



Contractor



**Forth Crossing** Bridge Constructors

HOCHTIEF Solutions  
American Bridge International  
DRAGADOS  
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

**VIBRATION MONITORING REPORT  
SEPTEMBER 2015**

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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 September 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**

**September 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	1	1	0	1
Butlaw Fisheries	1	0	0	0
Clufflat Brae	8	1	0	0
Dundas Home Farm	1	0	0	0
Echline	0	0	0	0
Inchgarvie Lodge	2	1	0	0
Scotstoun	0	1	0	0
Springfield	5	4	0	0
Tigh-Na-Grian	3	1	0	0
Whinnyhill	15	2	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 September 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 Works</li> <li>• Roadworks</li> </ul>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> <li>• Central Tower rebar, formwork, concreting works stay cable installation</li> <li>• North Tower rebar, formwork, concreting works, deck section lifts, stay cable installation</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>• Pier S2 rebar, formwork and concrete works</li> <li>• Central Tower rebar, formwork, concreting works stay cable installation</li> <li>• South Tower rebar, formwork, concreting works, deck section lifts, stay cable installation</li> <li>• Pile removal at pier S6</li> </ul>
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> <li>• Scaffolding shuttering and reinforcement to deck. Pier S1 rebar, formwork &amp; concrete works</li> <li>• Rebar installation at Pier S2</li> <li>• Central Tower rebar, formwork, concreting works Stay cable installation</li> <li>• South Tower rebar, formwork, concreting works stay cable installation, deck section lifts</li> <li>• Main Carriageway earthworks</li> <li>• Test pier removal</li> <li>• Pile removal at pier S6</li> </ul>
M11	Linn Mill	Network (close proximity to	<ul style="list-style-type: none"> <li>• AVS – scaffolding, shuttering and reinforcement to deck. No night time or Sunday construction in the</li> </ul>



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		Crossing)	<p>vicinity</p> <ul style="list-style-type: none"> <li>• Pile removal at pier S6</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>• AVS – scaffolding, shuttering and reinforcement to deck No night time or Sunday daytime construction in vicinity.</li> <li>• Test pier removal</li> <li>• Main carriageway roadworks</li> </ul>
M14	Springfield	Network	<ul style="list-style-type: none"> <li>• AVS – scaffolding, shuttering and reinforcement to deck Earthworks South Abutment area</li> <li>• Excavation, Break rock, fill/trim mainline &amp; fill launch</li> <li>• Test pier removal</li> </ul>
M15	Echline	Network	<ul style="list-style-type: none"> <li>• AVS – scaffolding, shuttering and reinforcement to deck 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>• Footpath works</li> <li>• Utility works</li> <li>• B800 North road works including bridge works</li> </ul>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> <li>• Footpath works</li> <li>• Utility works</li> <li>• Mainline Roadworks</li> <li>•</li> <li>•</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 September 2015.

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

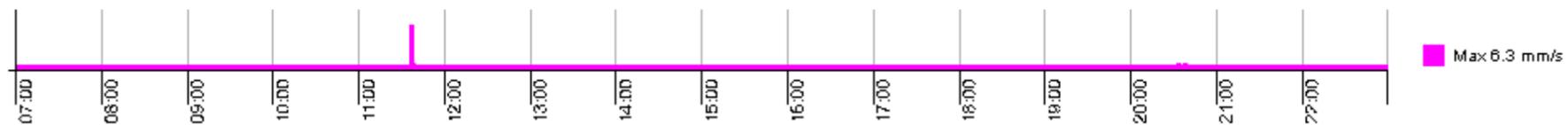
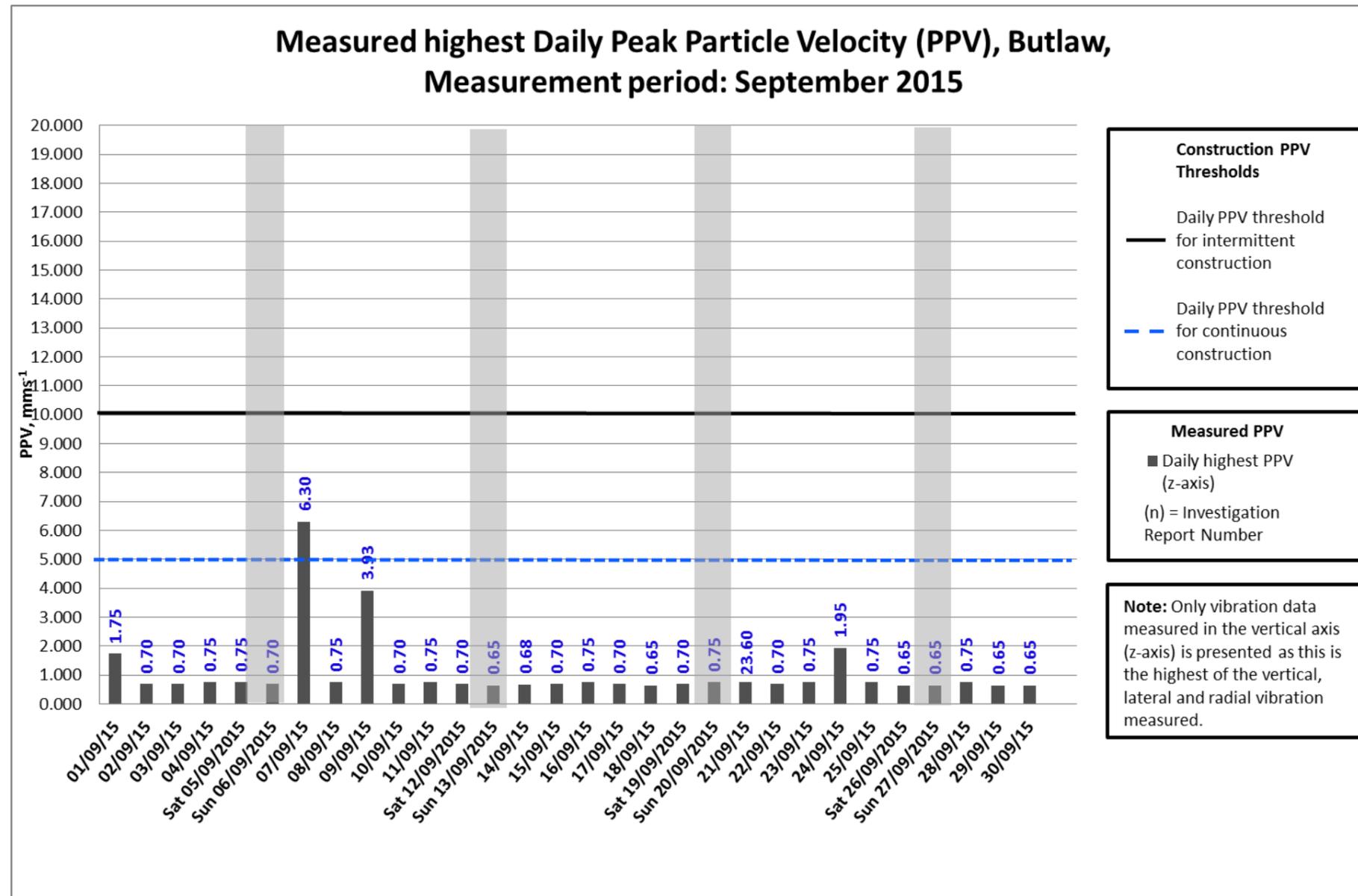
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s <sup>-1.75</sup> )
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae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

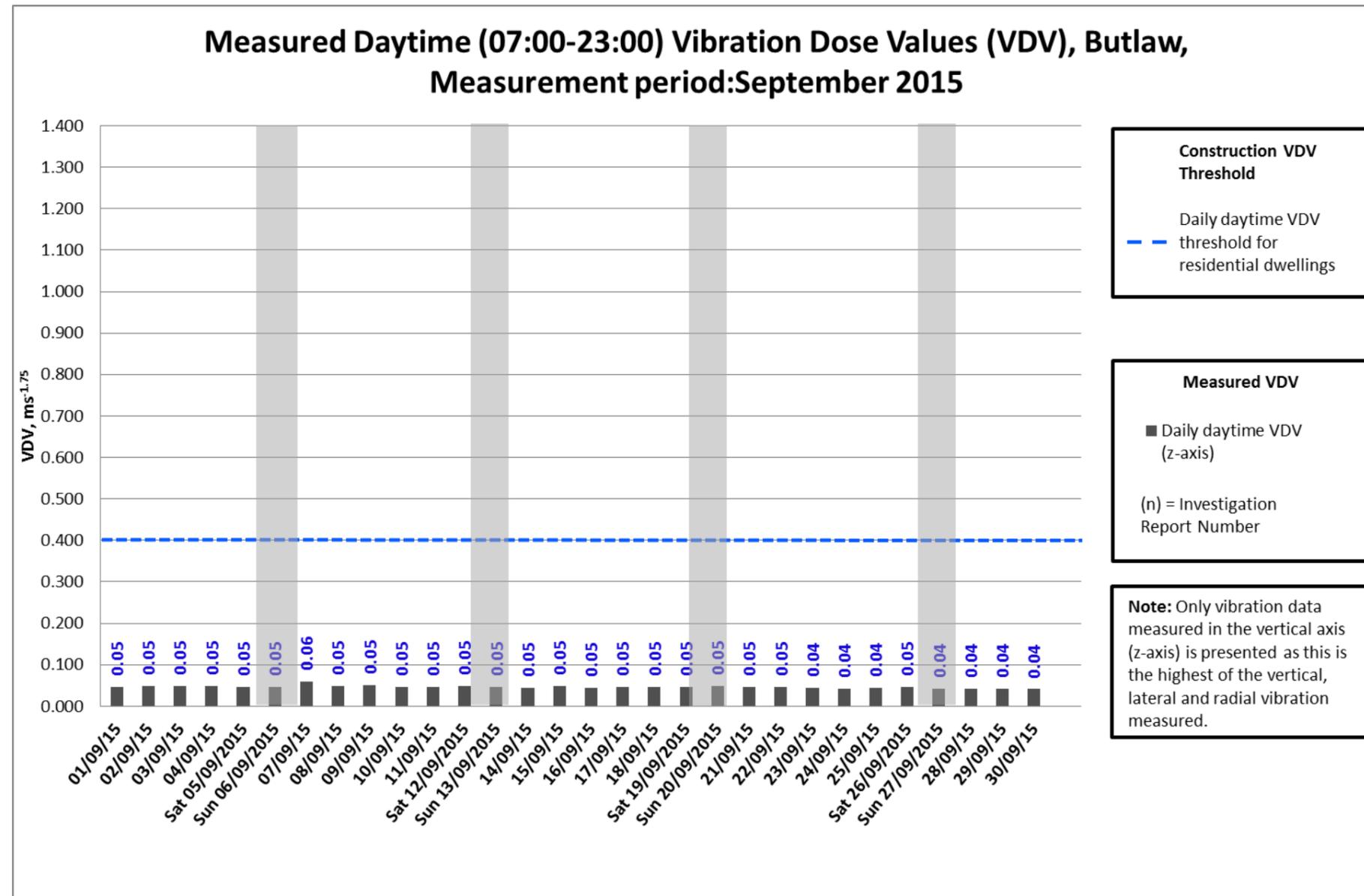
**Notes on Table 3**

- 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.

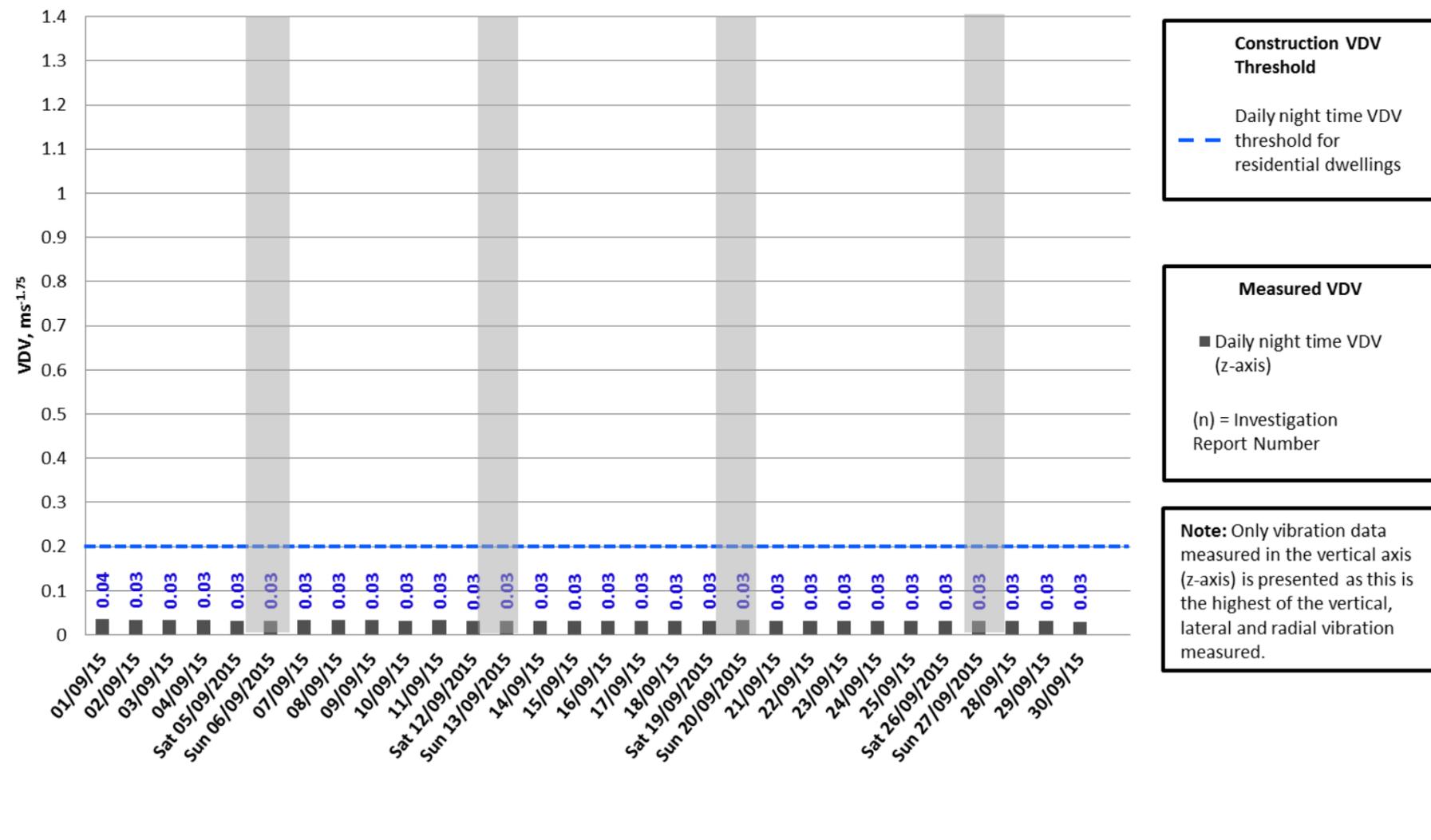
## APPENDIX B – VIBRATION GRAPHS



Exceedance on the 07/09/2015 has been investigated and found to be caused by maintenance of the noise monitor that is in close proximity of the vibration monitor. It is highly unlikely that the exceedance was caused by construction related activities (Graph above from the 07/09/2015).



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



**Construction VDV Threshold**

Daily night time VDV threshold for residential dwellings

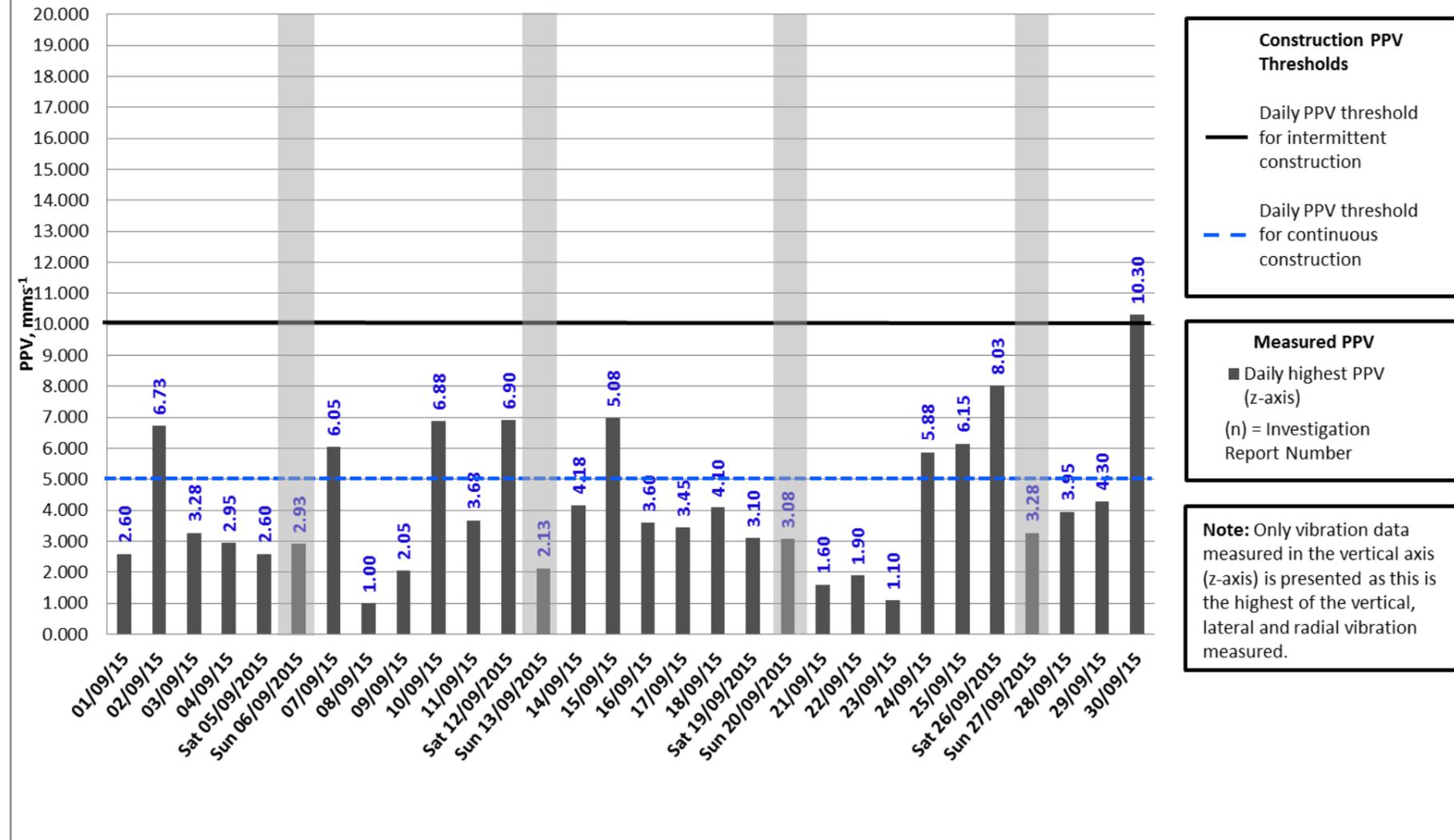
**Measured VDV**

■ 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.

### Measured highest Daily Peak Particle Velocity (PPV), Clufflat Brae, Measurement period: September 2015



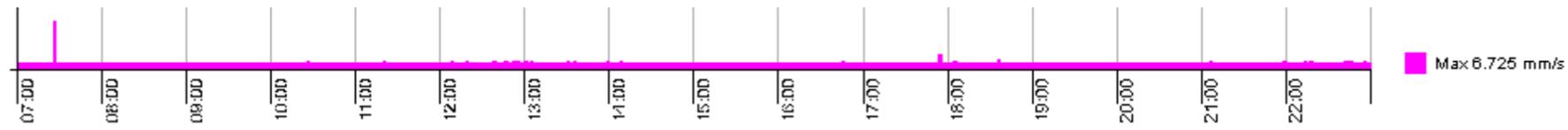
**Construction PPV Thresholds**

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

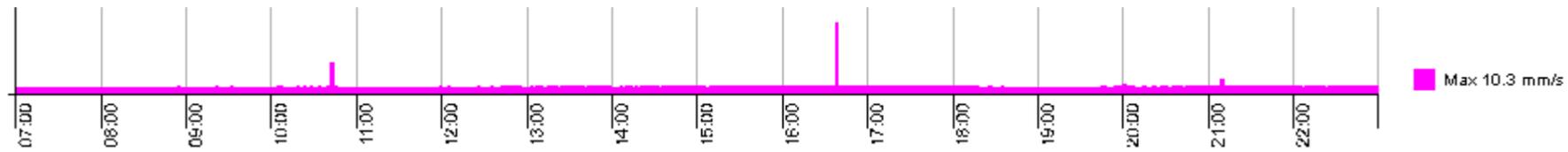
**Measured PPV**

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

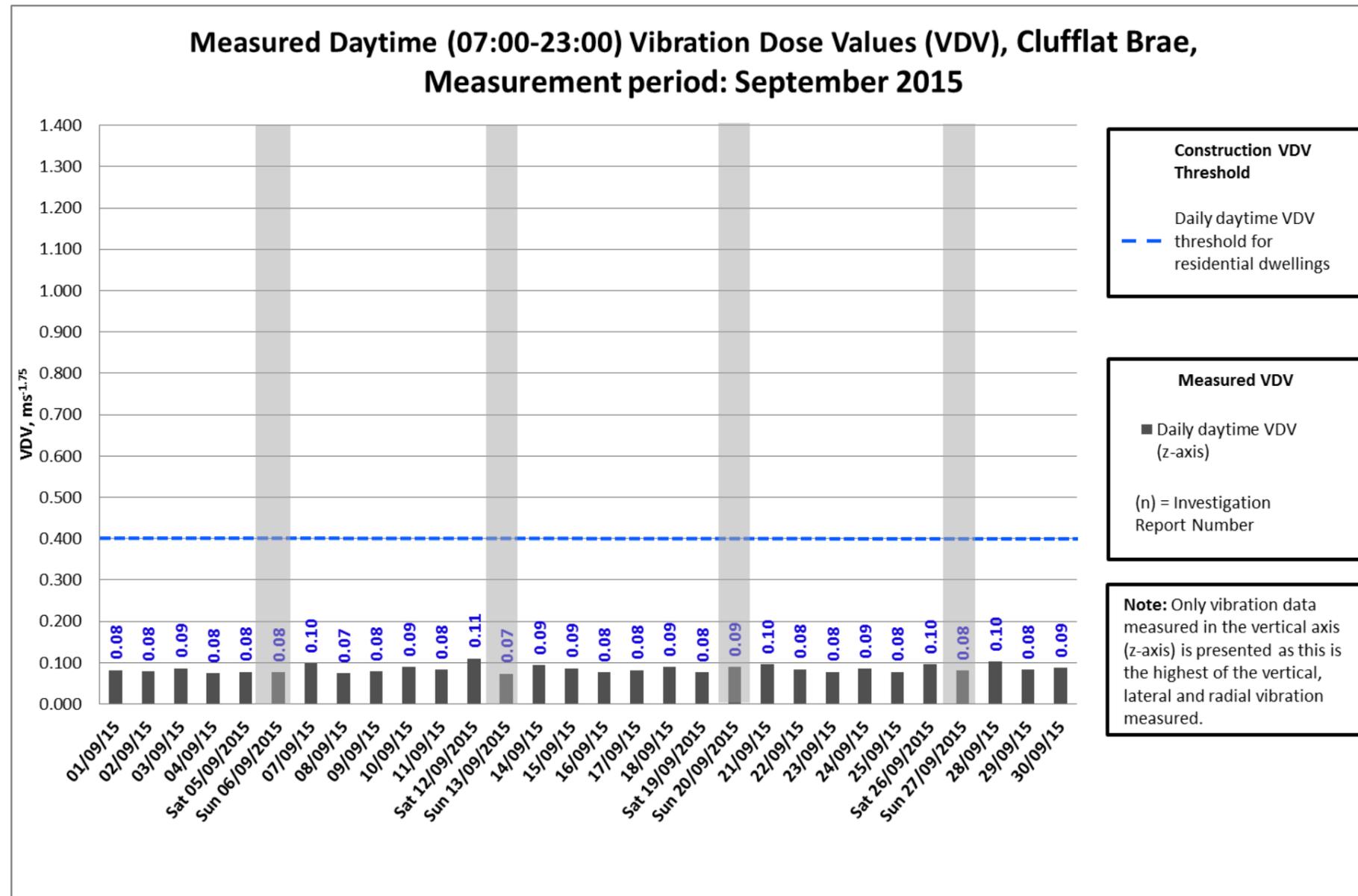
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

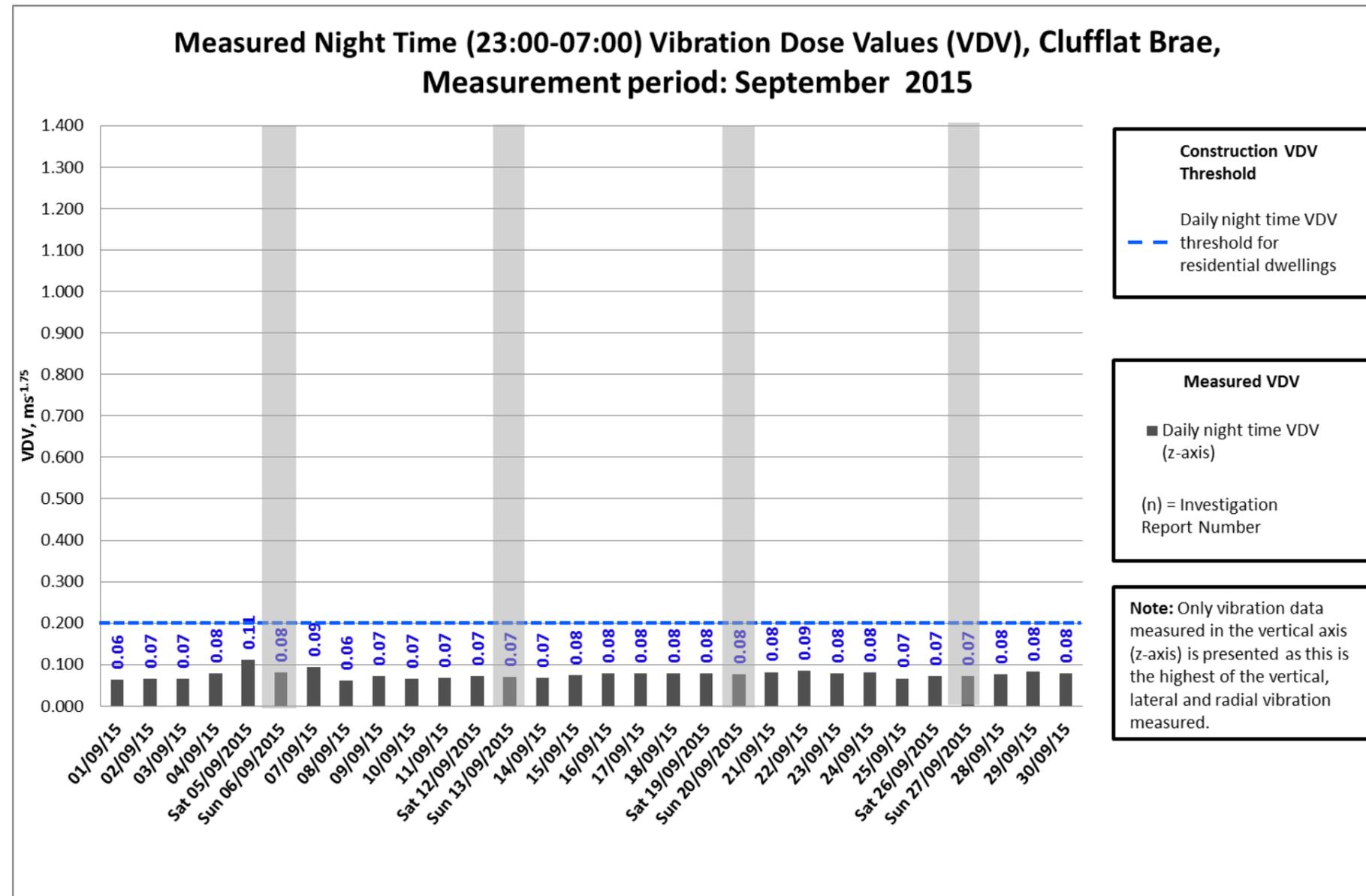


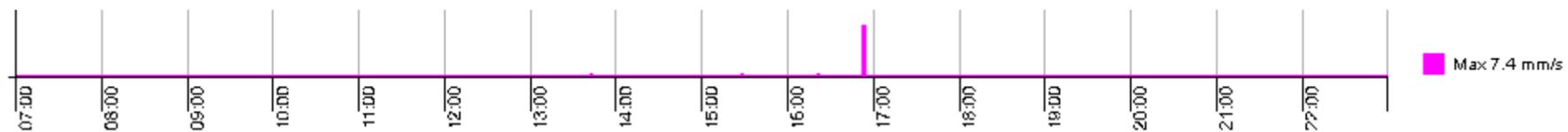
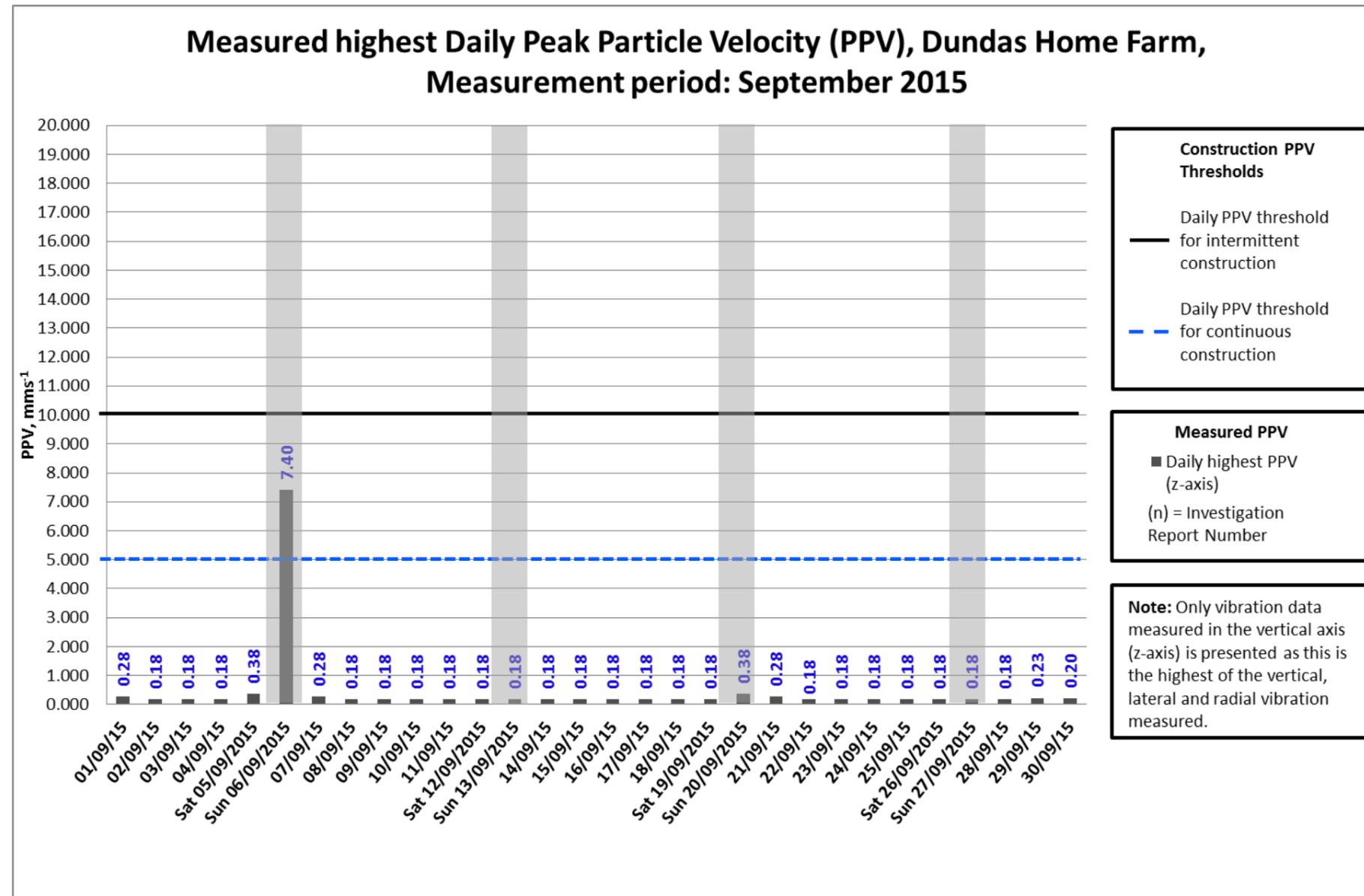
Exceedances from the 02/09/2015 to the 26/09/2015 have been investigated and found to be one off isolated events that are highly unlikely to be caused by construction related activities due to the distance away from the closest works which is approximately 200 meters away (graph above from the 02/09/2015).



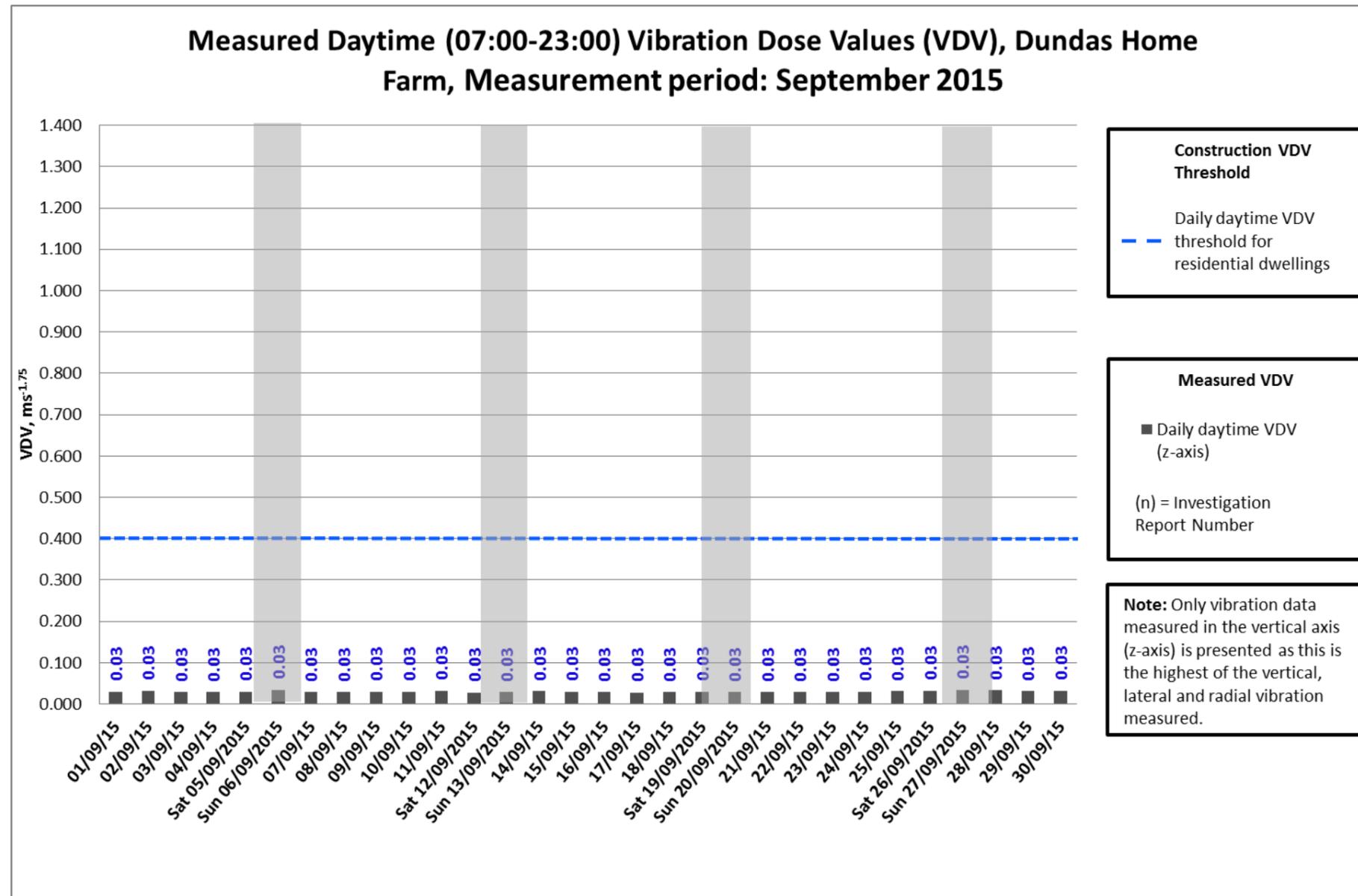
Exceedance on the 30/09/2015 has been investigated and found to be caused by maintenance of the noise monitor that is in close proximity of the vibration monitor. It is highly unlikely that the exceedance was caused by construction related activities (Graph above from the 30/09/2015).



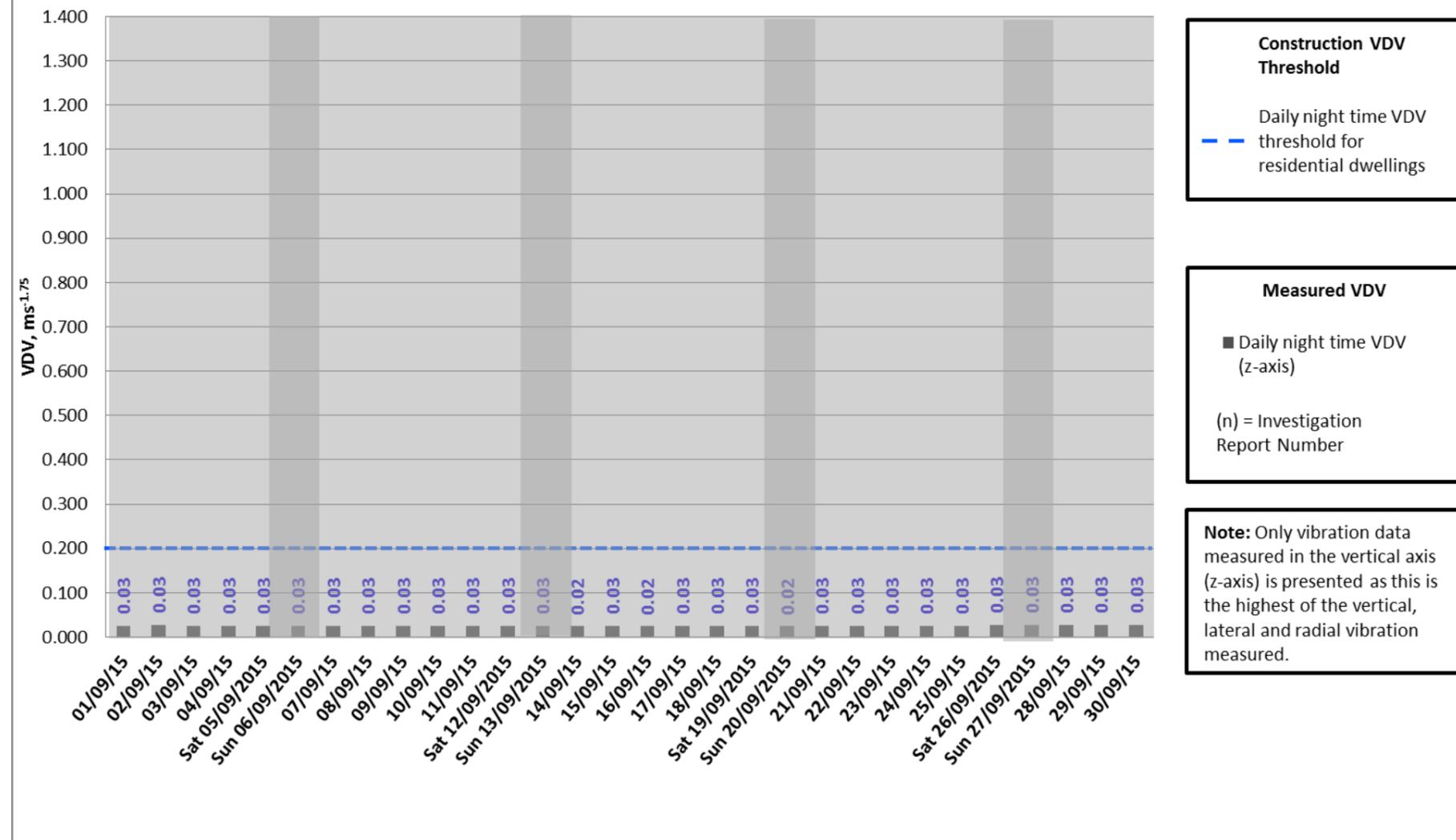


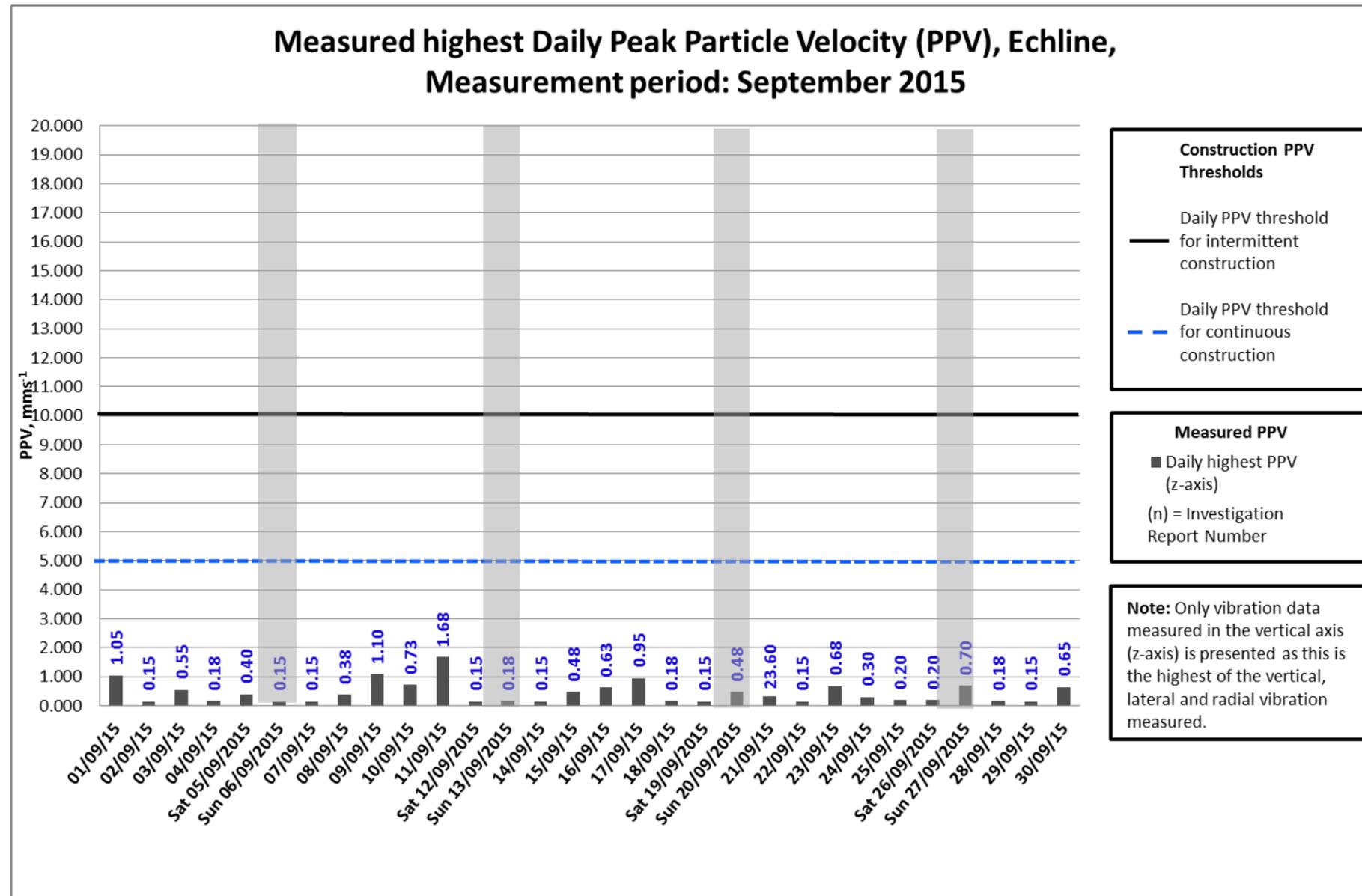


Exceedance on the 06/09/2015 has been investigated and found to be an isolated event that was out with construction working hours and is highly unlikely to be related to construction (graph above from the 06/09/2015).

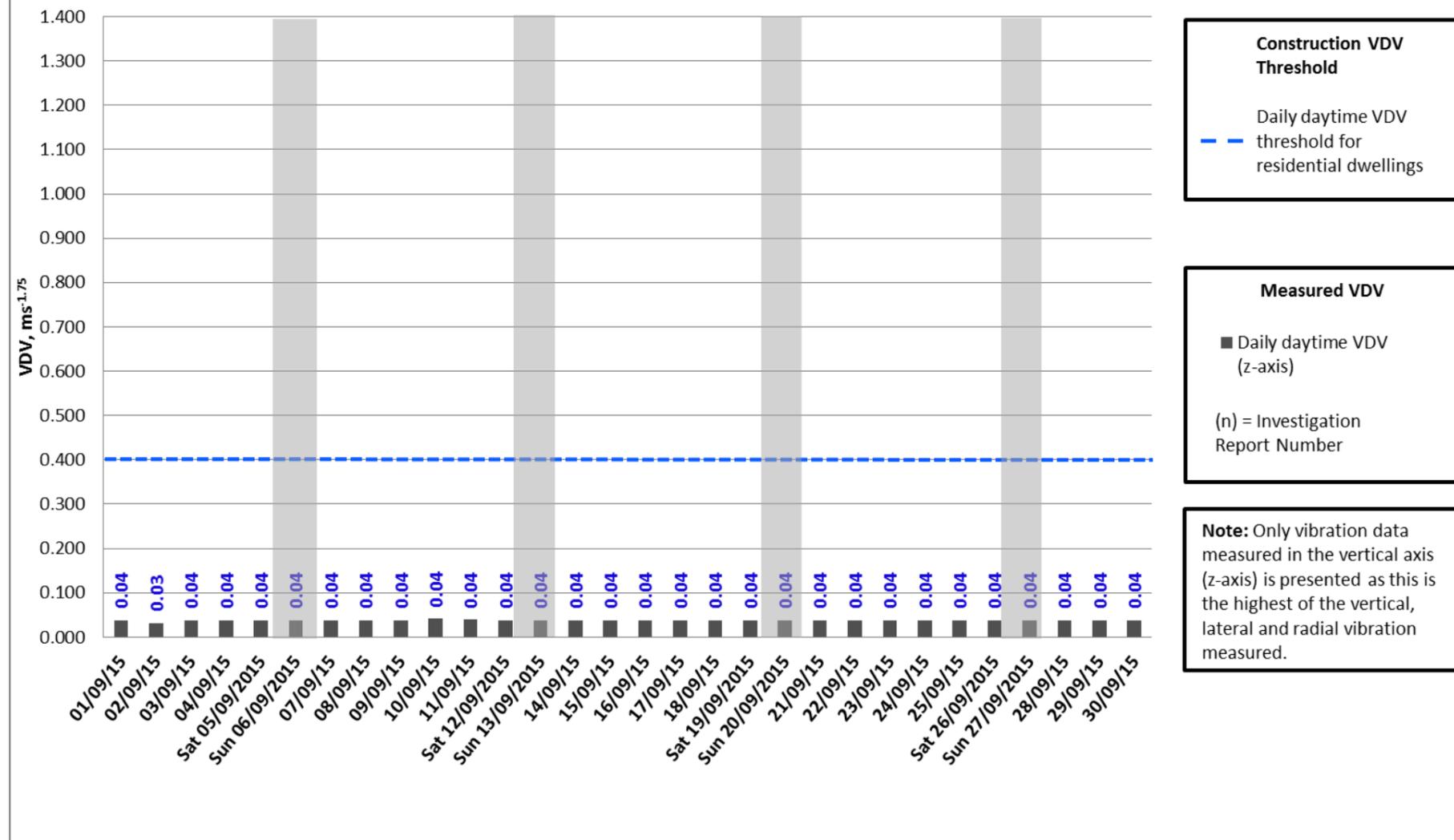


### Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: September 2015





### Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Echline, Measurement period: September 2015



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

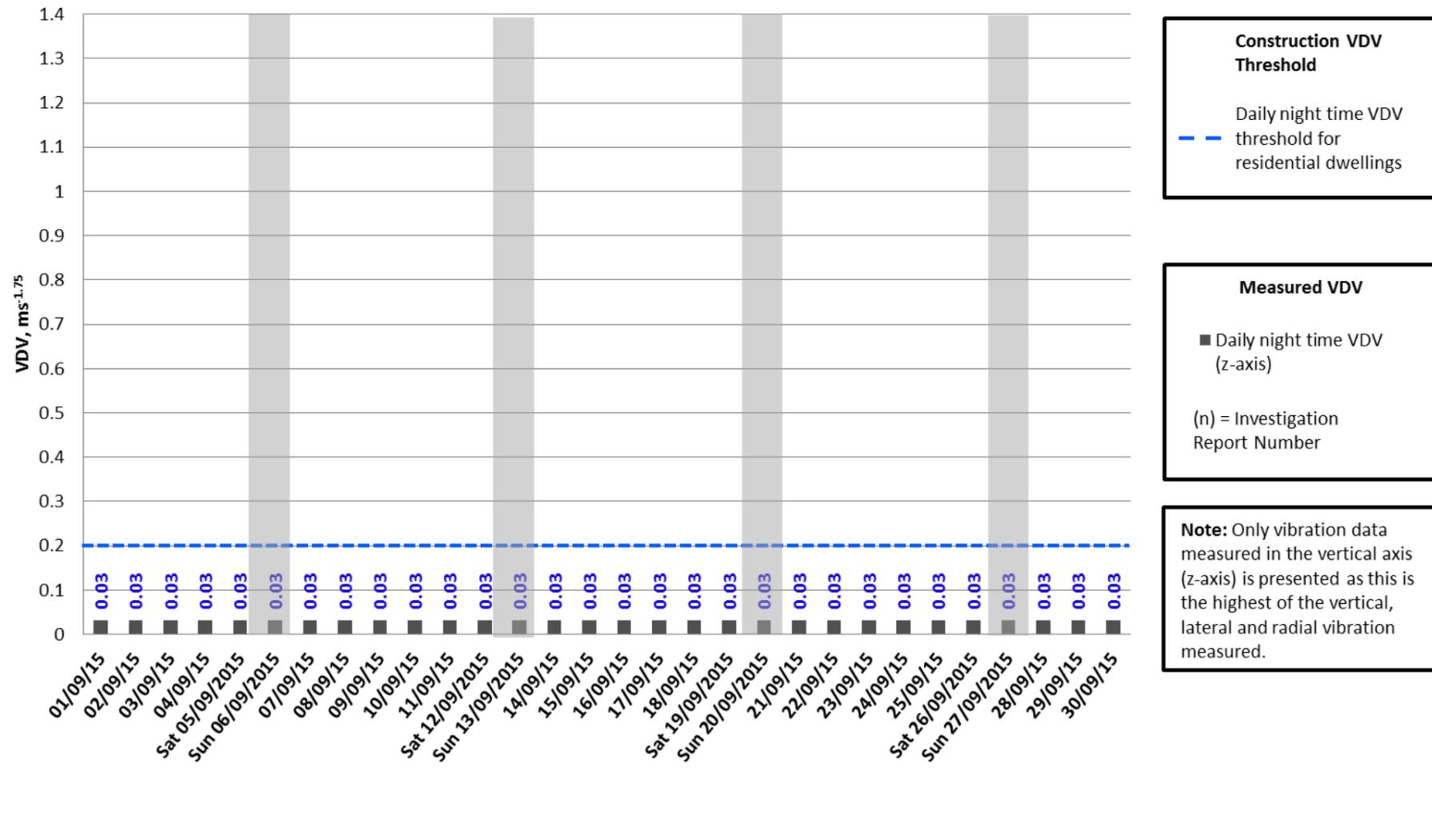
**Measured VDV**

■ 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), Echline,  
 Measurement period: September 2015**



**Construction VDV Threshold**

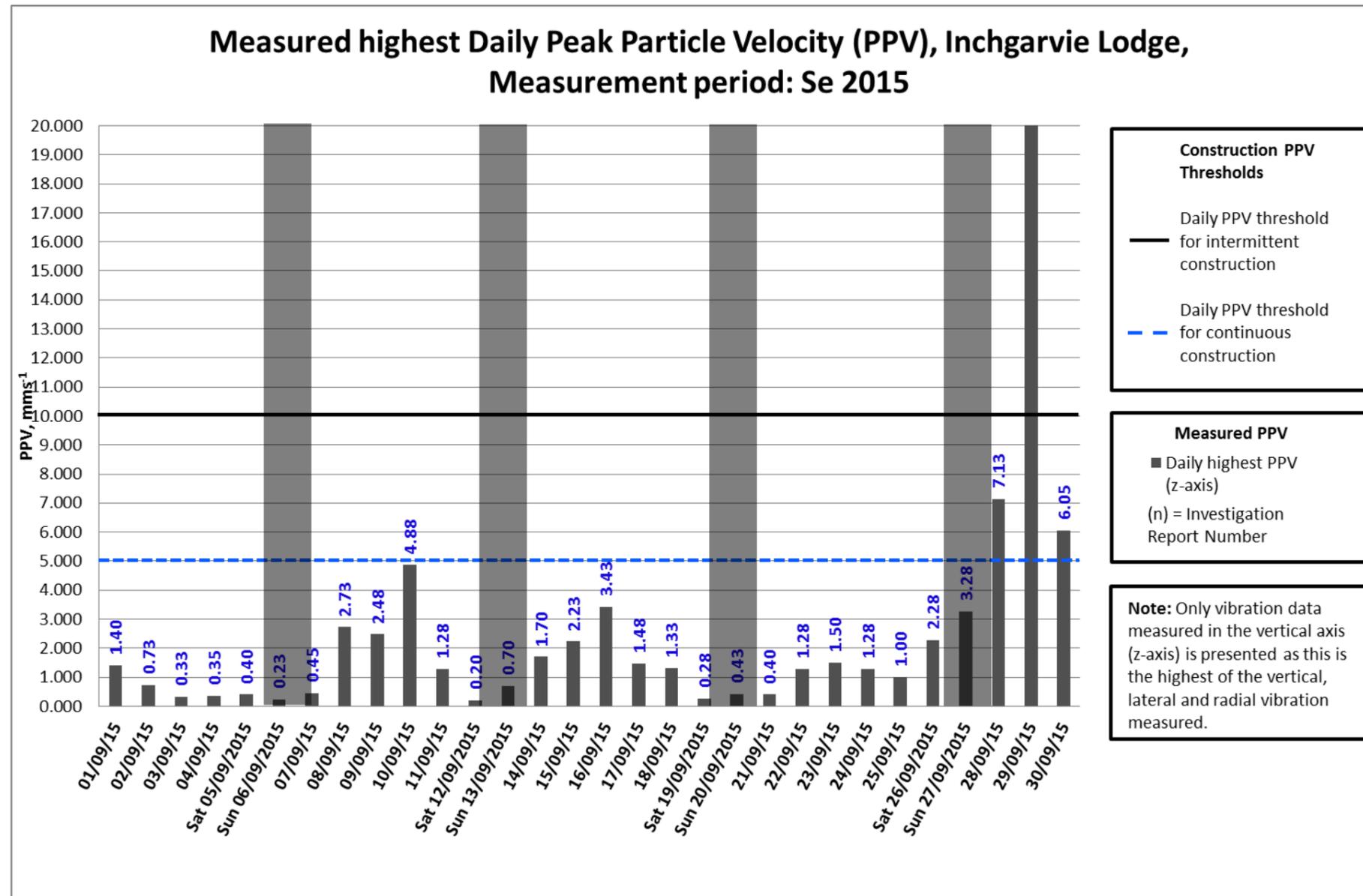
Daily night time VDV threshold for residential dwellings

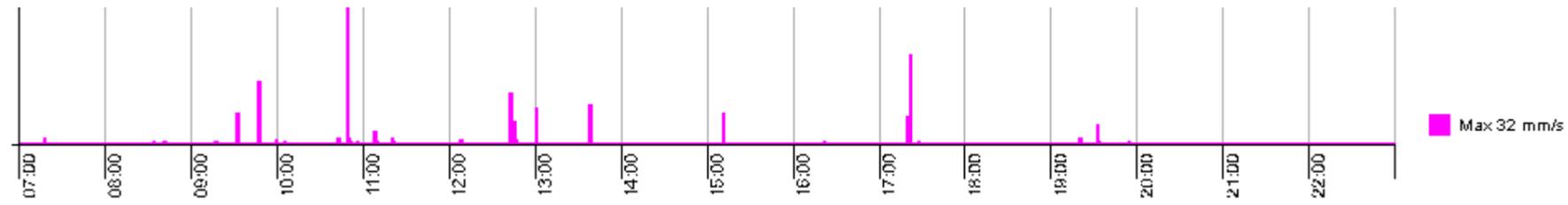
**Measured VDV**

■ 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.



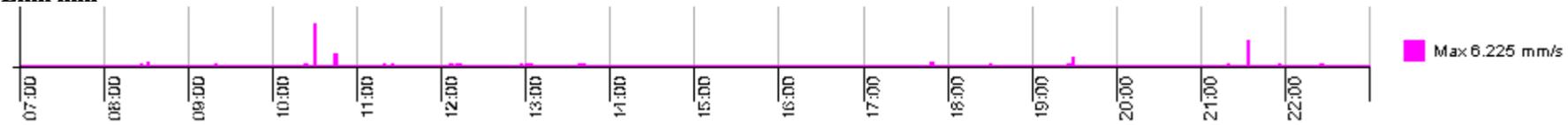


Exceedance on the 28/09/2015, 29/09/2015 and on the 30/09/2015 have been investigated and found to be intermittent vibration which is unlikely to be caused by construction related activities and more likely to be caused by the localised construction of an extension of the nearby house (graph above from the 29/09/2015).

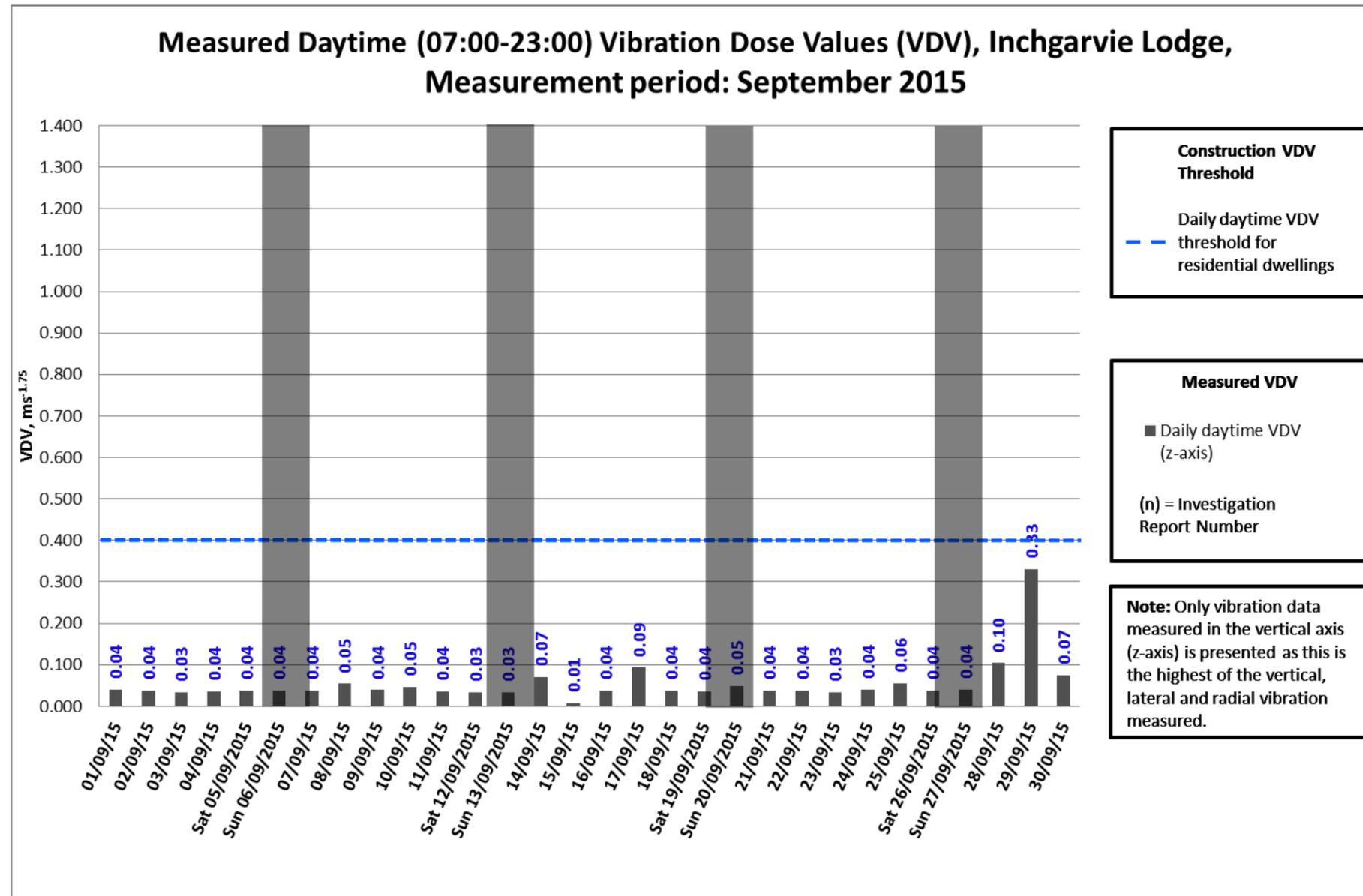
**Inchgarvie**

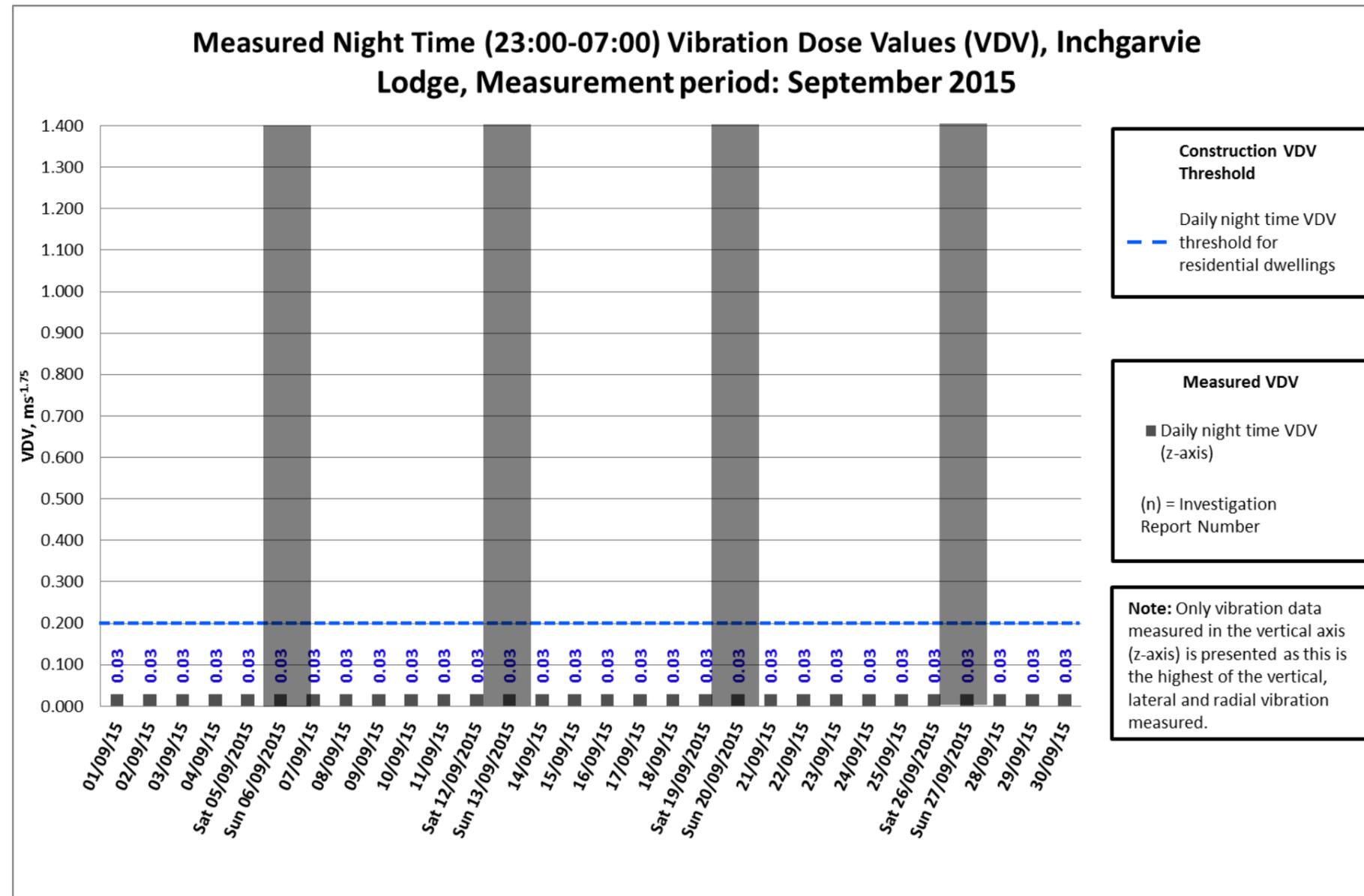


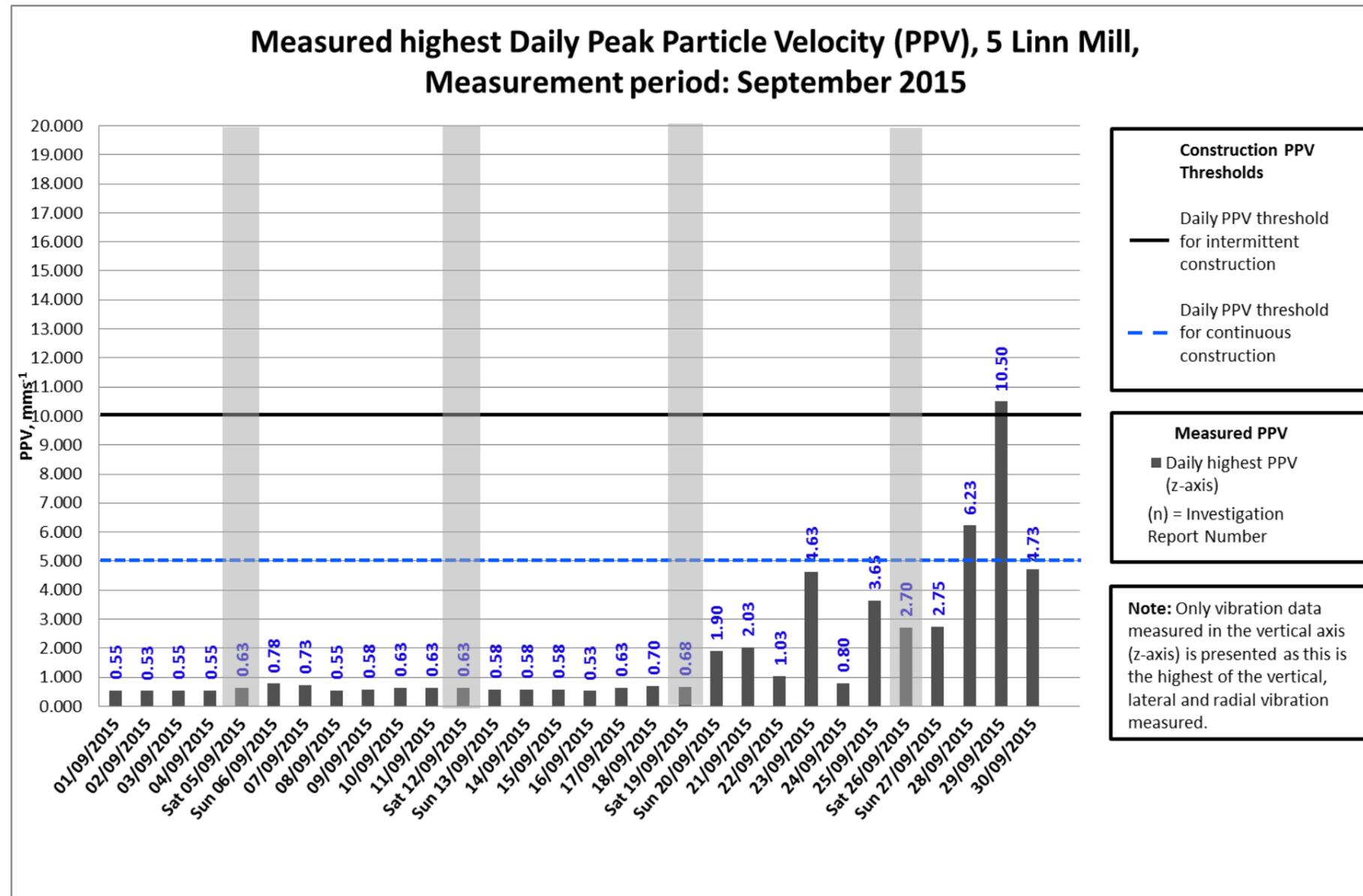
**Linn mill**



Due to similarity's in vibration levels at Linn mill and Inchgarvie lodge further investigation into the exceedances was carried out and it was found that the similarity's was a coincidence and were not related (reference graph above from the 28<sup>th</sup> of September).

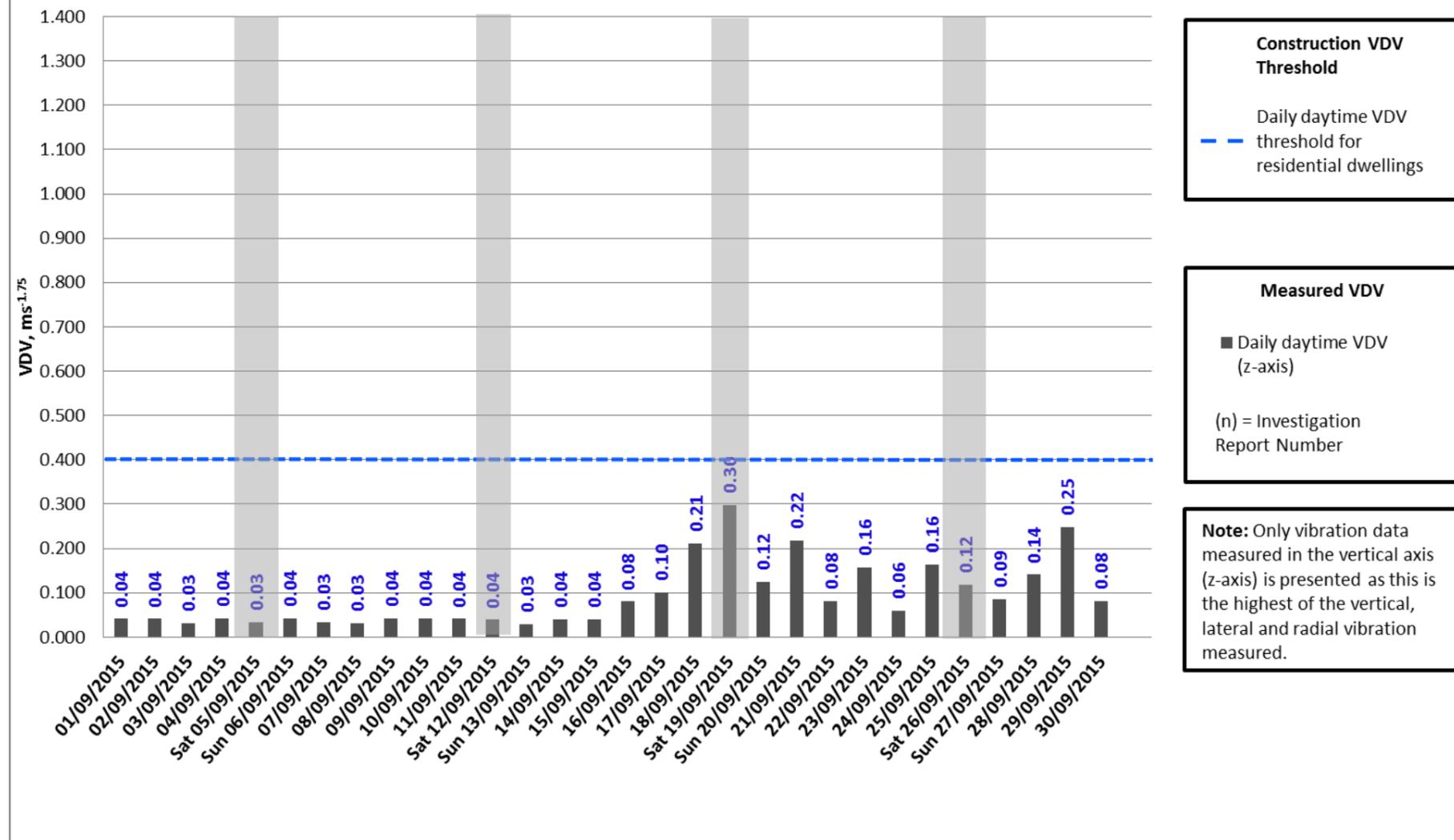


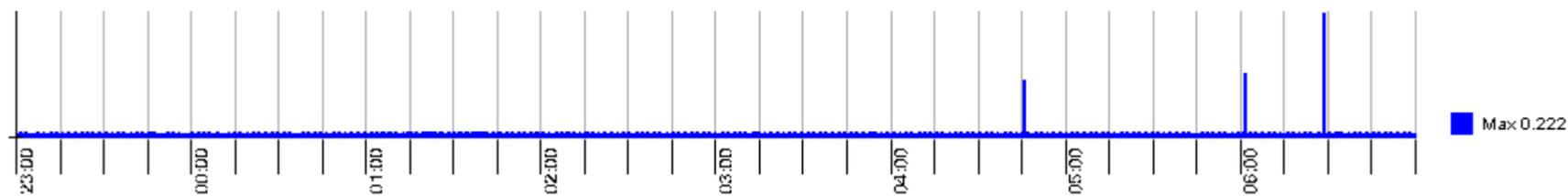
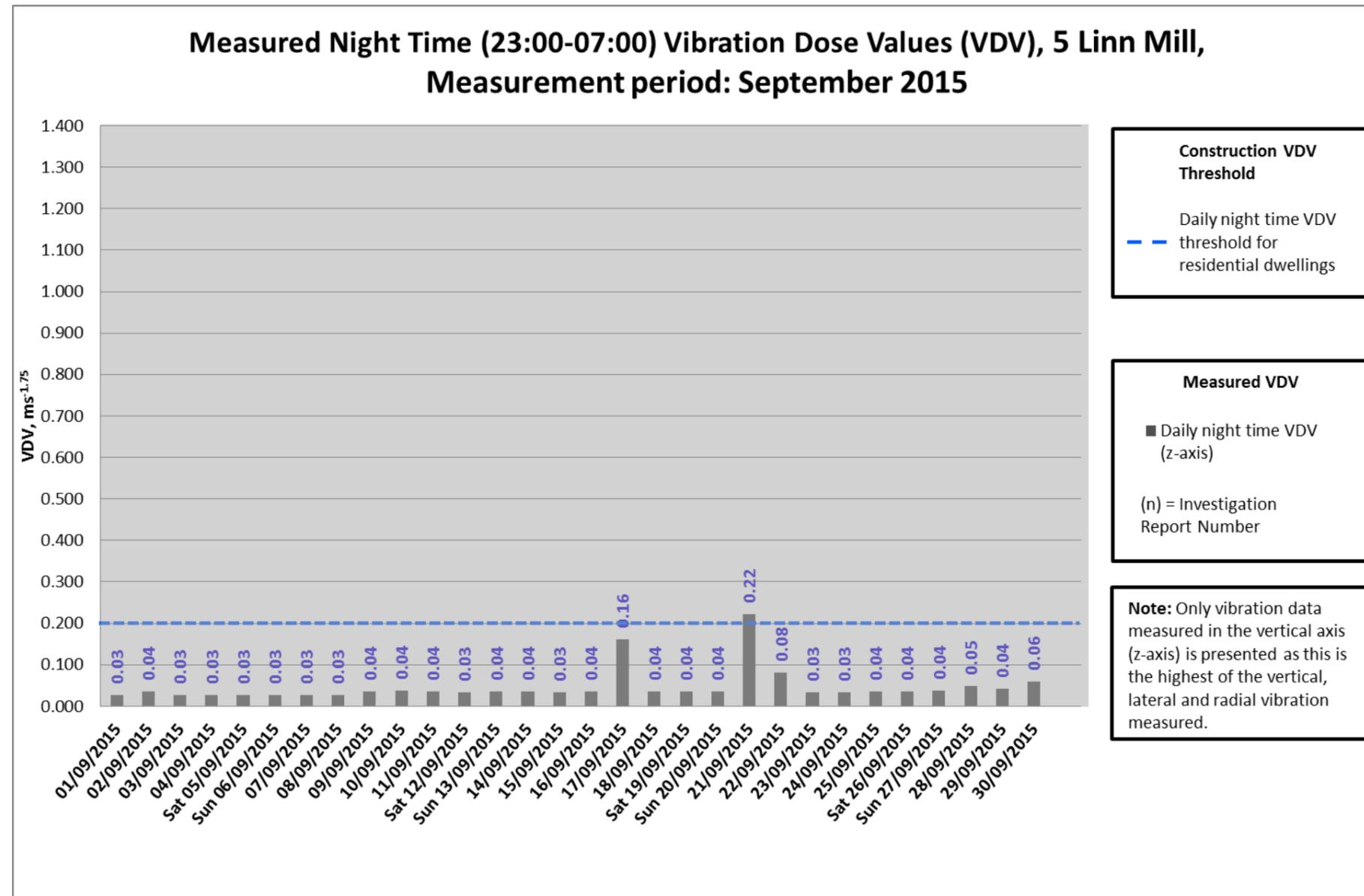




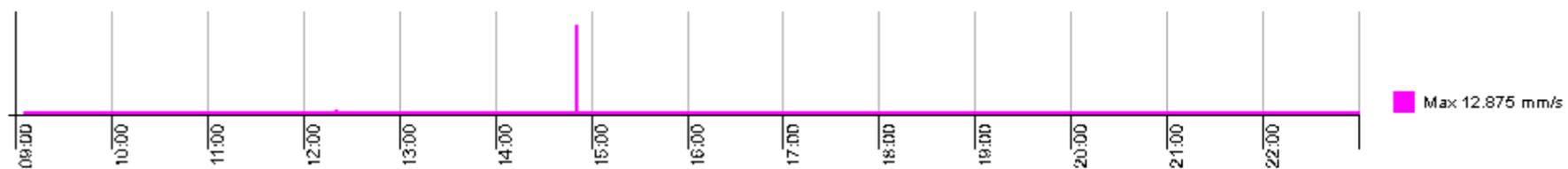
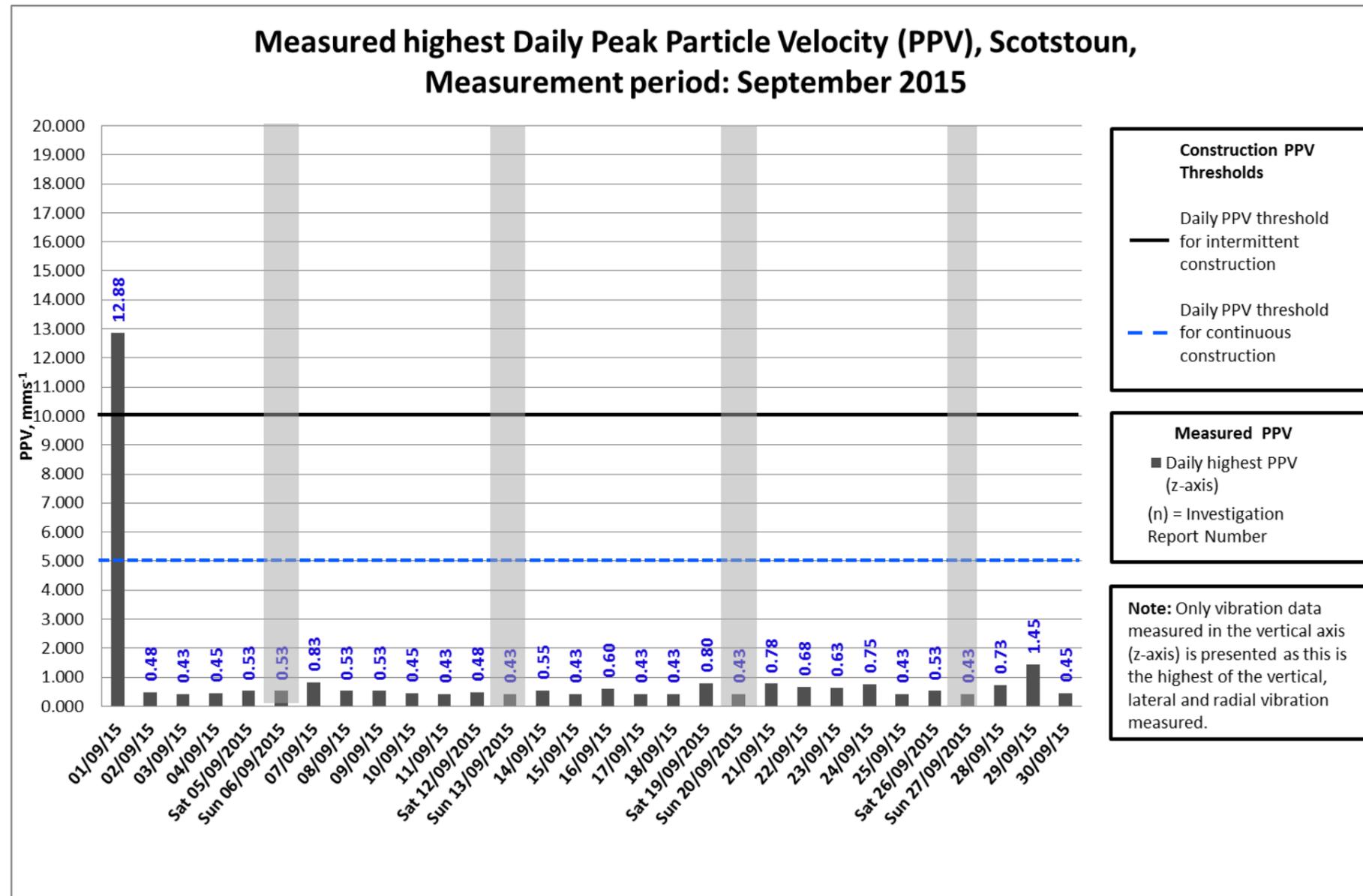
Exceedances on the 28/09/2015 and on the 29/09/2015 have been investigated and found to be isolated events that are unlikely to be caused by construction related activities. It was also noted that the intermittent vibration levels happened within and out with construction working hours (graph above from the 28/09/2015).

**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), 5 Linn Mill,  
 Measurement period: September 2015**

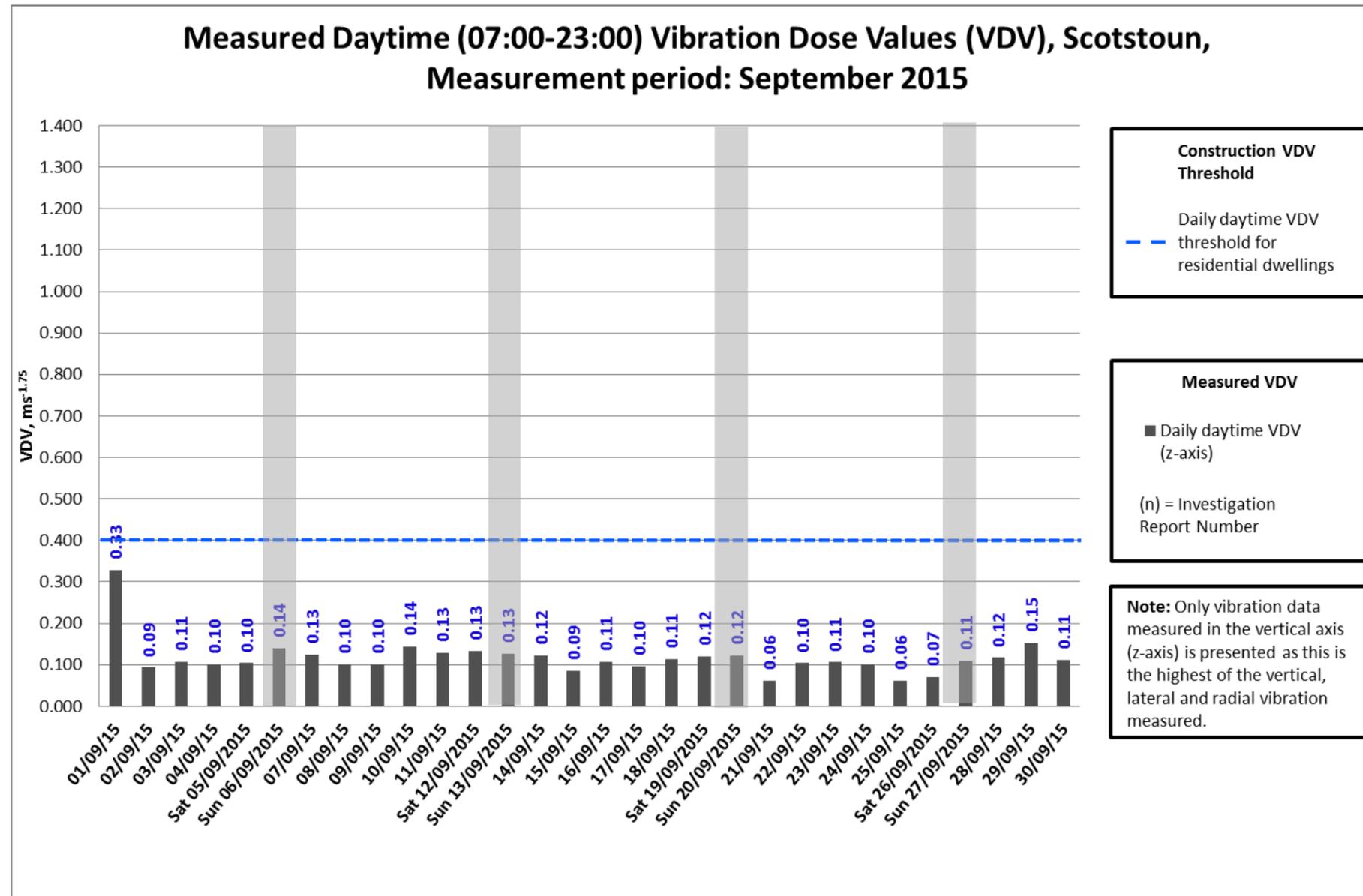




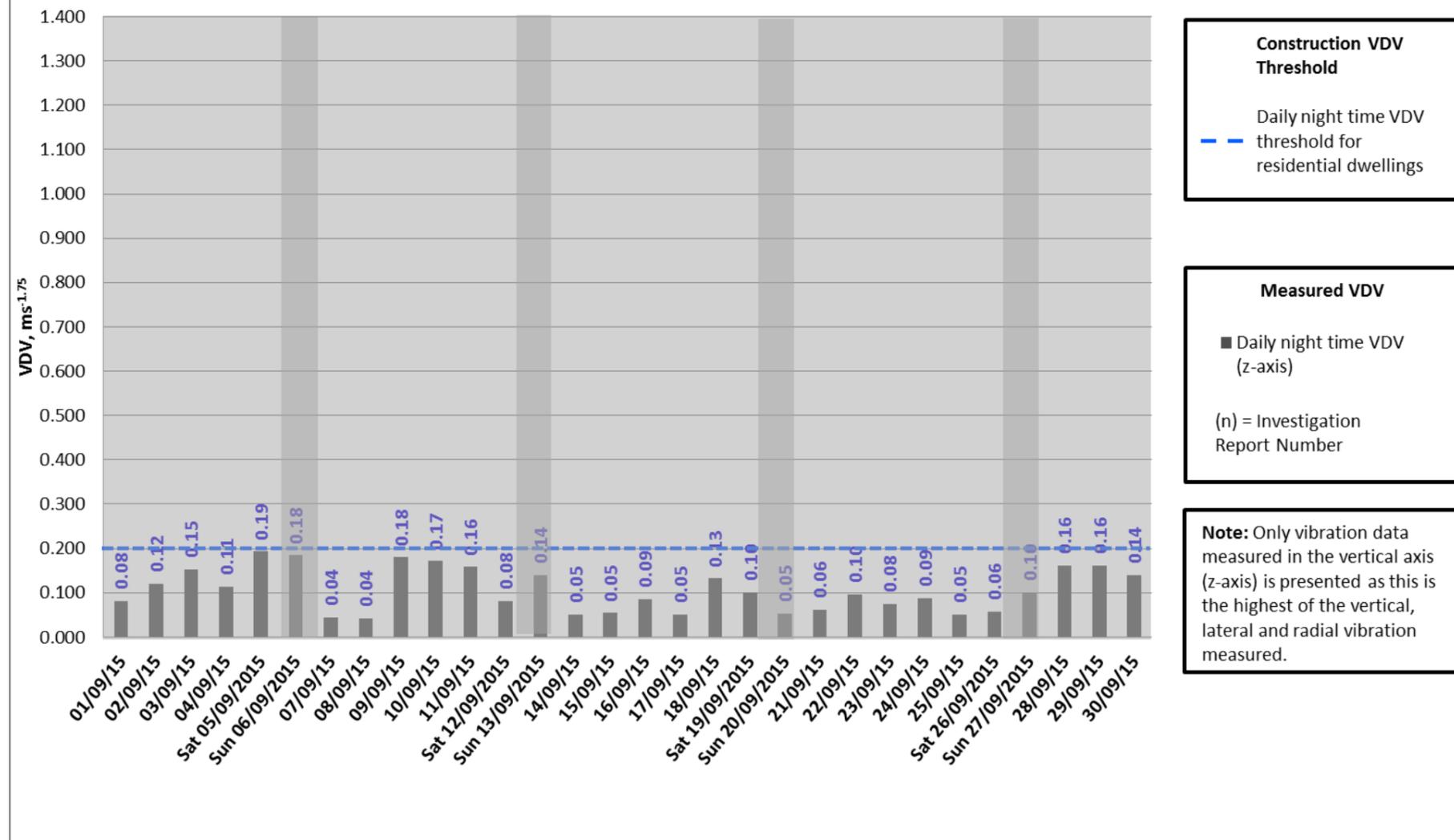
Exceedance on the 21/09/2015 has been investigated and found to be out with construction working hours and is highly unlikely to be caused by construction related activity (graph above from the 21/09/2015).



Exceedance on the 01/09/2015 has been investigated and found to be a one off isolated event that is highly unlikely to be related to construction activities (graph above from the 01/09/2015).



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



**Construction VDV Threshold**

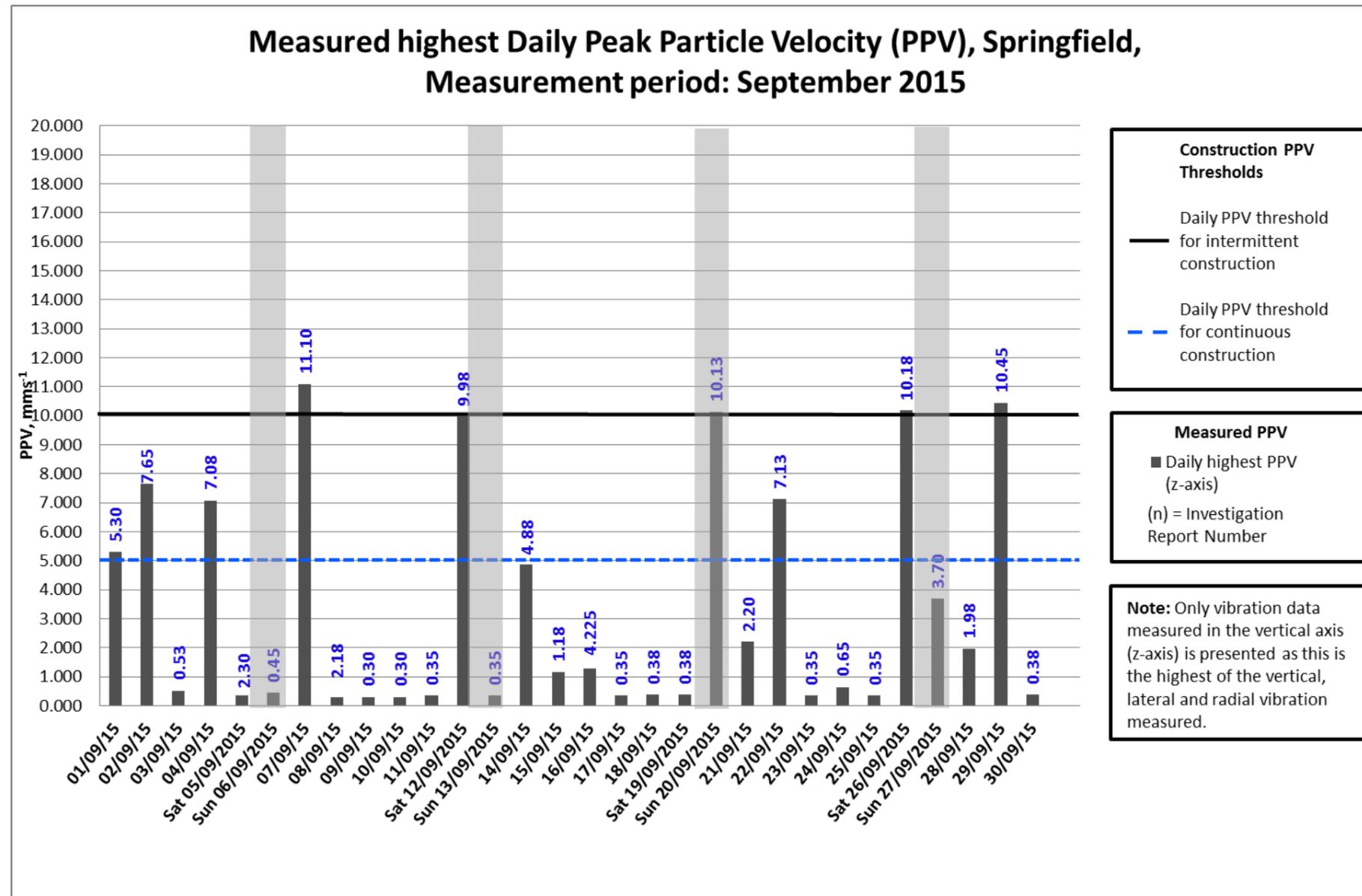
Daily night time VDV threshold for residential dwellings

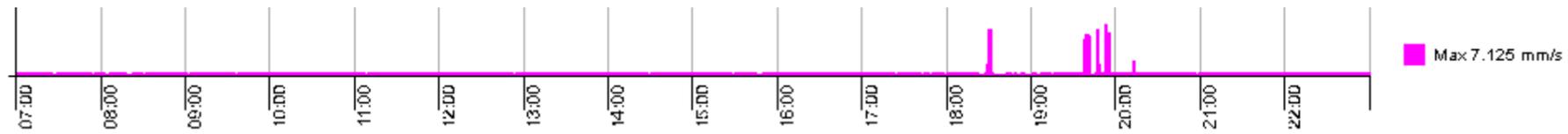
**Measured VDV**

■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

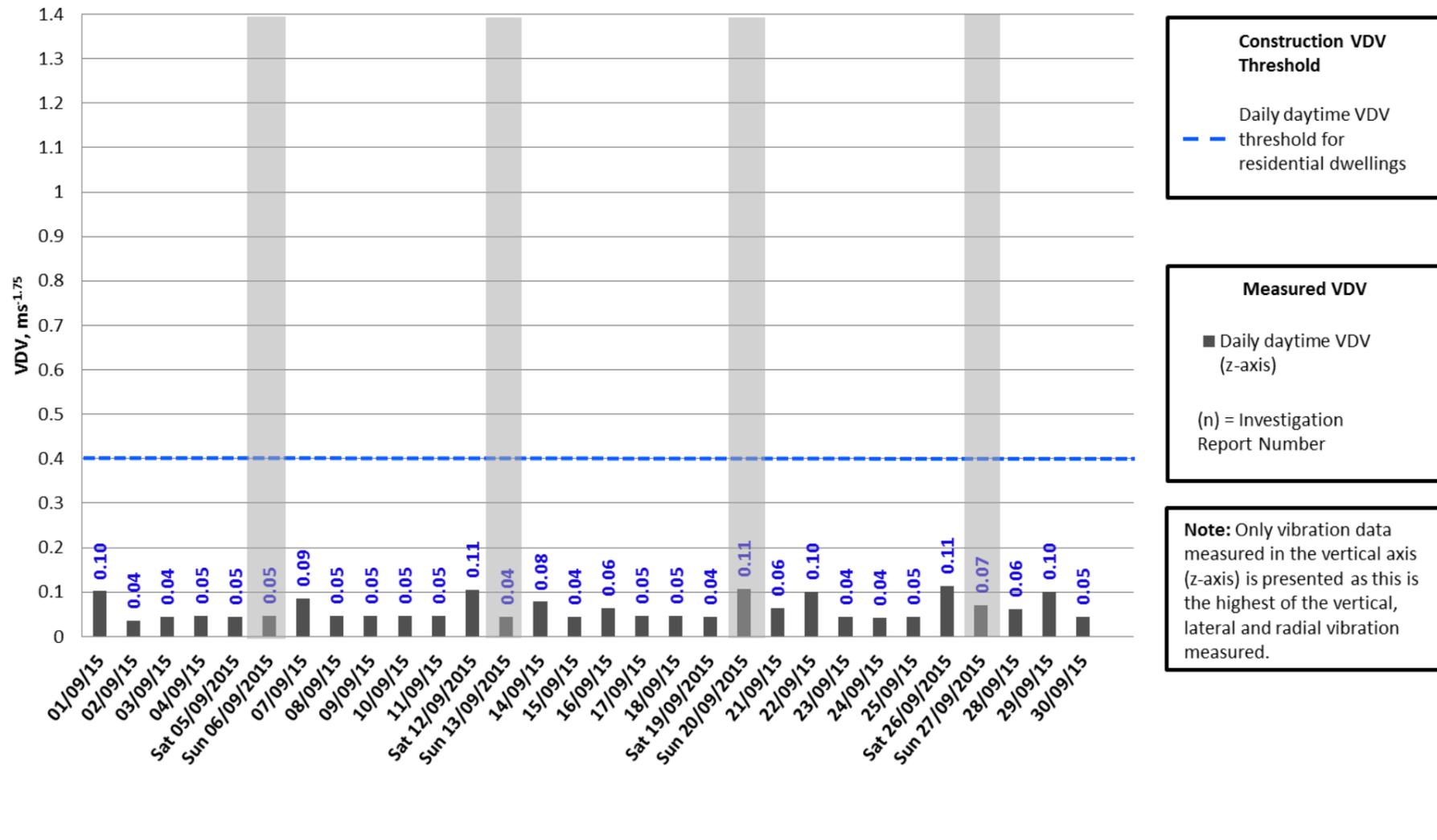
**Note:** Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.





All exceedances in the month of September at Springfield have been investigated and found unlikely to be caused by construction related activities. Exceedances on the 20/09/2015 and on the 22/09/2015 have been found to be out with construction working hours. Exceedances on the 01/09/2015, 02/09/2015, 04/09/2015, 07/09/2015, 12/09/2015, 26/09/2015 and on the 29/09/2015 have been investigated and found to be isolated events that are unlikely to be related to construction due to being approximately 265 meters away from the closest construction works (graph above from the 22/09/2015).

**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield,  
 Measurement period: September 2015**



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

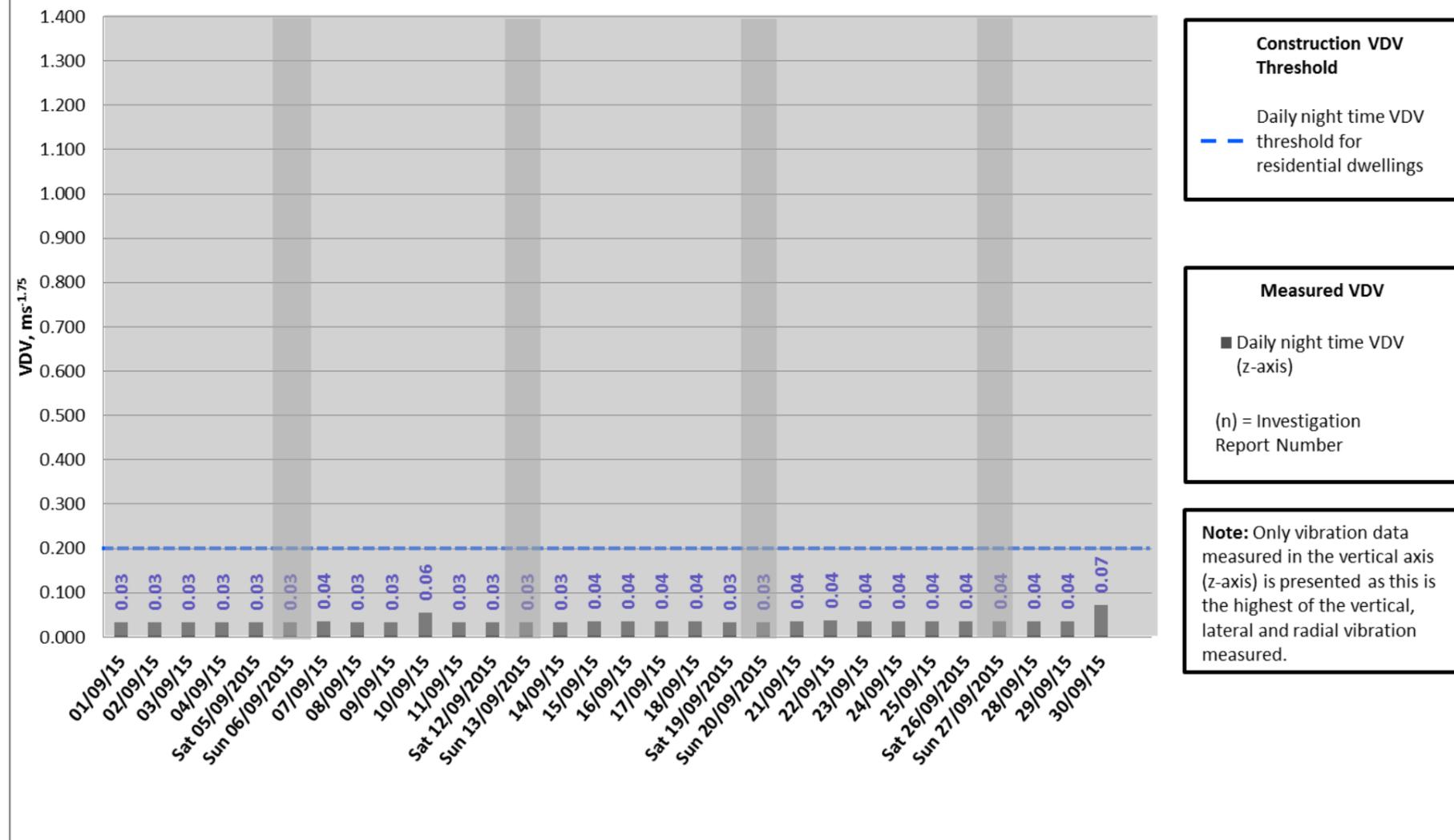
**Measured VDV**

■ 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), Springfield, Measurement period: September 2015



**Construction VDV Threshold**

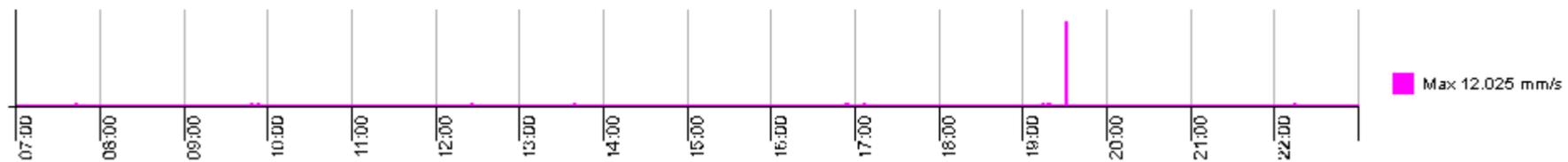
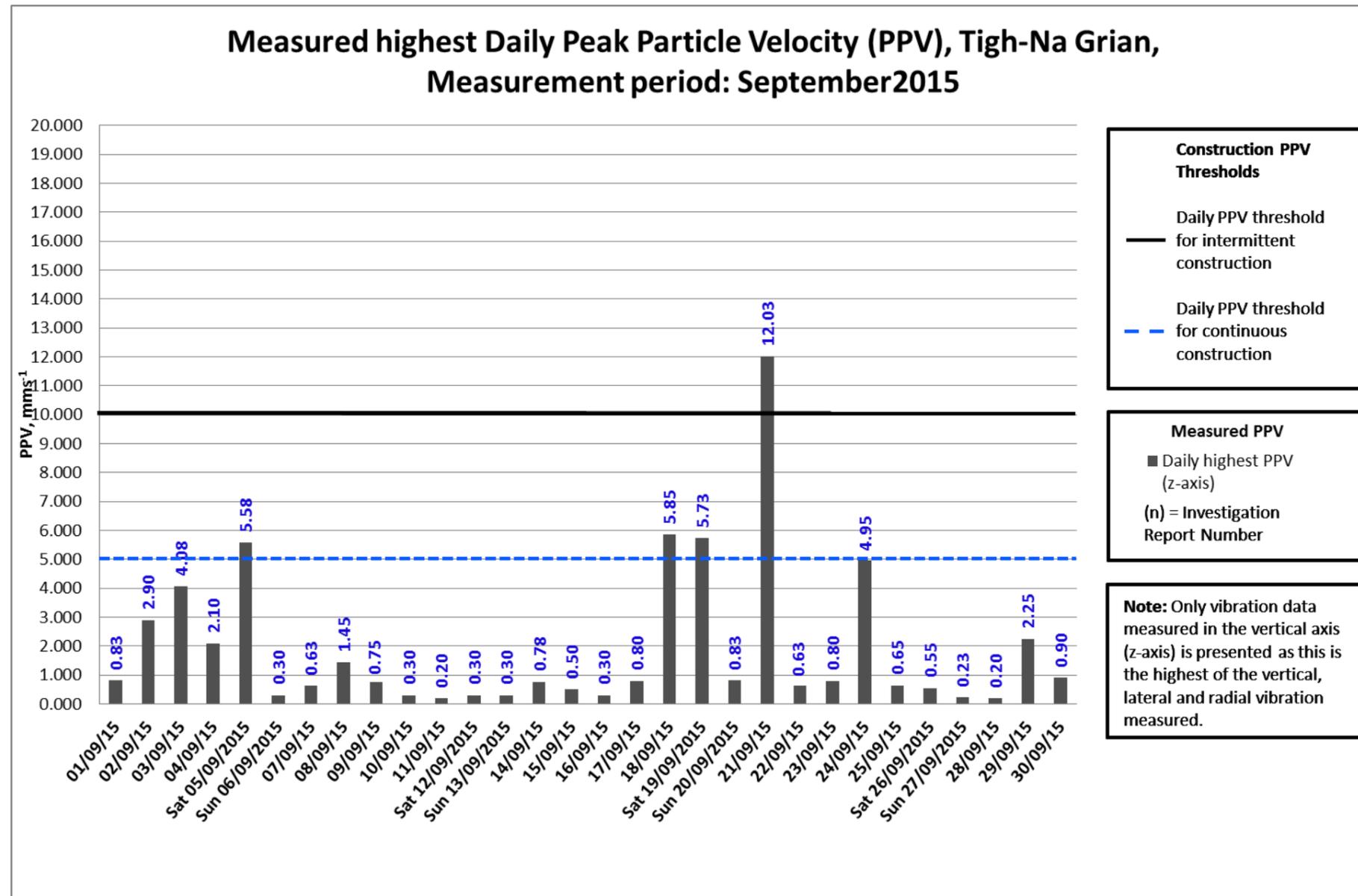
Daily night time VDV threshold for residential dwellings

**Measured VDV**

■ Daily night time VDV (z-axis)

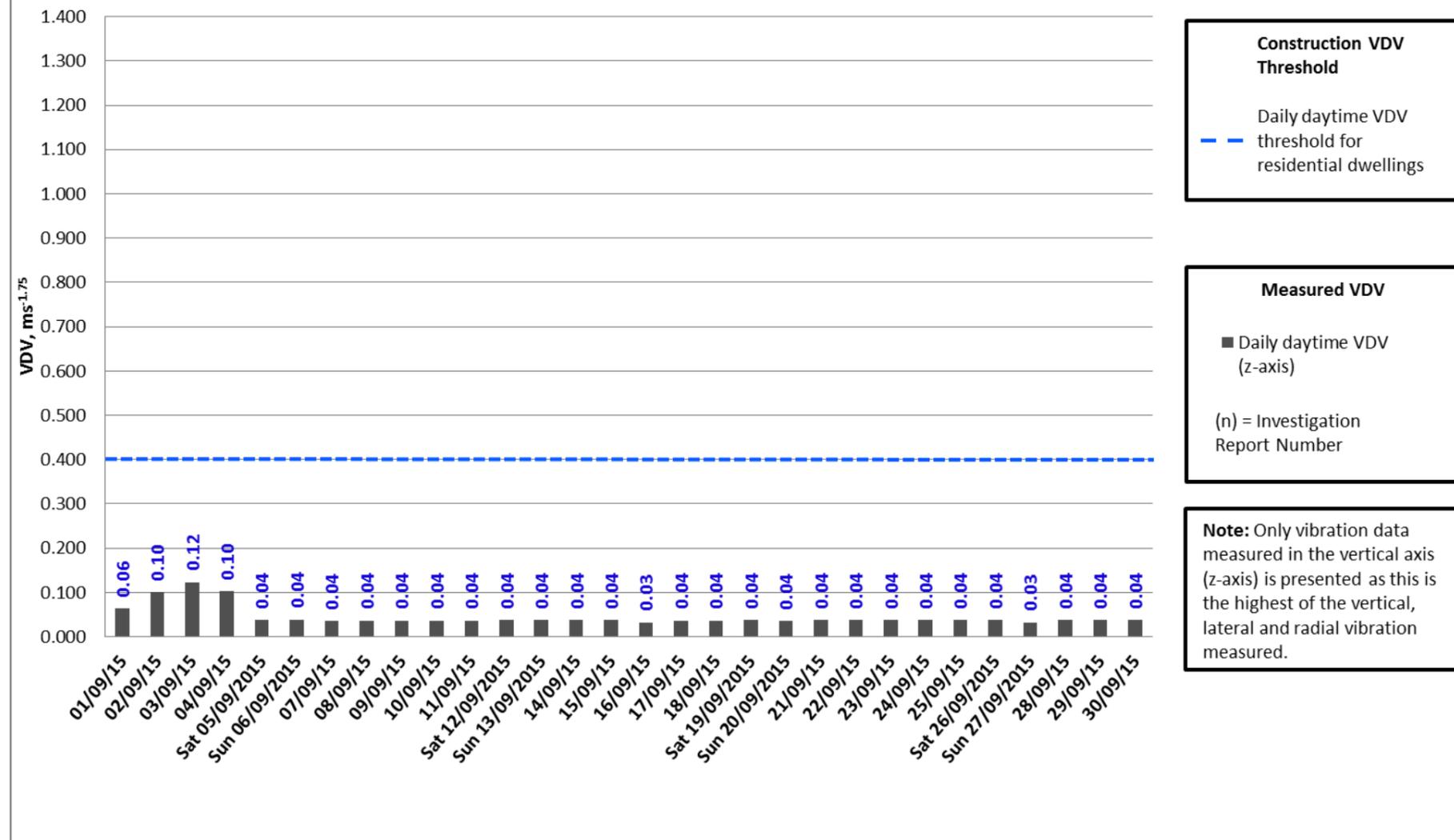
(n) = Investigation Report Number

**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.



All exceedances have been investigated and found to be one off isolated events that is unlikely to be caused by construction related activities (graph above from the 21/09/2015).

**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian,  
 Measurement period: September 2015**



**Construction VDV Threshold**

Daily daytime VDV threshold for residential dwellings

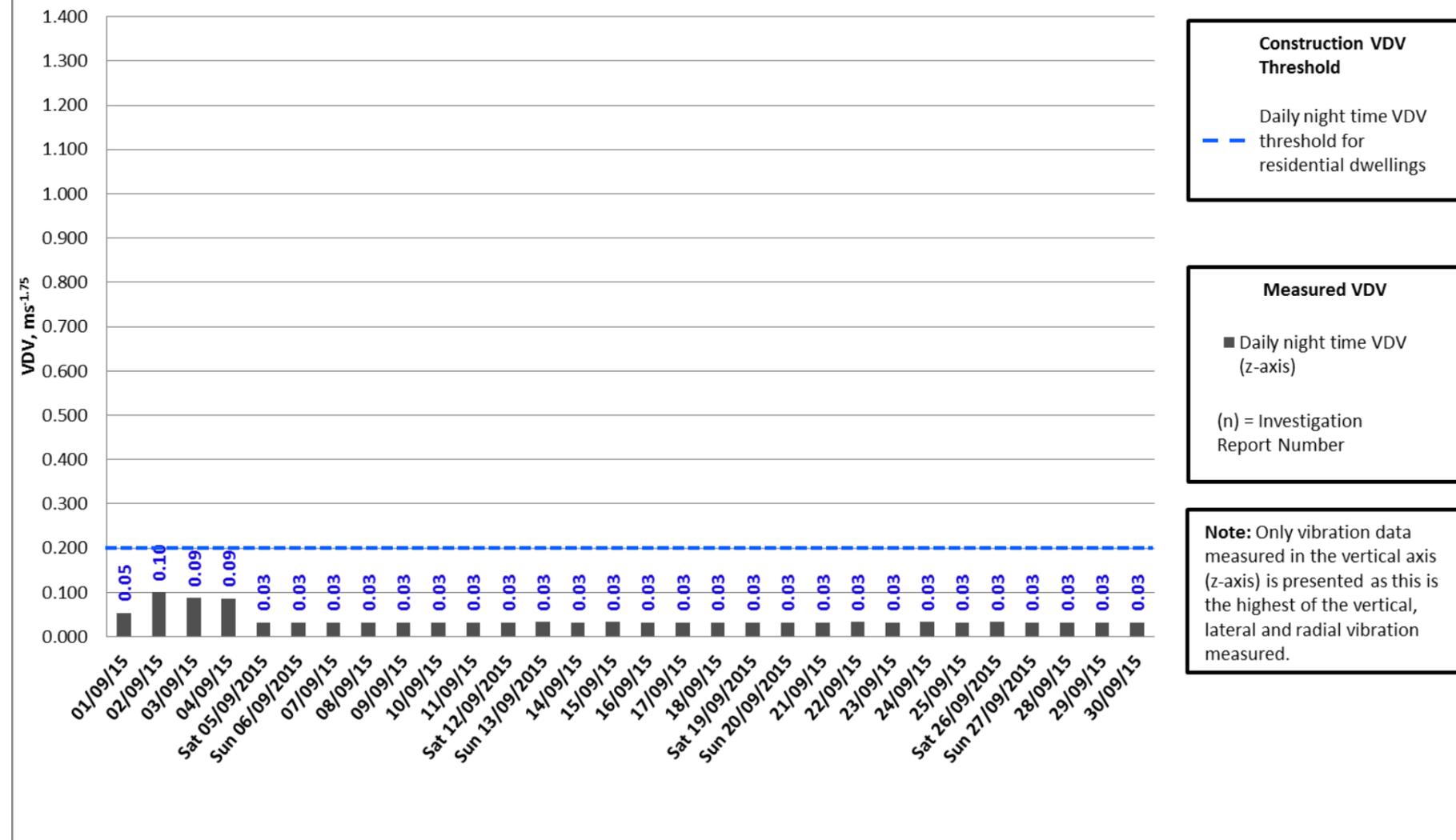
**Measured VDV**

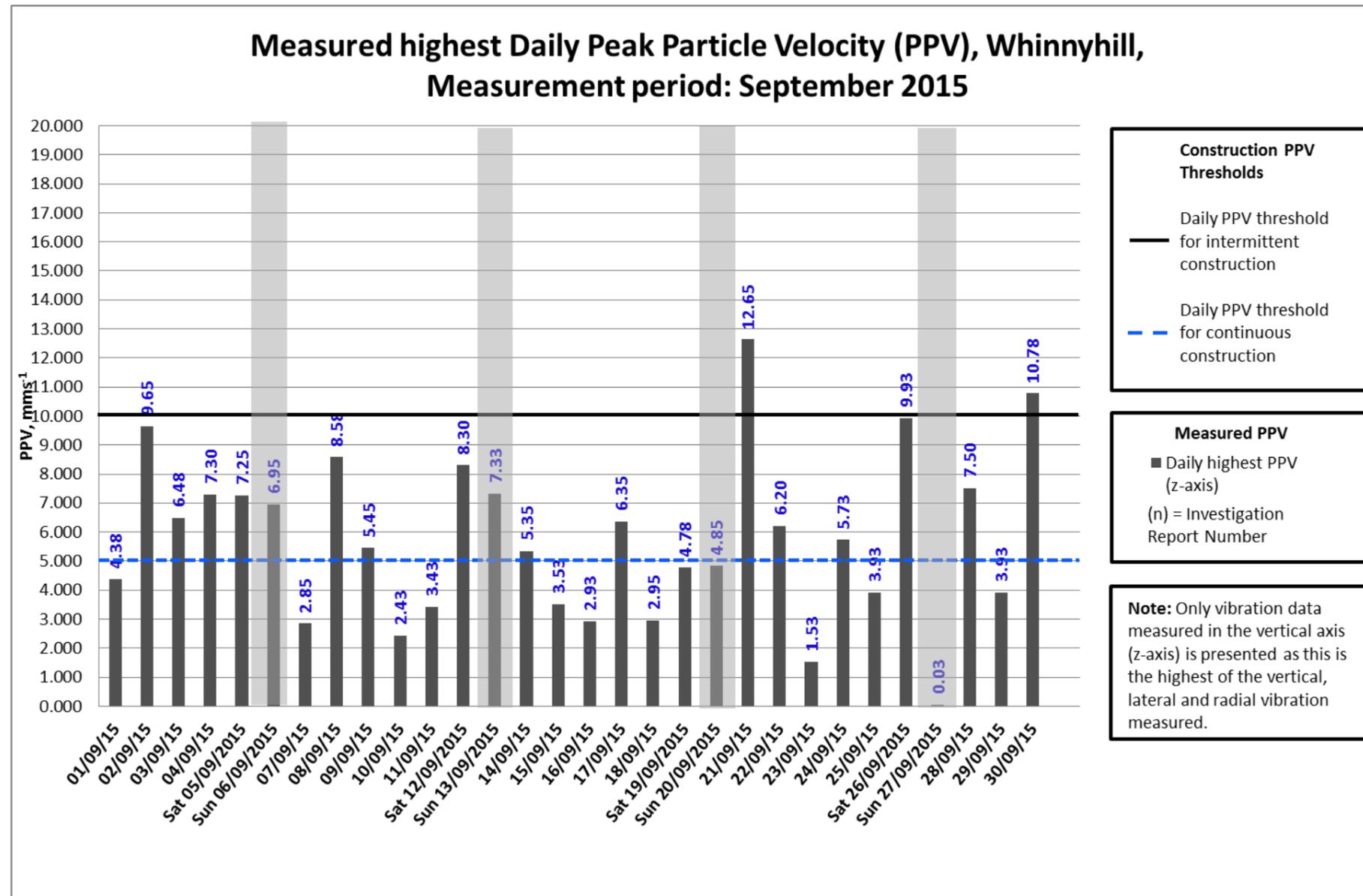
■ Daily daytime VDV (z-axis)

(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), Tigh-Na Grian,  
 Measurement period: September 2015**



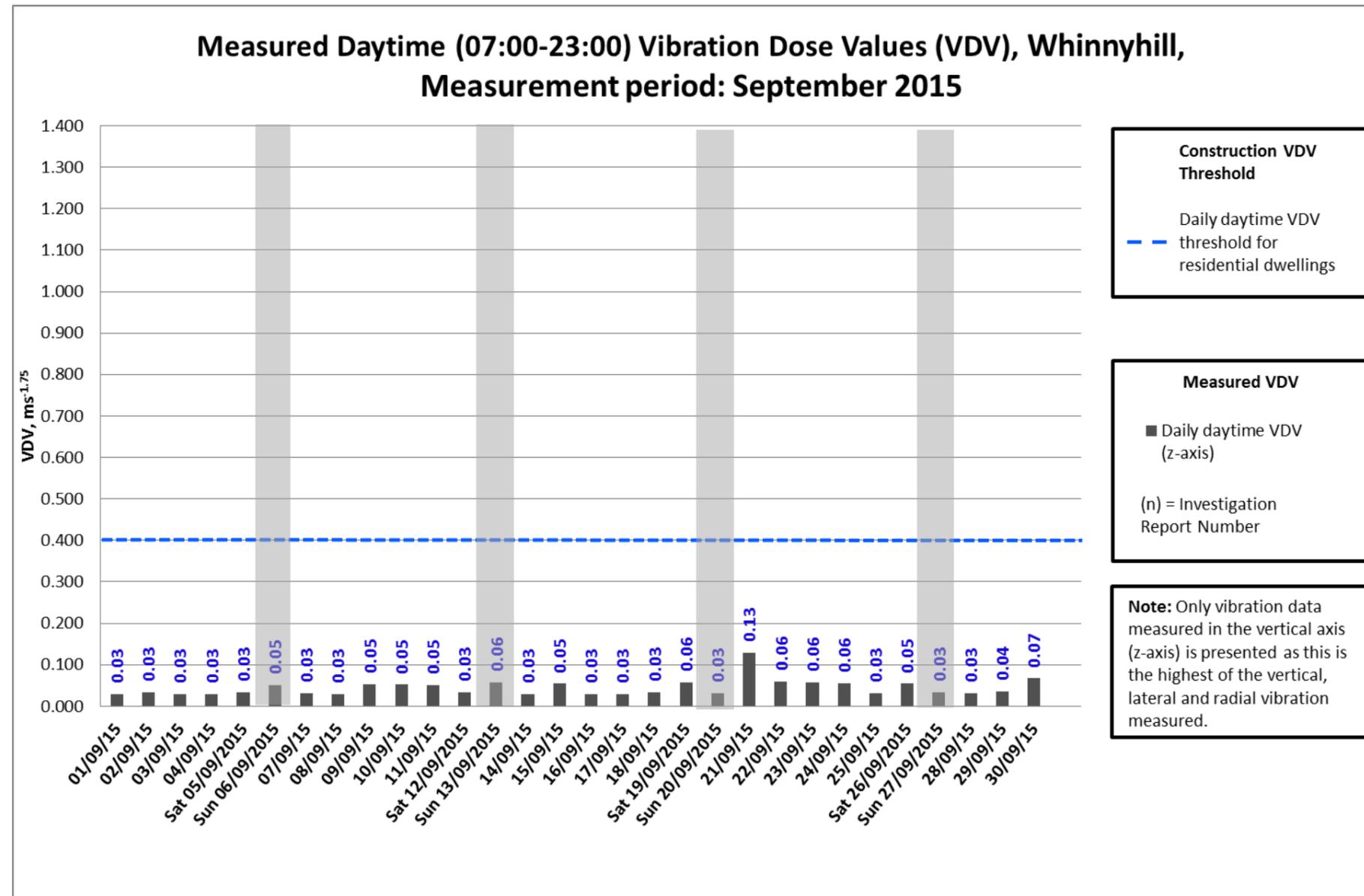




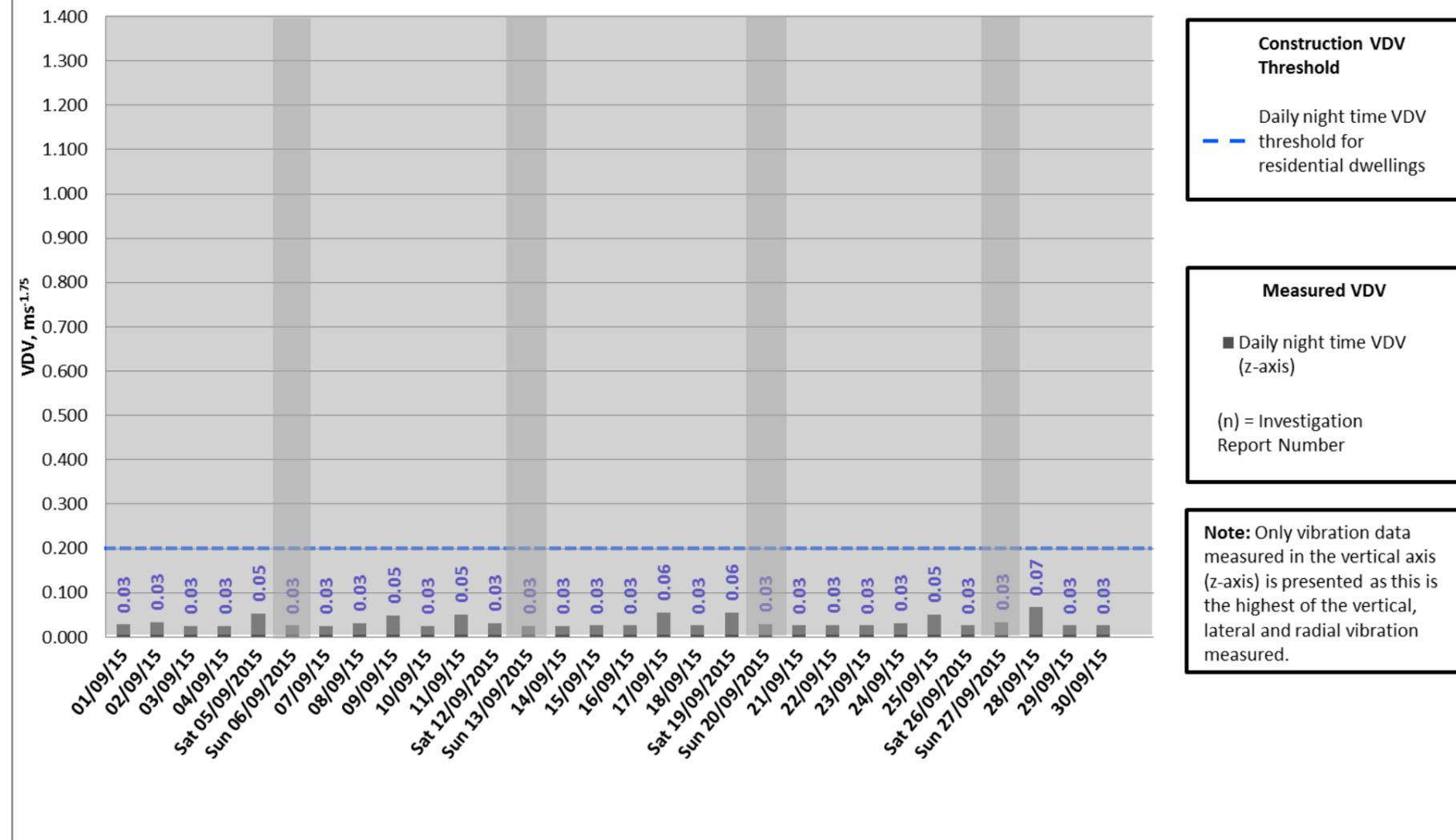
Exceedances on the 08/09/2015, 09/09/2015, 12/09/2015, 14/09/2015, 17/09/2015, 21/09/2015, 22/09/2015 and on the 30/09/2015 have been investigated and found to be one off isolated events that is unlikely to be related to construction due to the distance away from the works (approximately 130 metres away) (graph above from the 12/09/2015).



Exceedance on the 02/09/2015, 03/09/2015, 04/09/2015, 05/09/2015, 06/09/2015, 13/09/2015, 24/09/2015, 26/09/2015 and on the 28/09/2015 have been investigated and found to be out of construction working hours and are unlikely to be caused by construction related activities (graph above from the 02/09/2015).



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