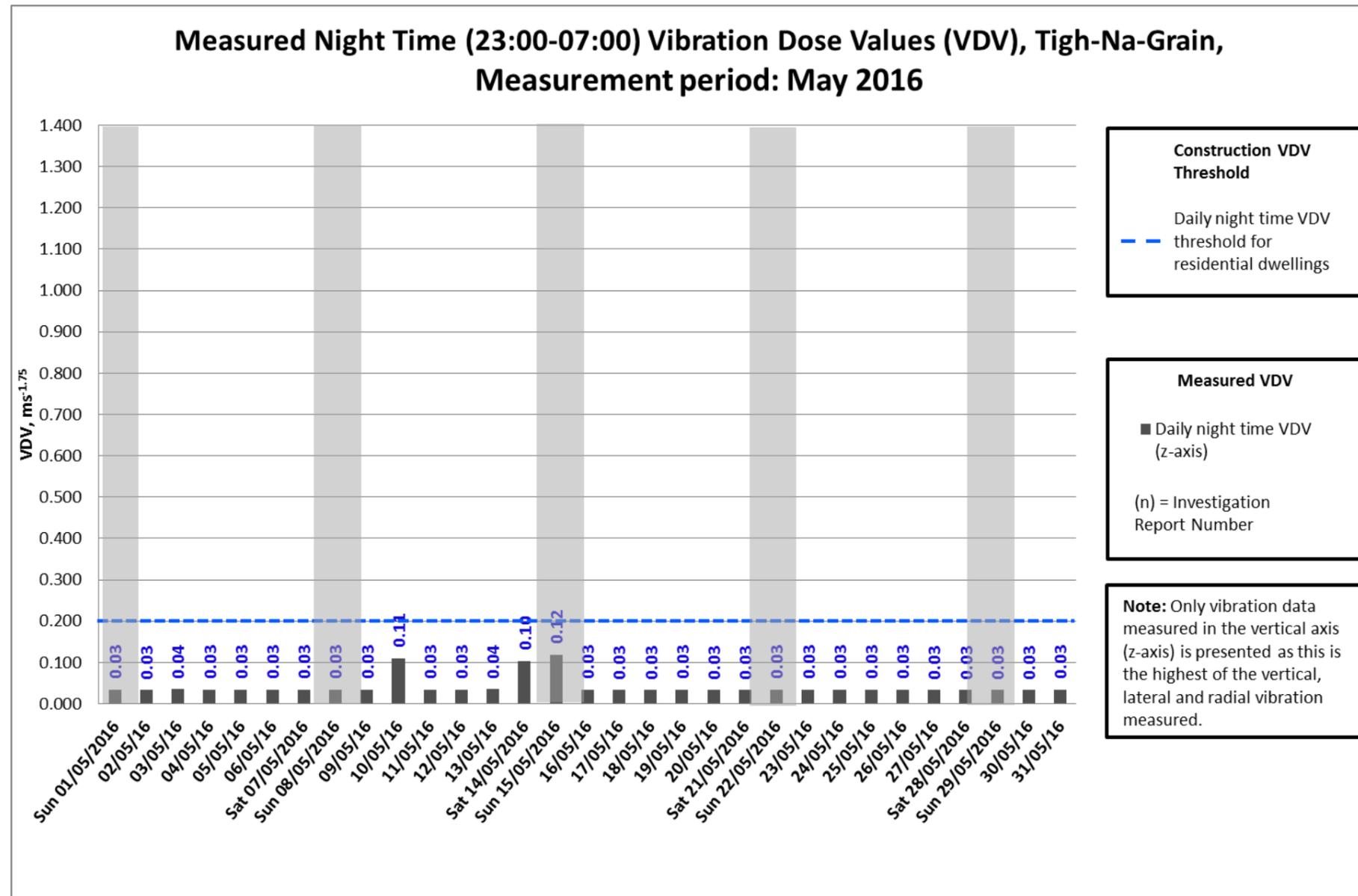
■ Daily night time VDV (z-axis)

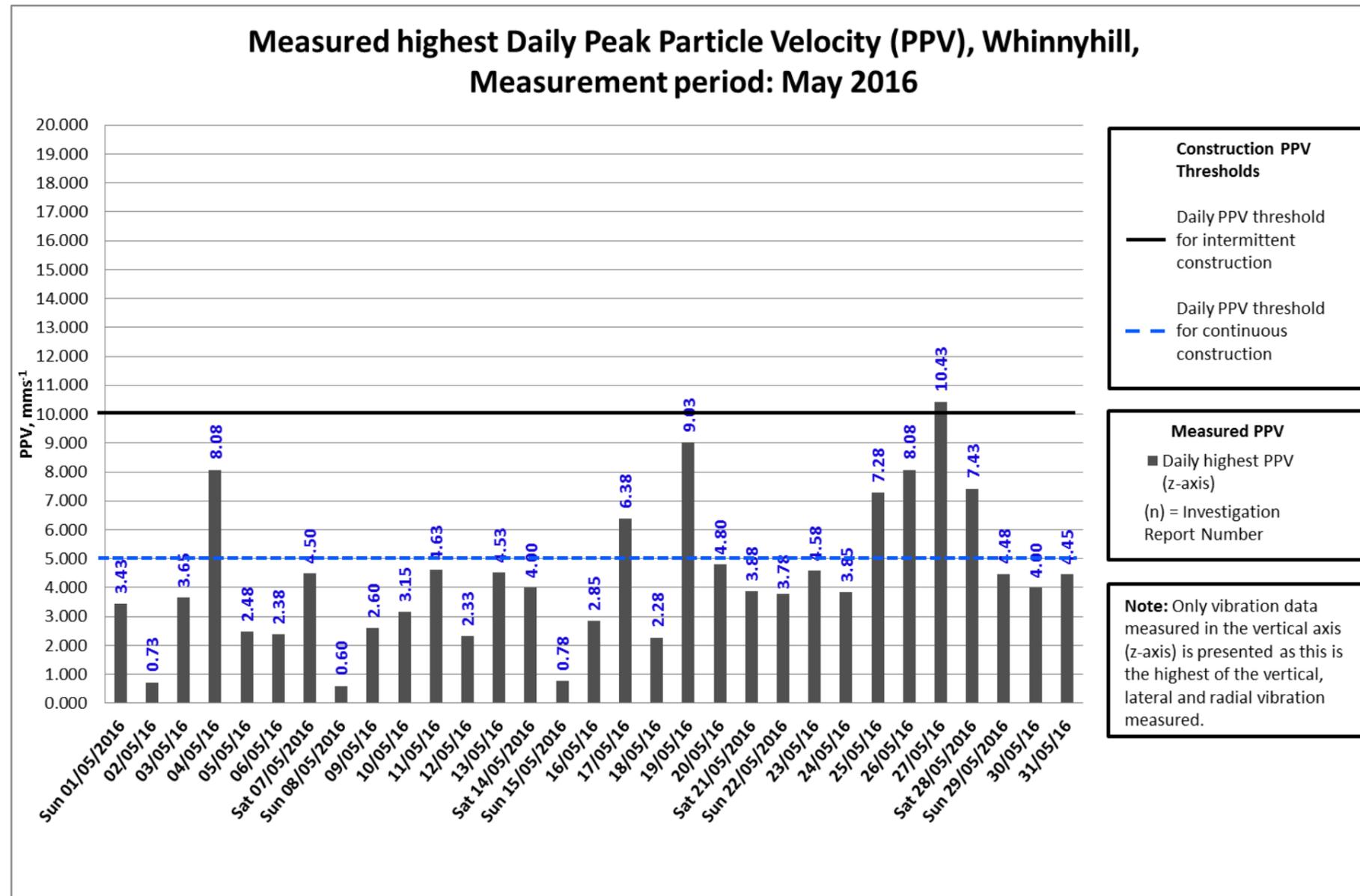
(n) = Investigation Report Number

**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.





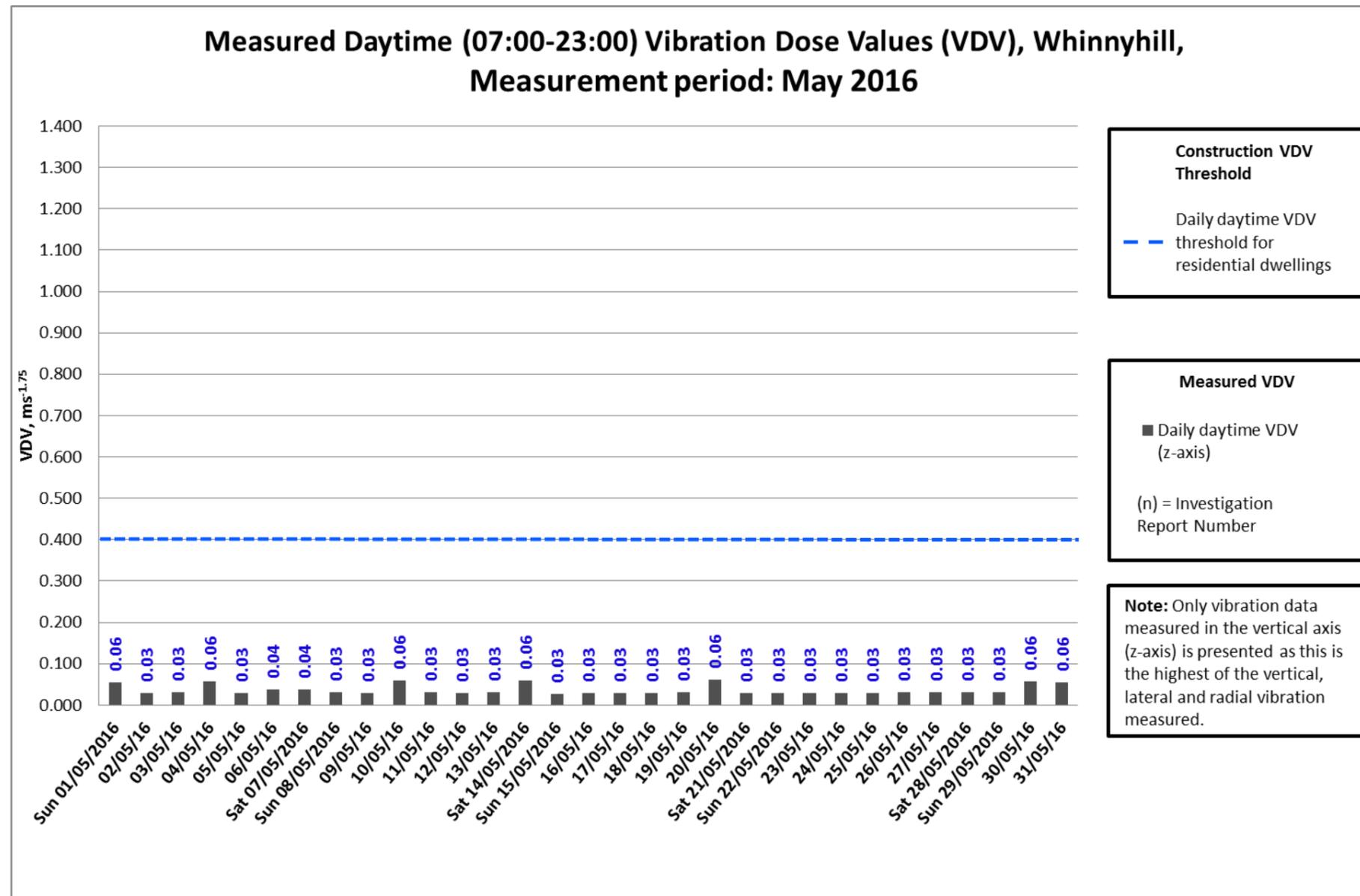




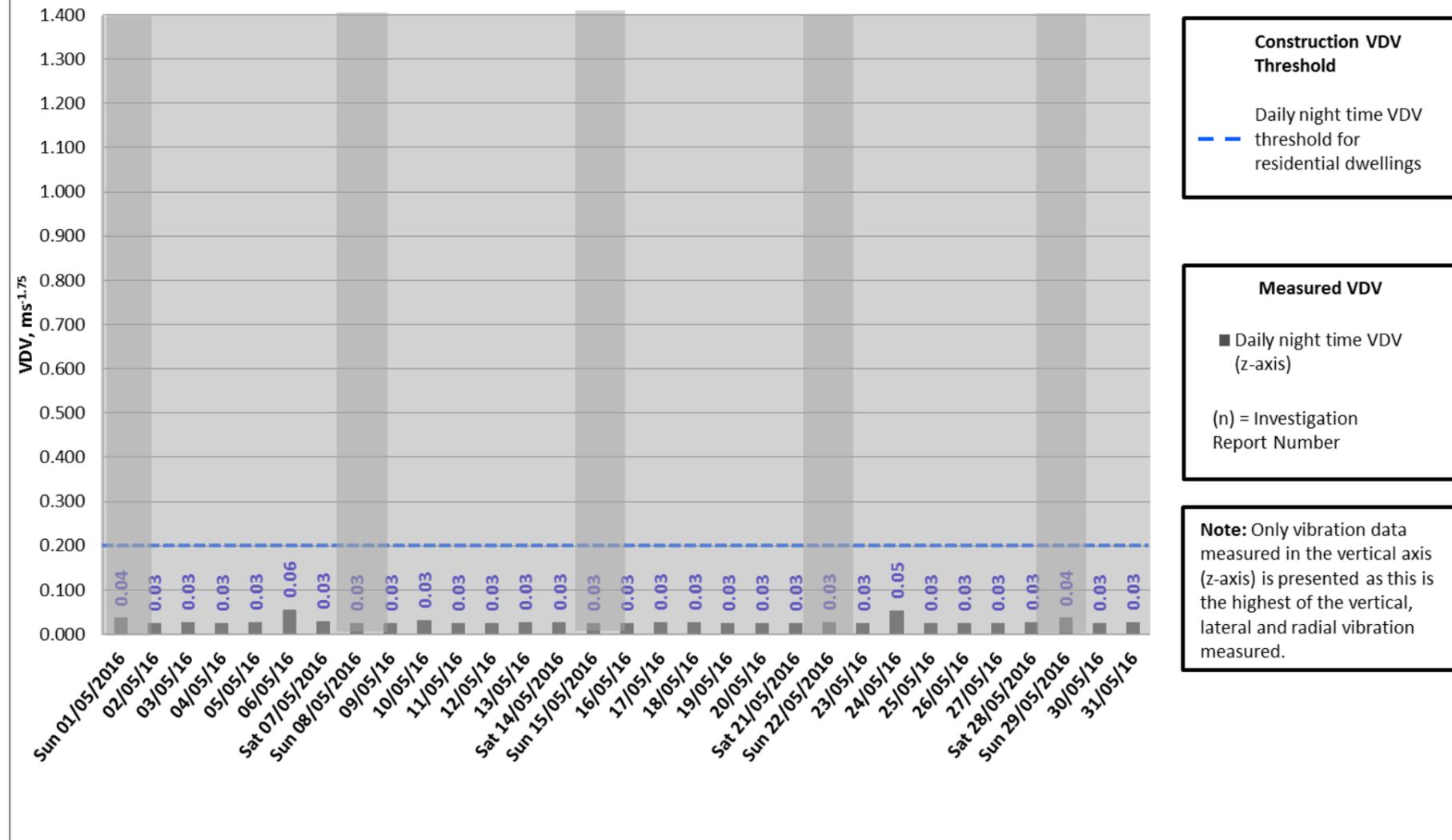
Exceedances on the 17<sup>th</sup>, 19<sup>th</sup>, 25<sup>th</sup>, 26<sup>th</sup>, 27<sup>th</sup> and 28<sup>th</sup> of May have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 17/05/2016).



Exceedances on the 4<sup>th</sup> of May have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activity was the cause of these (graph above from the 04/05/2016).



### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: May 2016



**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.