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Project FORTH REPLACEMENT CROSSING

Document title

VIBRATION MONITORING REPORT
JANUARY 2016

00	05/02/16	First draft	MRN	SWR	SWR
Rev	Rev. Date	Purpose of revision	Made	Reviewed	Approved

<p style="font-size: 1.5em; font-weight: bold; margin: 0;">FOR REVIEW</p>	
Made by Michael Richardson	Checked By: Steven Westwater
Initials: MRN	Initials: SWR
Document number REP-00269	Rev 00

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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 January 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.
- 2.6.** During the period from the 1st to the 3rd of January there was no ongoing construction works due to the Christmas shutdown.

Table 1: Exceedances of thresholds set out in the CoCP

January 2016

Location	PPV Exceedance		VDV Exceedance	
	<i>Continuous</i> (5 mm.s^{-1})	<i>Intermittent</i> (10 mm.s^{-1})	<i>Day</i> ($0.4 \text{ m.s}^{-1.75}$)	<i>Night</i> ($0.2 \text{ m.s}^{-1.75}$)
Linn Mill	2	2	0	0
Butlaw Fisheries	0	0	0	0
Clufflat Brae	6	3	0	0
Dundas Home Farm	0	0	0	0
Echline	0	0	0	0
Inchgarvie Lodge	4	21	0	1
Scotstoun	0	0	0	0
Springfield	6	2	0	1
Tigh-Na-Grian	0	0	0	0
Whinnyhill	8	0	0	0

- 2.7.** 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).
- 2.8.** 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^{-1} for continuous construction (e.g. piling), and 10 mm.s^{-1} for intermittent construction (e.g. blasting).
- 2.9.** 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.

- 2.10.** 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 m.s^{-2} and the time period over which the VDV is measured is in seconds. This yields V DVs in $\text{m.s}^{-1.75}$.
- 2.11.** 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.
- 2.12.** 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.
- 2.13.** 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.

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 January 2016
M1	Whinny Hill	Network	<ul style="list-style-type: none"> • Earthworks/Fill placement • New Ferrytoll road • FT03 & FT04 deck works • FT09 works • FT19 Works • FT07 demolition • Roadworks
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts • North Tower rebar, formwork, concreting works deck section lifts • Pier N1 & N2 bearing works • AVN works
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts • South Tower rebar, formwork, concreting works deck section lifts • Pier S1 rebar, formwork & concrete works • Pier S2 rebar, formwork & concrete works
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts • South Tower rebar, formwork, concreting works deck section lifts • Pier S1 rebar, formwork & concrete works • Pier S2 rebar, formwork & concrete works • AVS rebar & concrete works • Main carriageway earthworks
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> • AVS rebar & concrete works • Main carriageway earthworks • No night time or Sunday construction in the vicinity
M13	Clufflat Brae	Crossing	<ul style="list-style-type: none"> • AVS rebar & concrete works • Main carriageway works • No night time or Sunday daytime construction in the vicinity
M14	Springfield	Network	<ul style="list-style-type: none"> • AVS rebar & concrete works • Main carriageway works • Earthworks south abutment area • No night time or Sunday daytime construction in the vicinity
M15	Echline	Network	<ul style="list-style-type: none"> • AVS rebar & concrete works • Earthworks south abutment area • Main carriageway works
M16	Scotstoun	Network	<ul style="list-style-type: none"> • Footpath works • Utility works • B800 North road works including bridge works • B800 piling works • Mainline NB merge works



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M17	Dundas Home Farm	Network	<ul style="list-style-type: none">• Utility works• B800 south roadworks including bridge works• B800 piling works• Mainline NB merge works
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Table 2: The main construction activities undertaken in the locality of each of the vibration monitors during the period of January 2016.

Table 3: PCNV Predicted PPV & VDV Levels

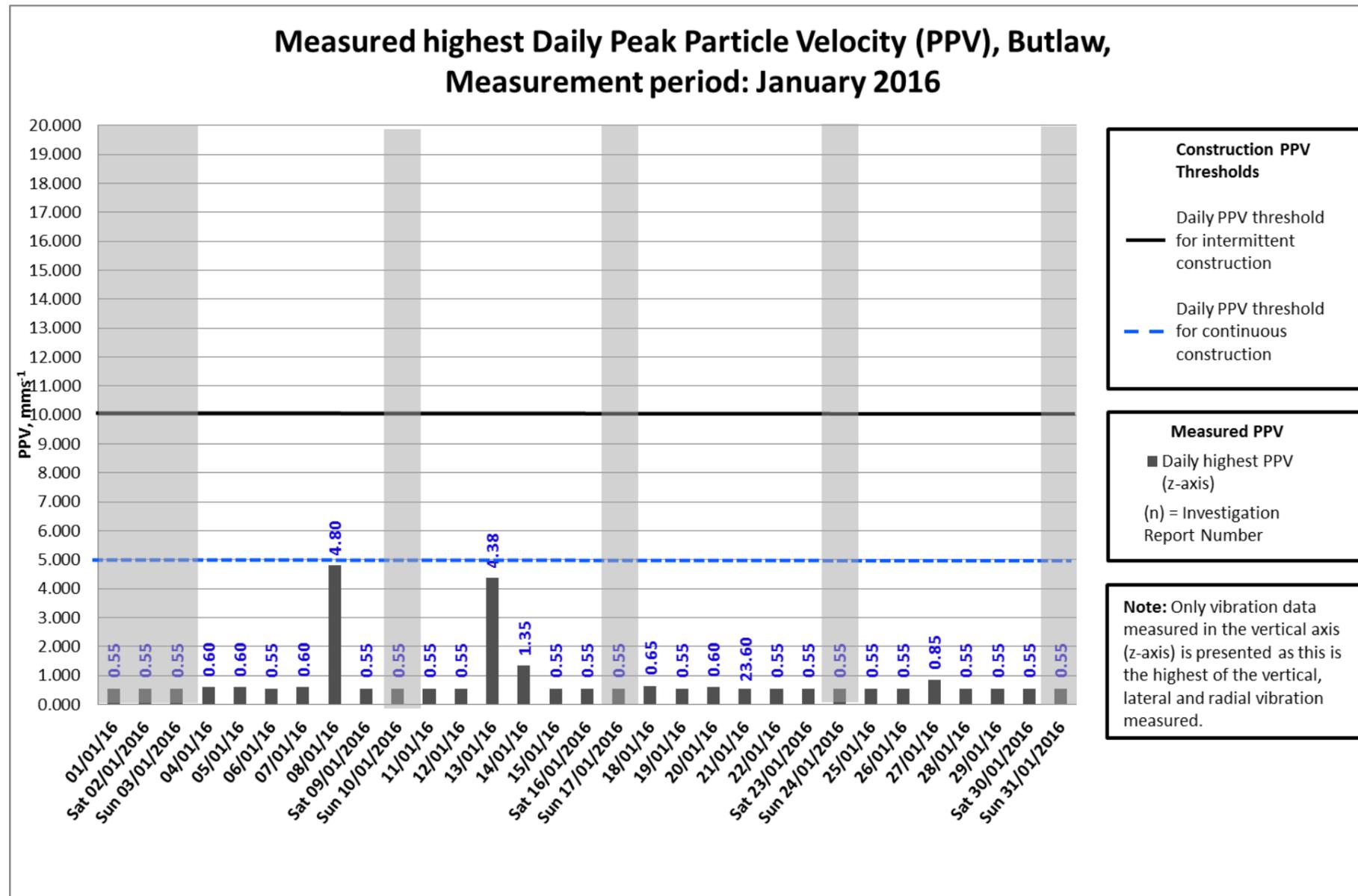
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	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.

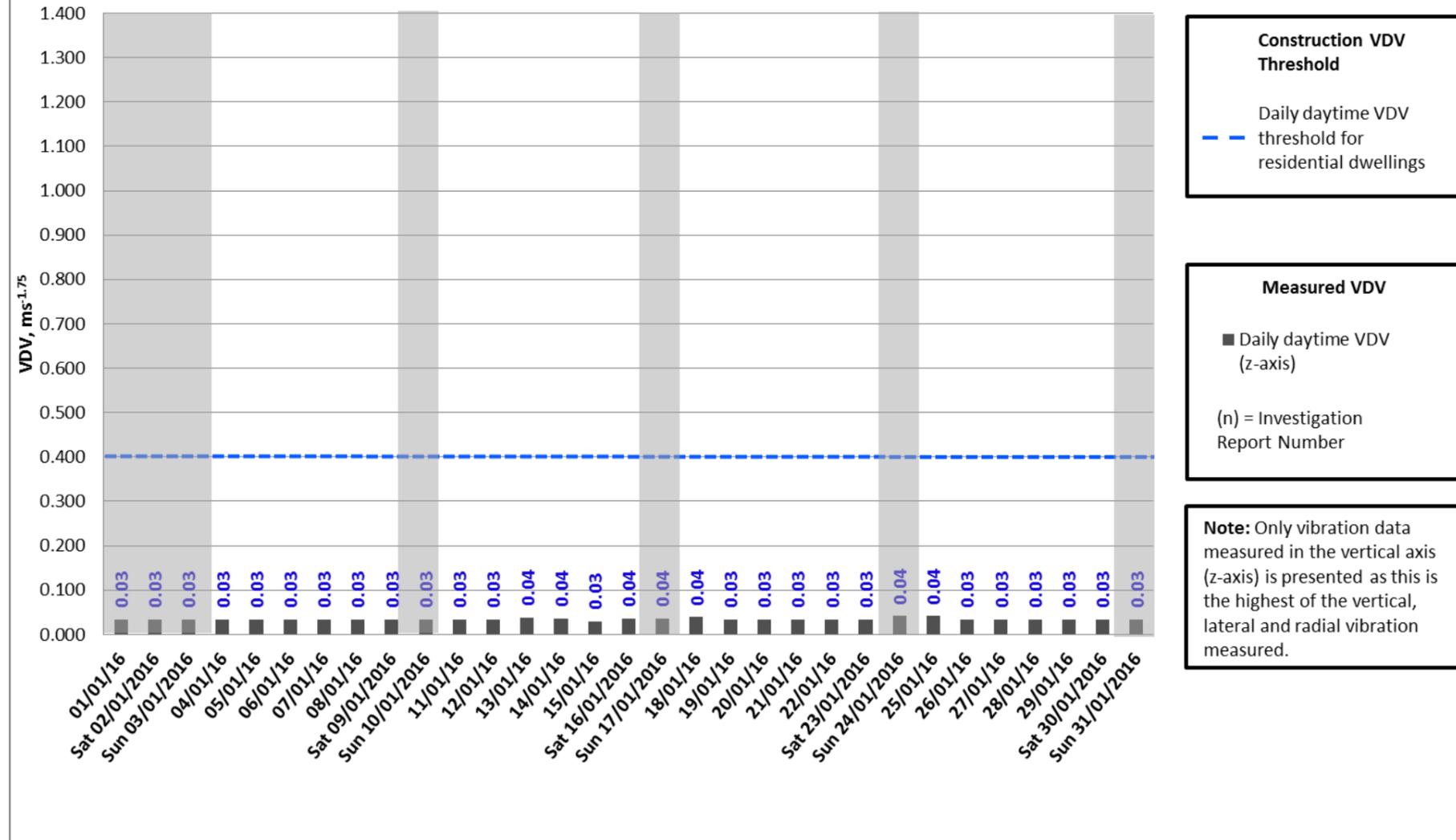
Notes on Table 3

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



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

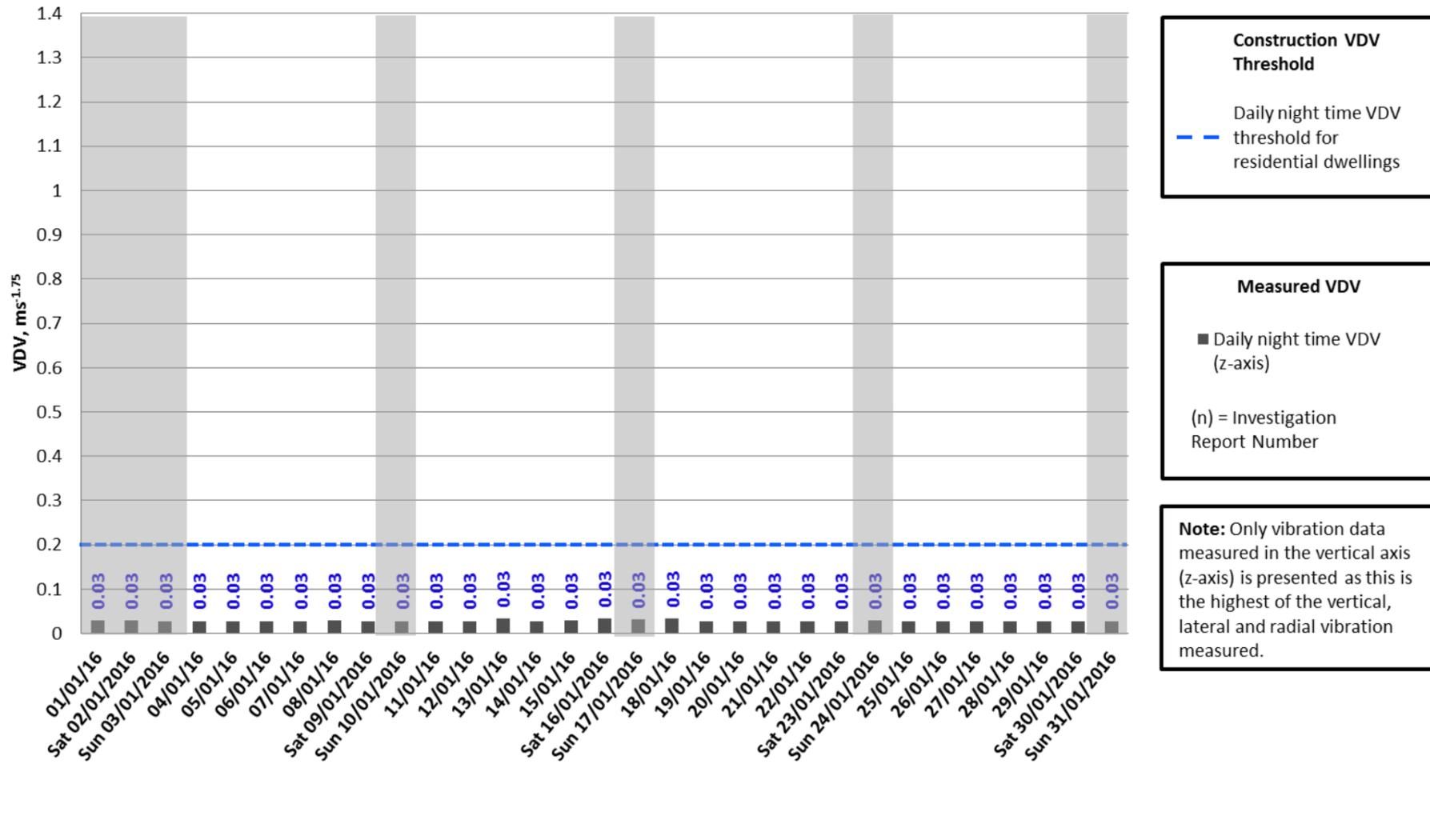
Measured VDV

■ 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), Butlaw, Measurement period: January 2016



Construction VDV Threshold

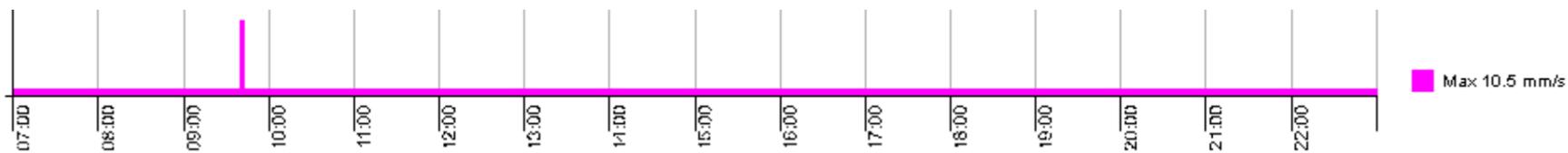
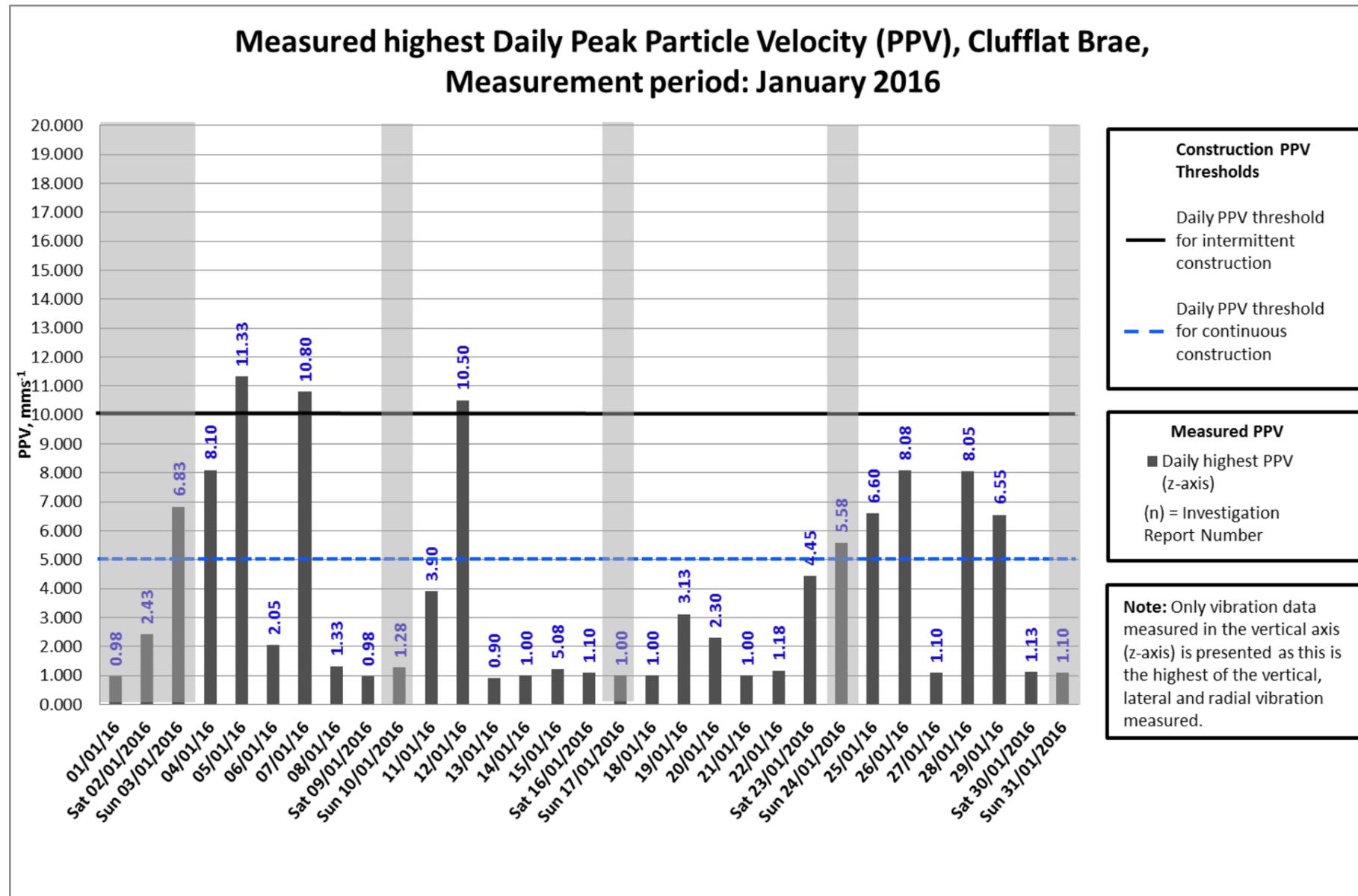
Daily night time VDV threshold for residential dwellings

Measured VDV

■ Daily night time VDV (z-axis)

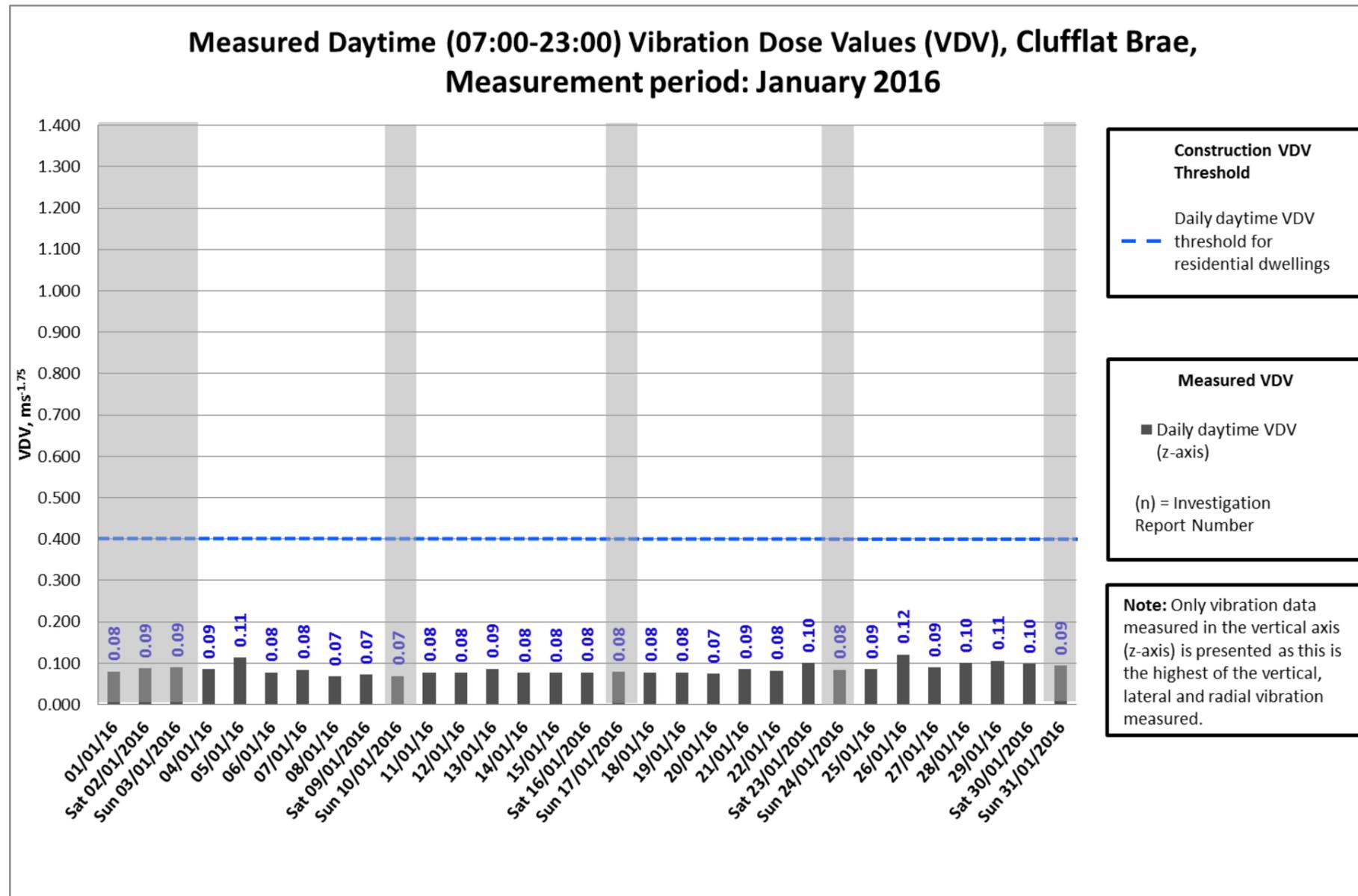
(n) = Investigation Report Number

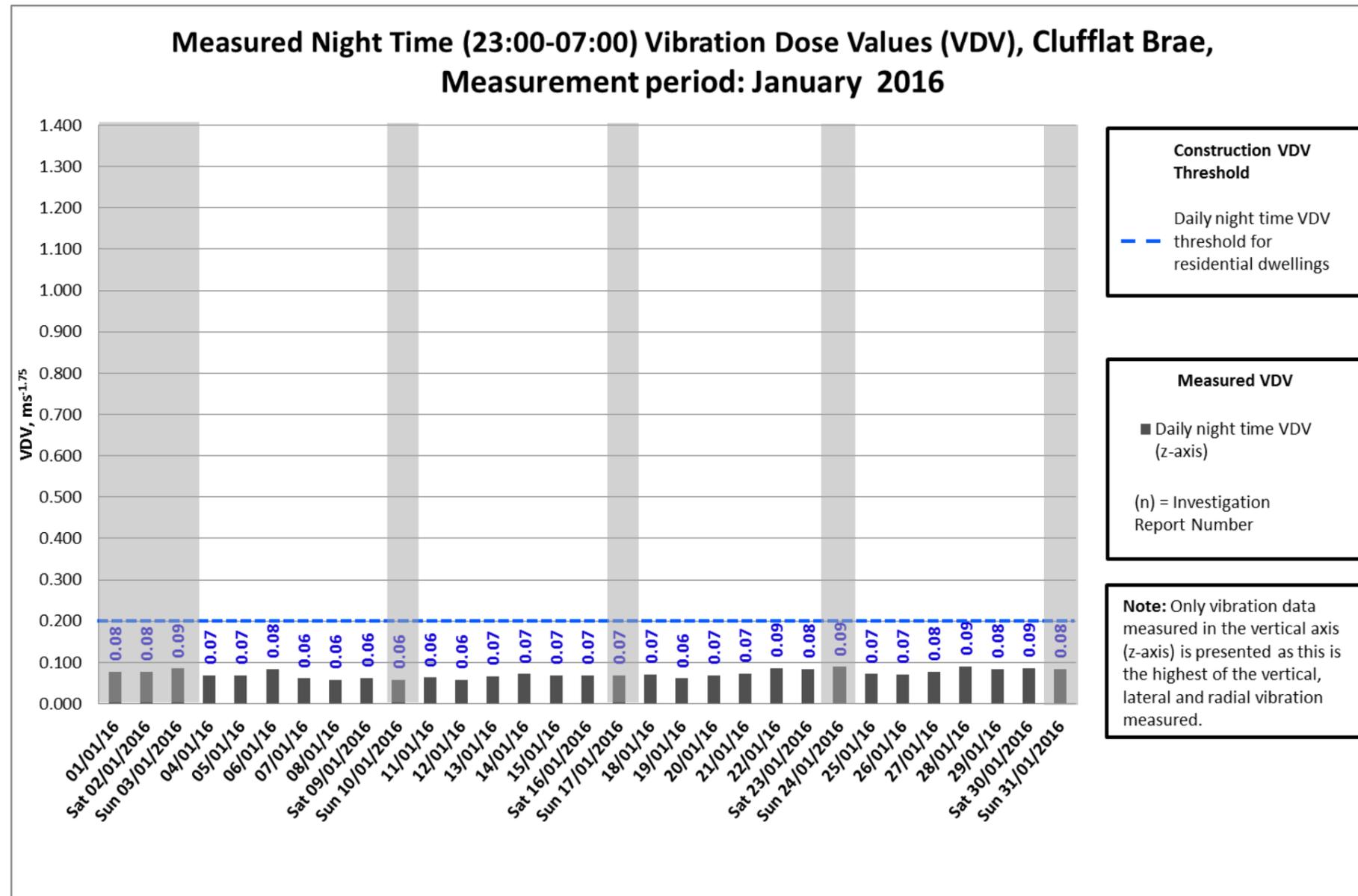
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



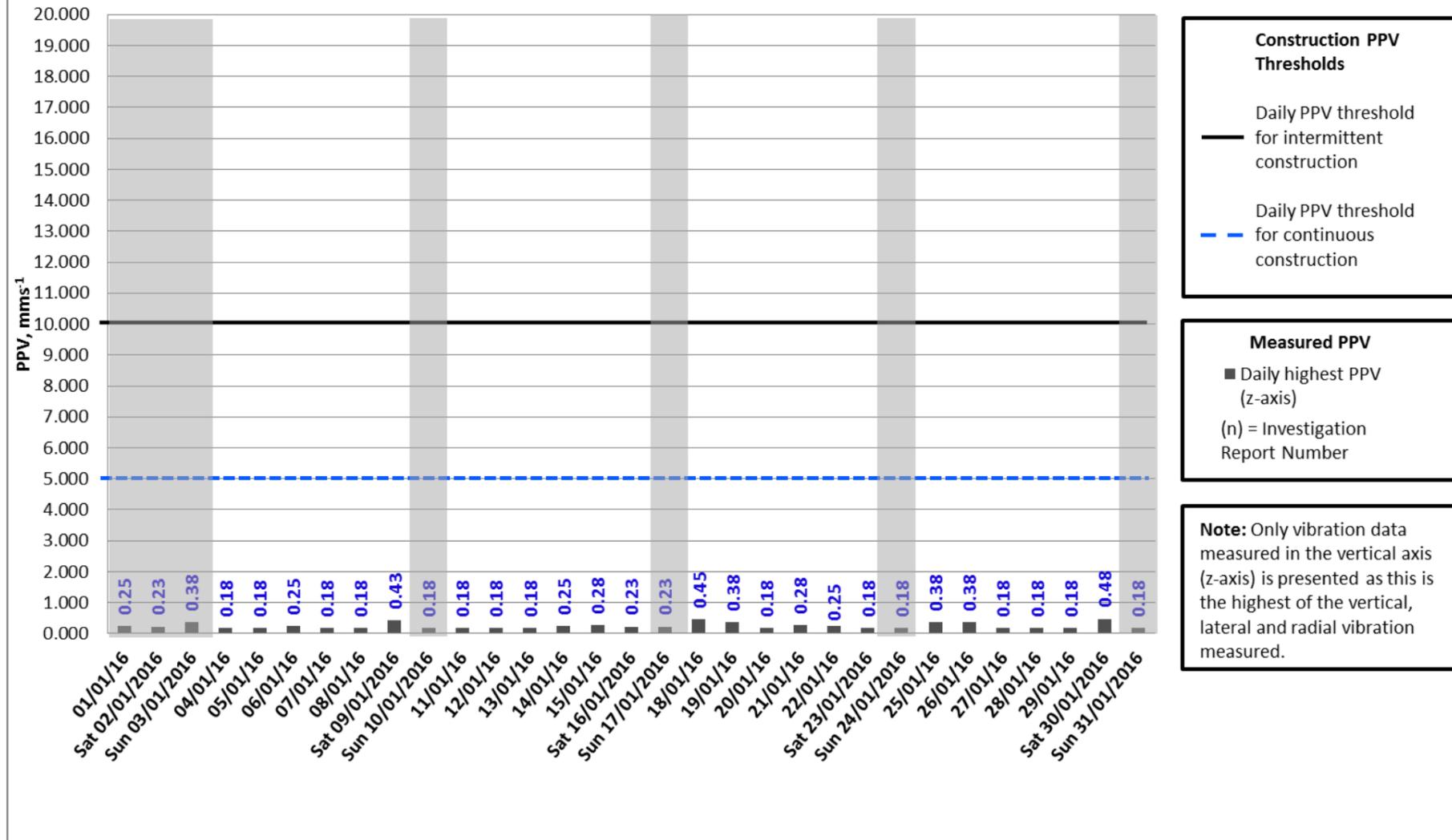
Exceedances on the 4th, 5th, 7th, 12th, 25th, 26th, 28th and 29th of January were found to be caused by isolated events that are unlikely to have been caused by construction related activities (graph above from the 12/01/2016).

Exceedance on the 24th of January was found to be out with working hours in the proximity of the monitor with the closest works being approximately 600m away. Due to this it is highly unlikely the exceedance was caused by construction related activities.

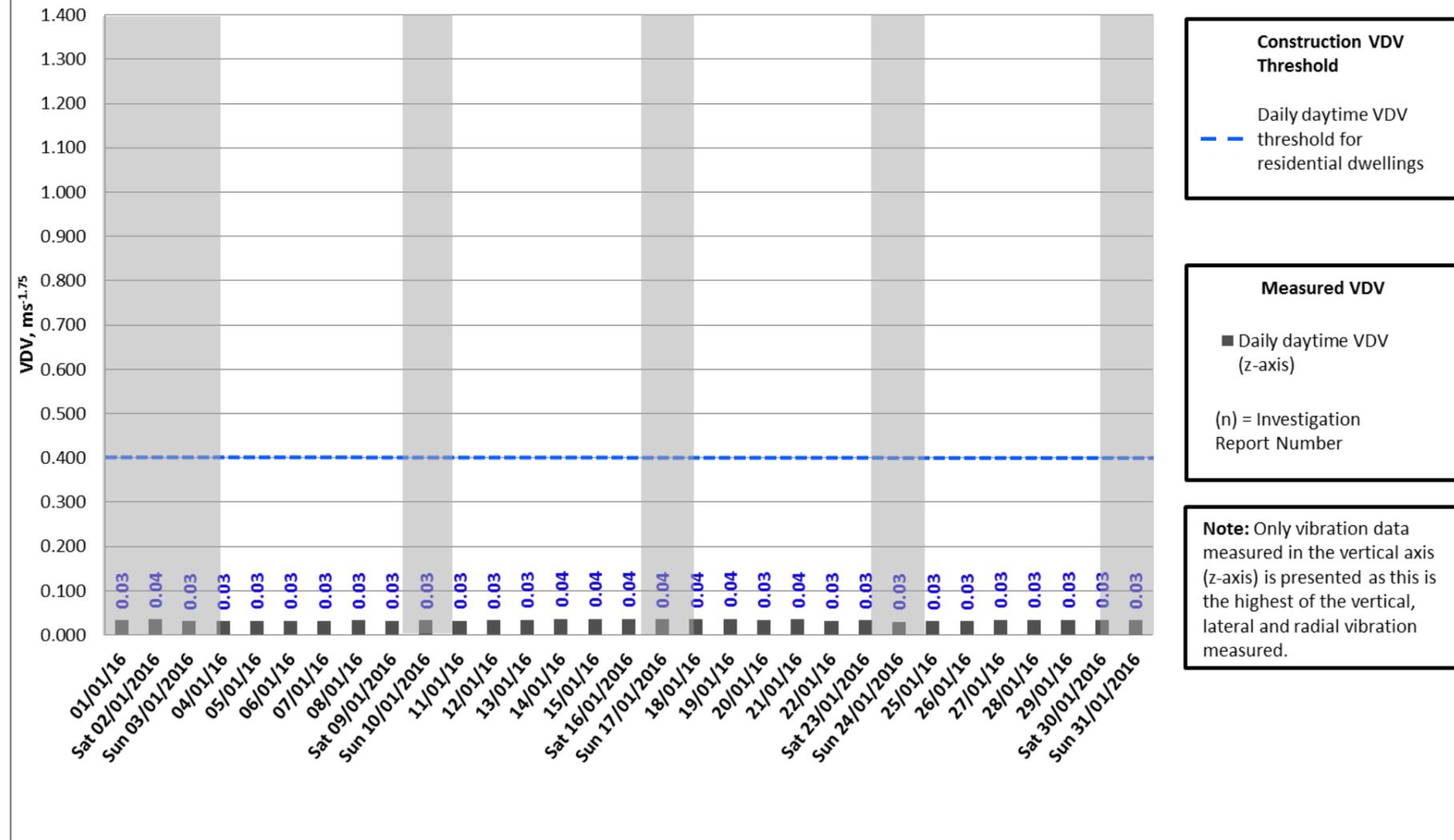




Measured highest Daily Peak Particle Velocity (PPV), Dundas Home Farm, Measurement period: January 2016



Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: January 2016



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

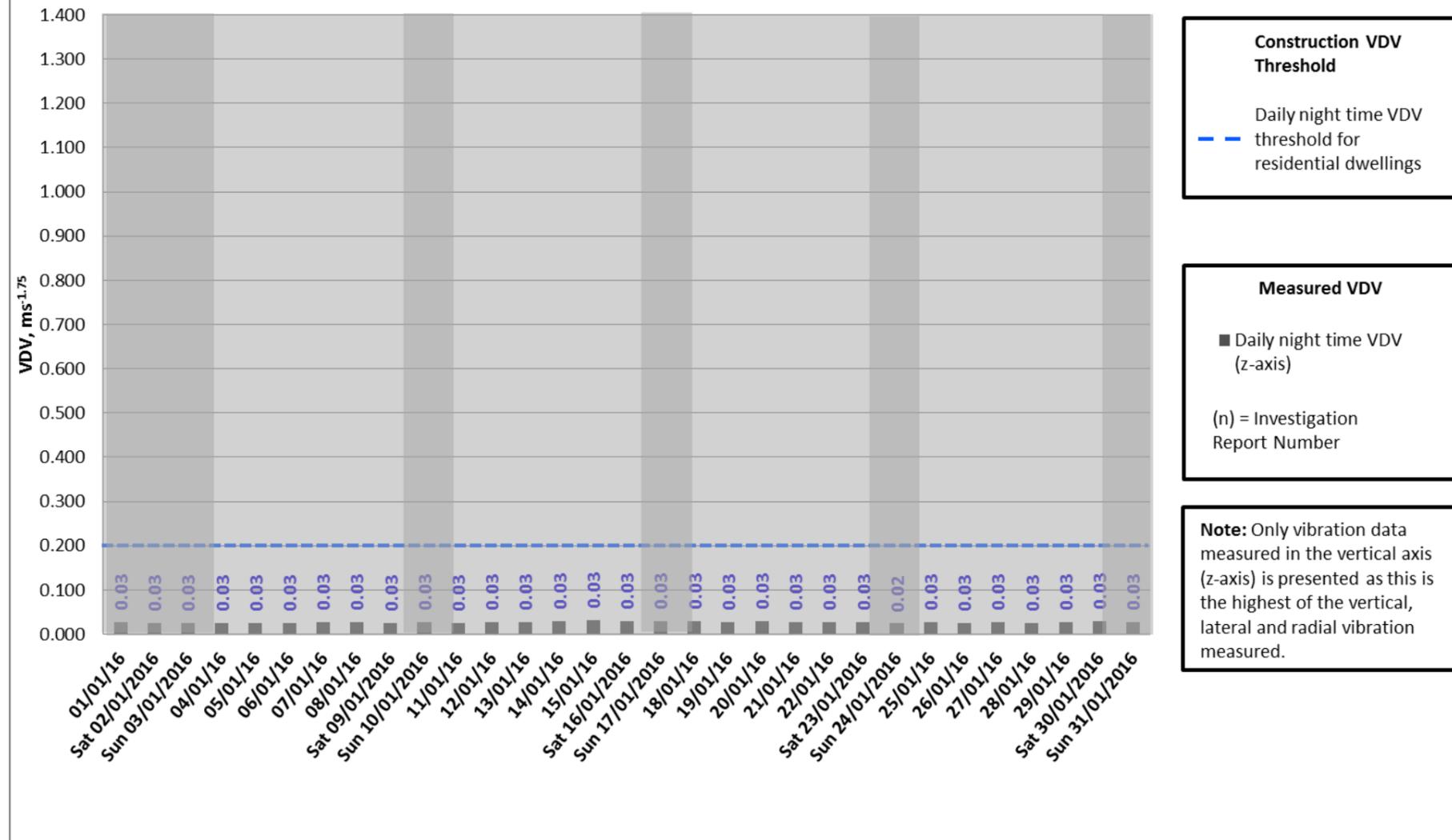
Measured VDV

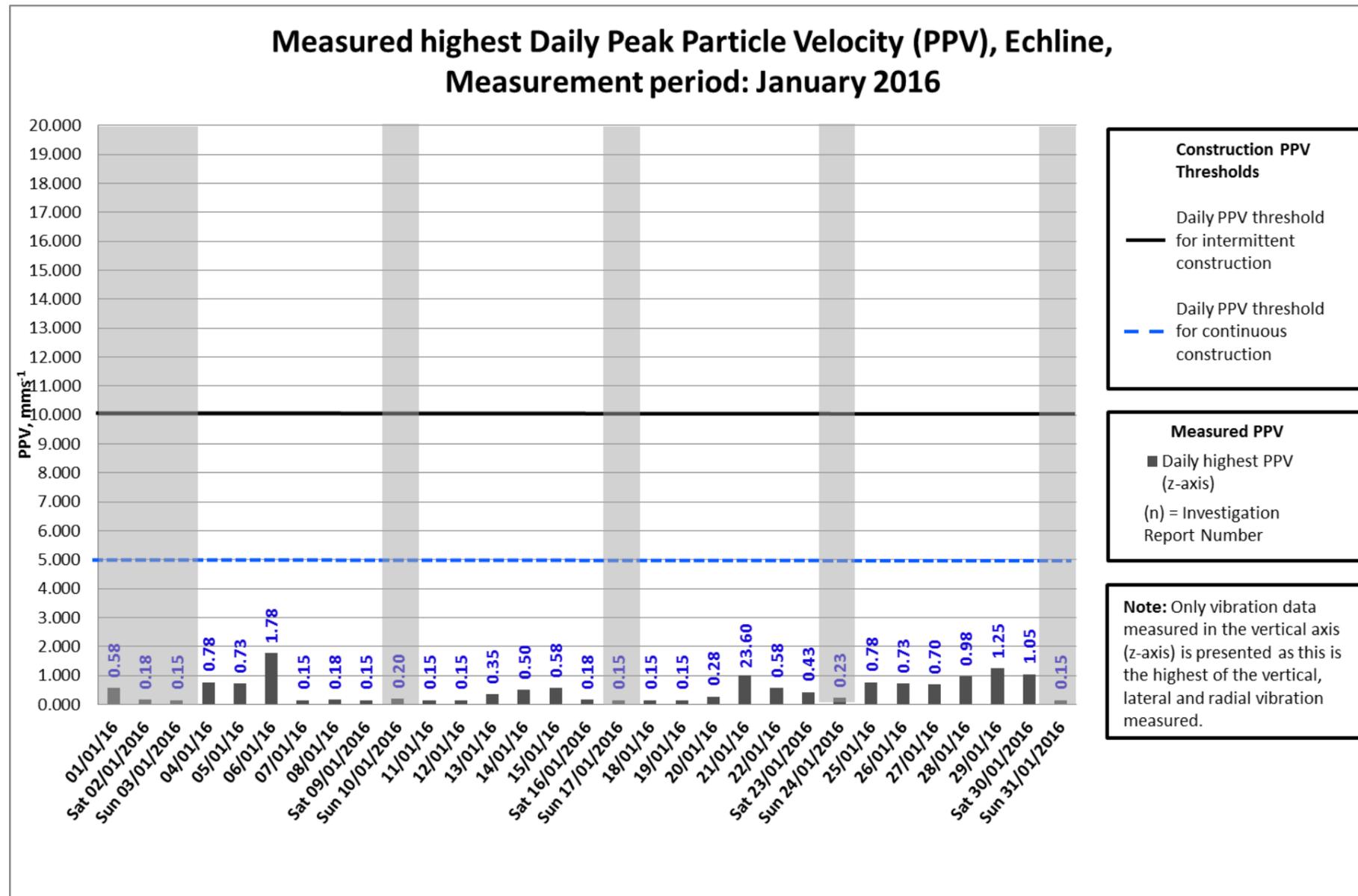
■ Daily daytime VDV (z-axis)

(n) = Investigation Report Number

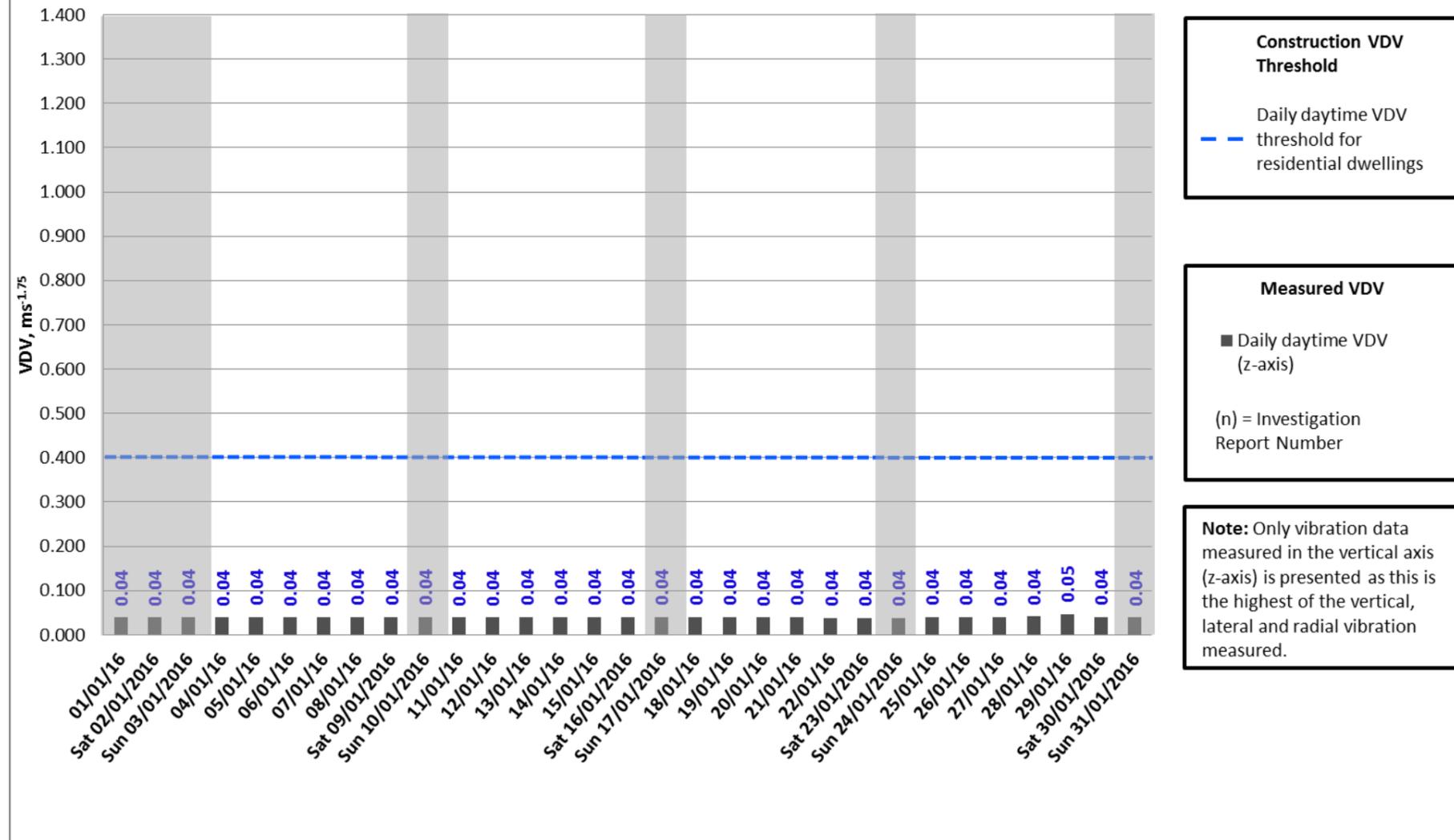
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

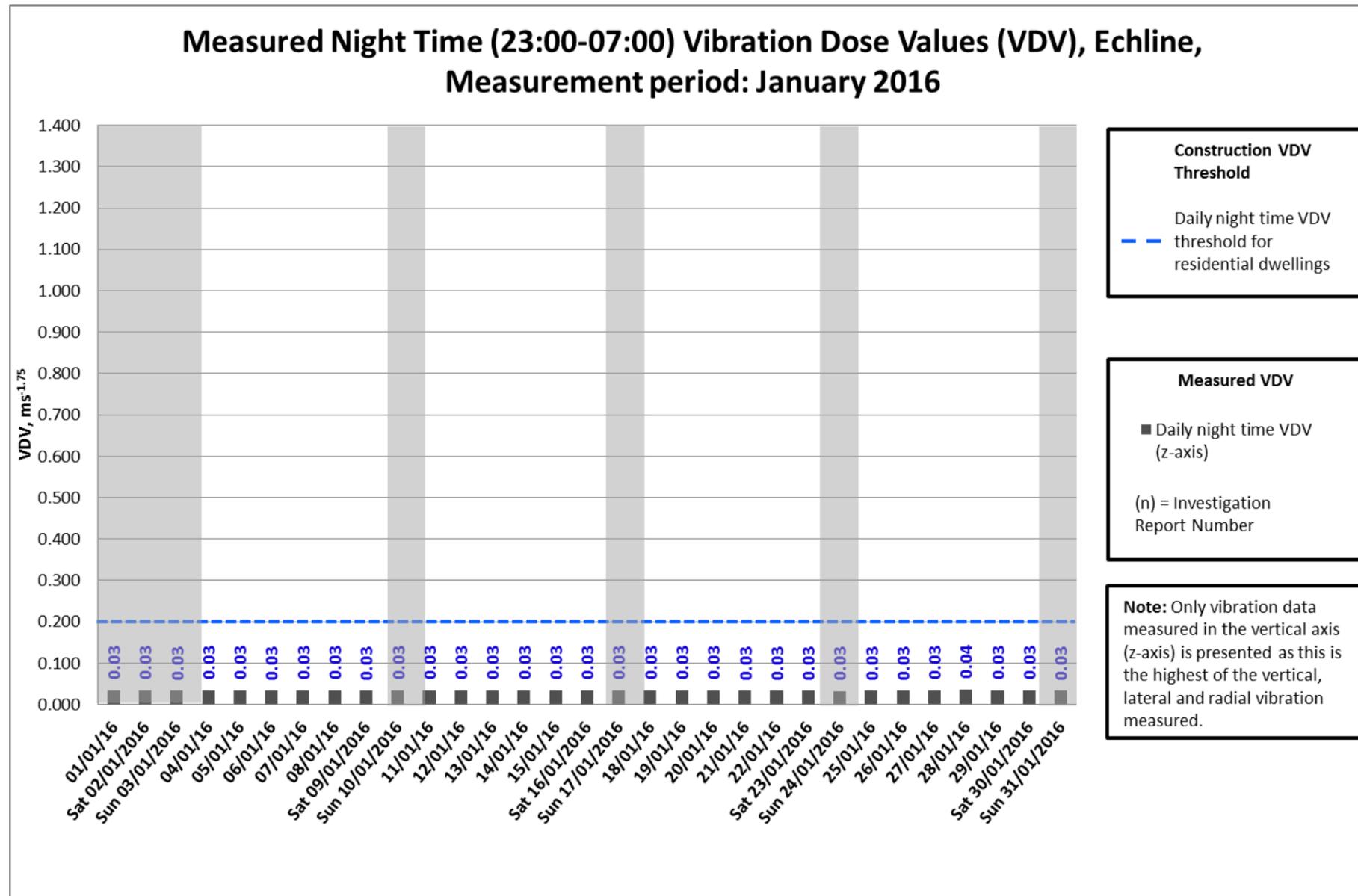
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Dundas Home Farm, Measurement period: January 2016

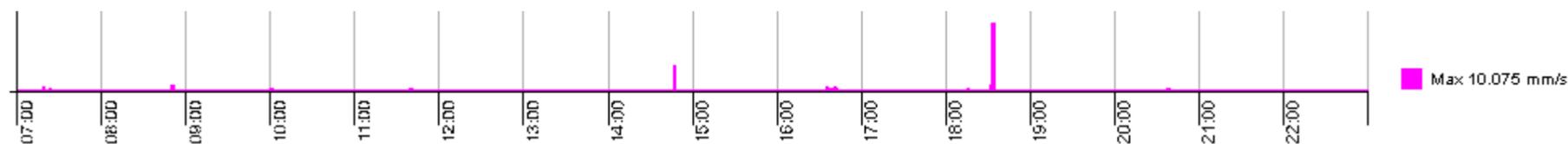
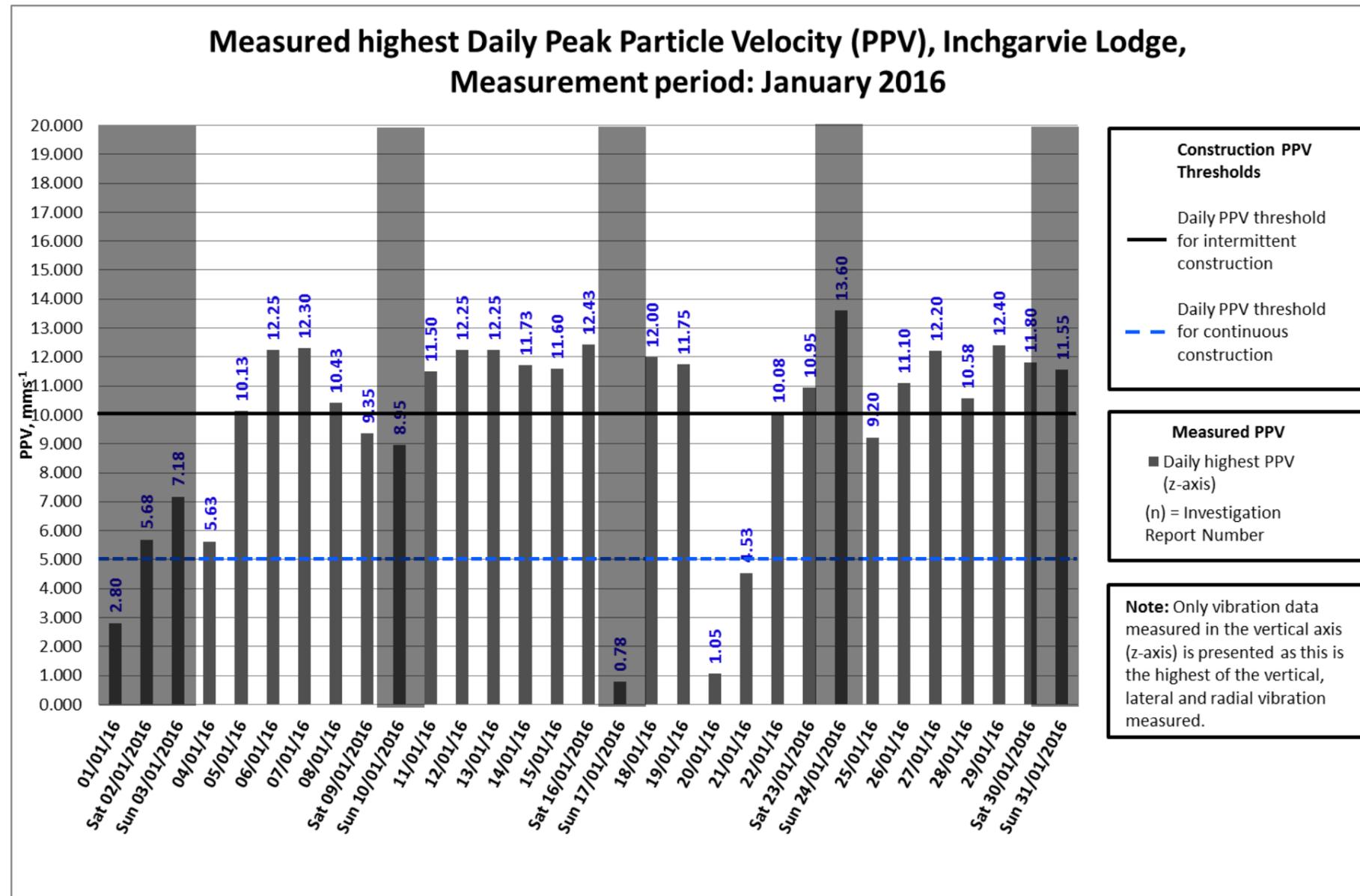




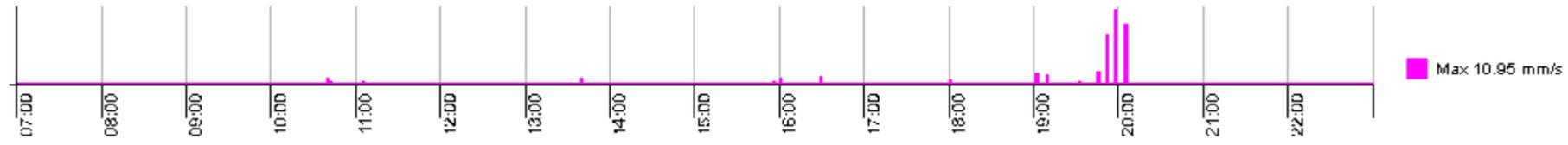
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Echline, Measurement period: January 2016



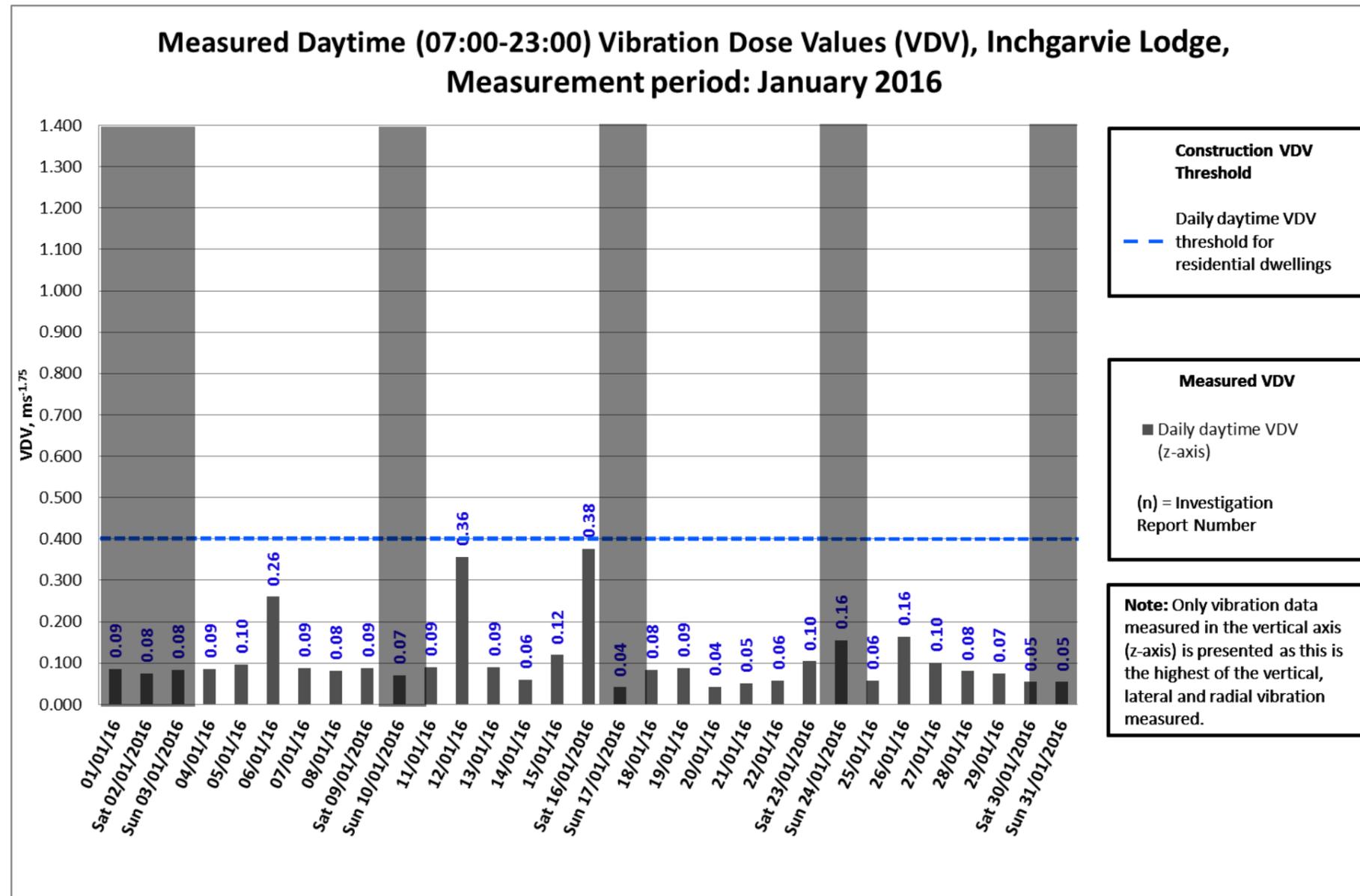


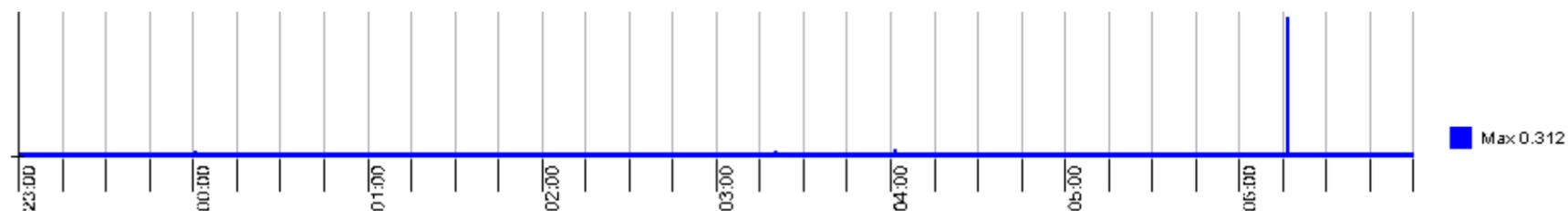
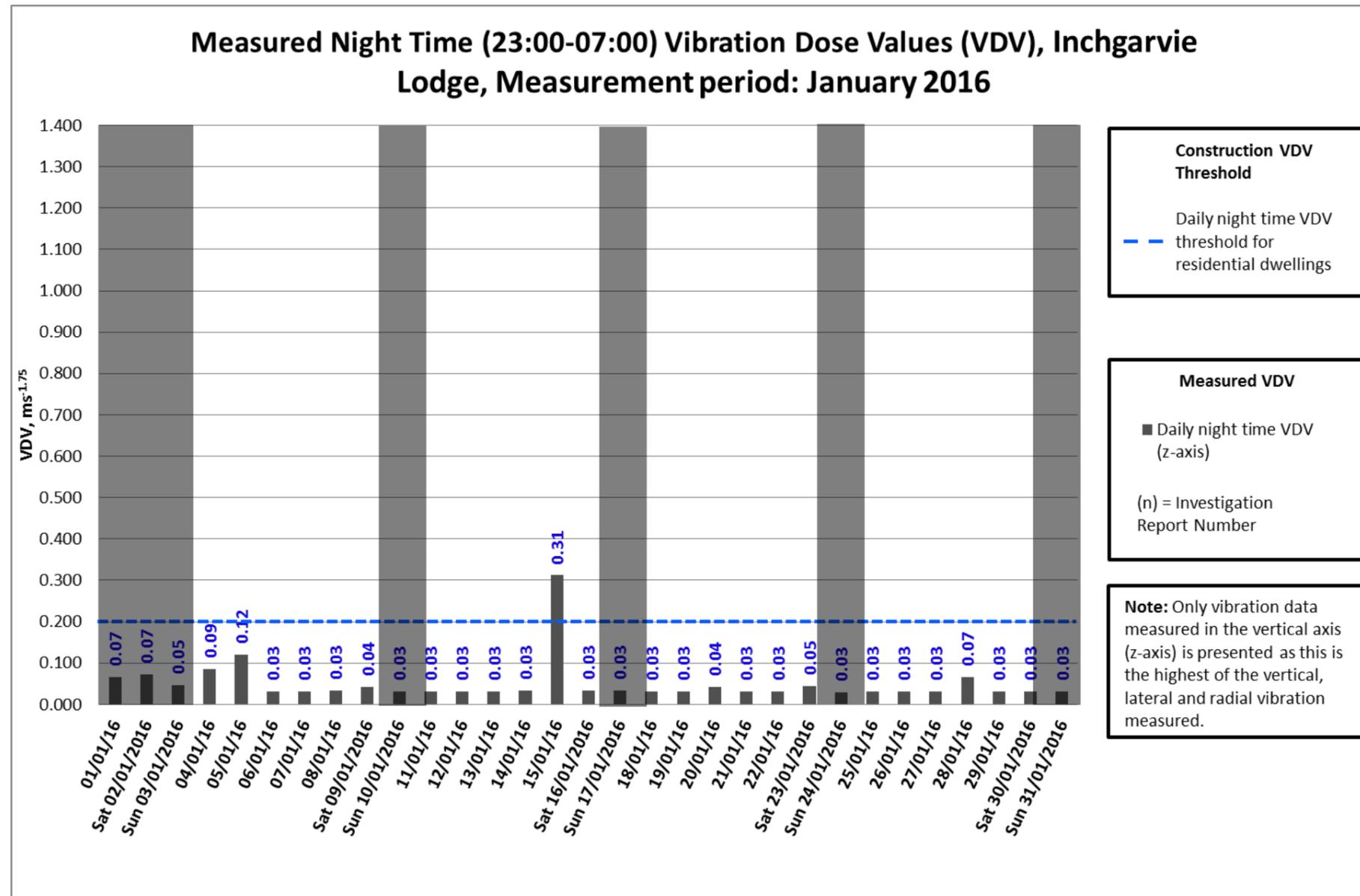


Exceedances on the 4th, 5th, 7th, 9th, 10th, 11th, 12th, 13th, 14th, 15th, 16th, 22nd, 24th, 25th, 26th, 27th, 28th, 29th and 30th have been investigated and found to be intermittent and are unlikely to be caused by construction related activities (closest works to the monitor is approximately 185m). During this period there have been ongoing private construction works on the property which are likely to have been the cause of the high vibration levels. Vibration levels in this location will continue to be closely monitored to identify the source of the vibration levels (graph above taken from data acquired on 22/01/2016).

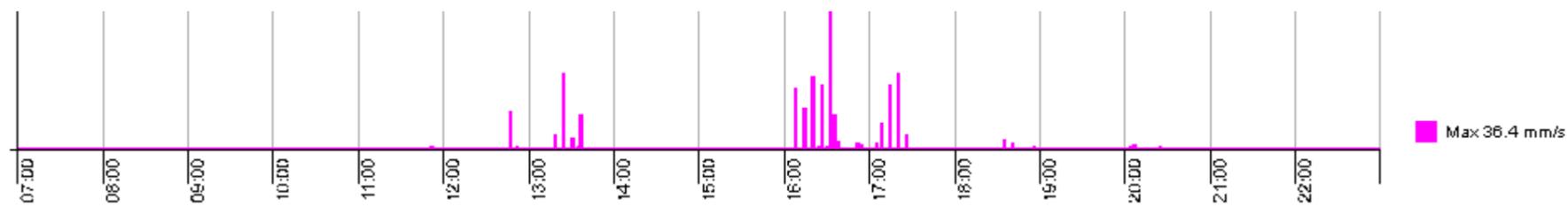
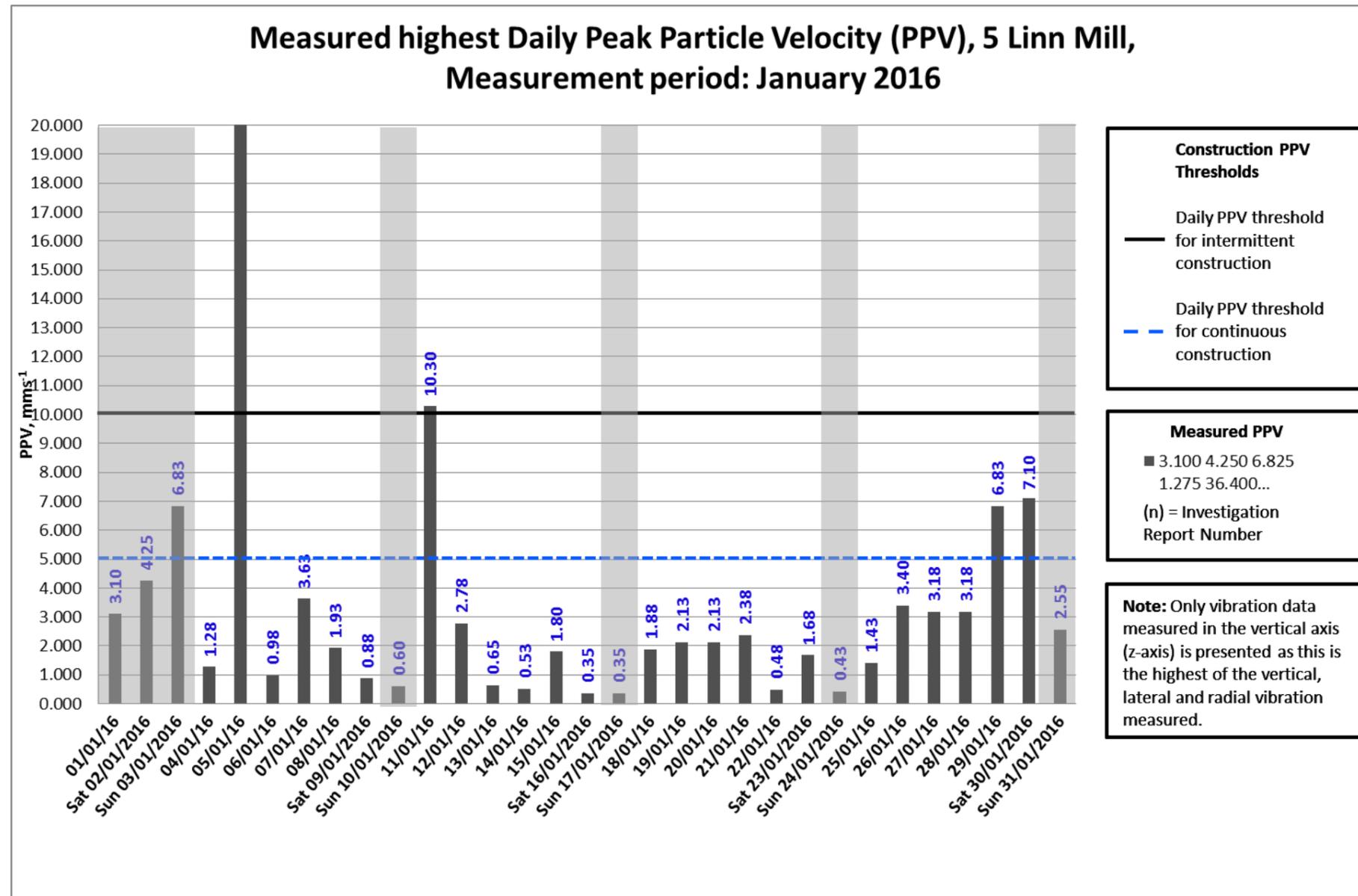


Exceedances on the 6th, 8th, 18th, 19th, 23rd and 31st have been investigated and found to be out with construction working hours, and therefore is highly unlikely to have been caused by construction related activities (graph above taken from data acquired on 23/01/2016).

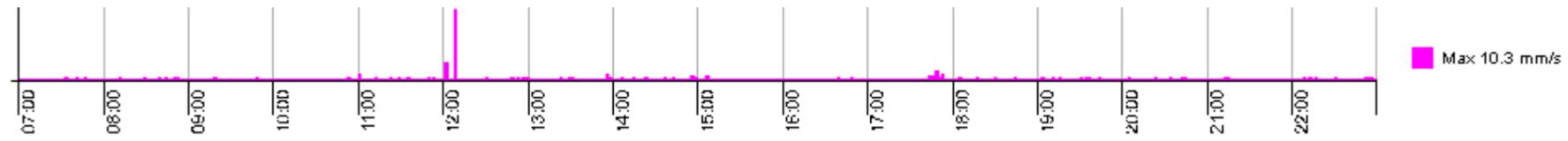




Exceedance on the 15th of January has been investigated and found to be out with working hours in the proximity of the monitor, with the closest known works being approximately 500m away. It is therefore highly unlikely that the exceedance was caused by construction related activities.

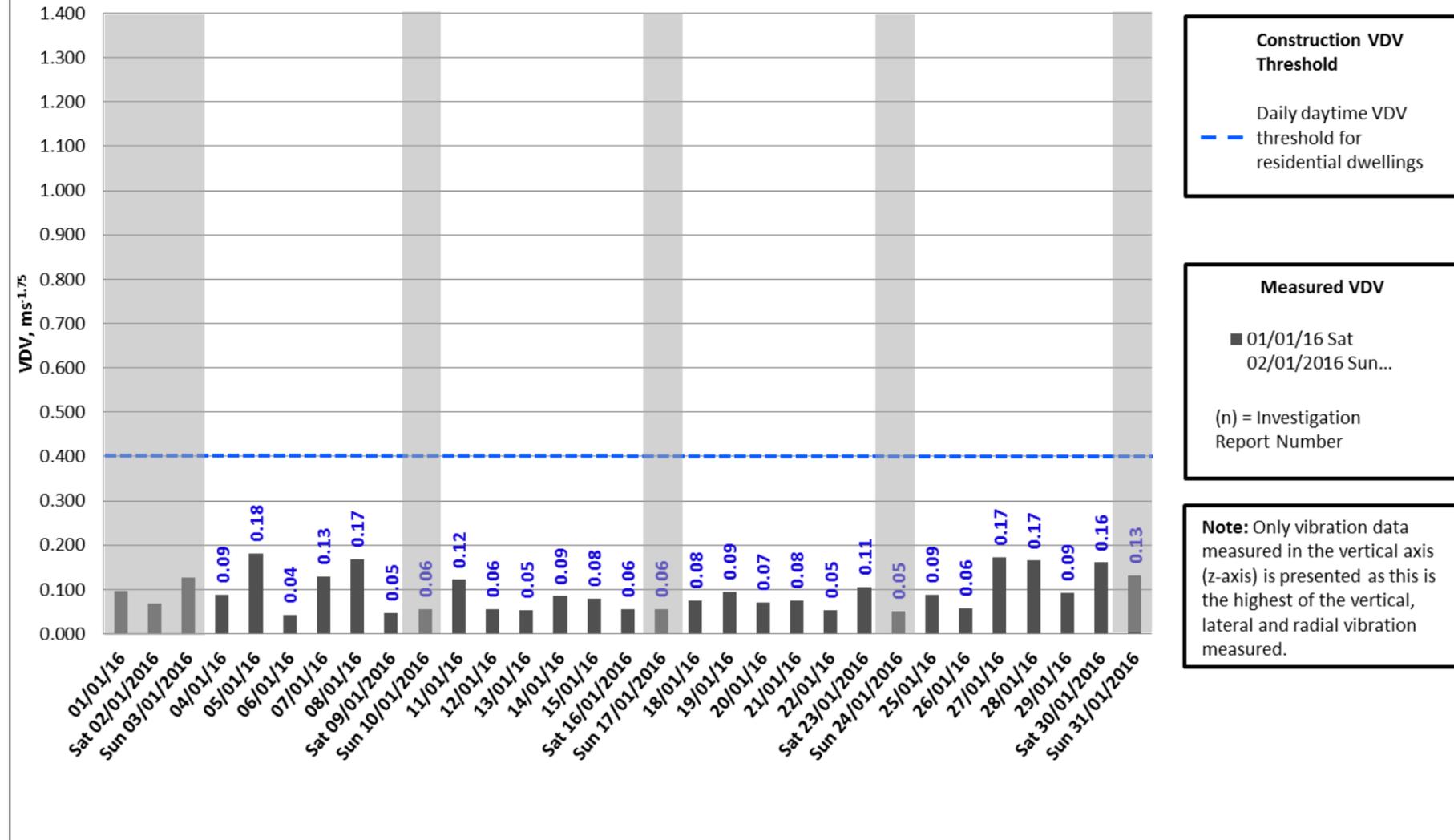


Exceedance on the 5th of January was caused by monitor maintenance by the Environmental department.



Exceedance on the 11th, 29th and 30th of January have been investigated and were found to be intermittent isolated events that are highly unlikely to have been caused by construction related activities (graph above taken from data acquired on 11/01/2016)

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), 5 Linn Mill, Measurement period: January 2016



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

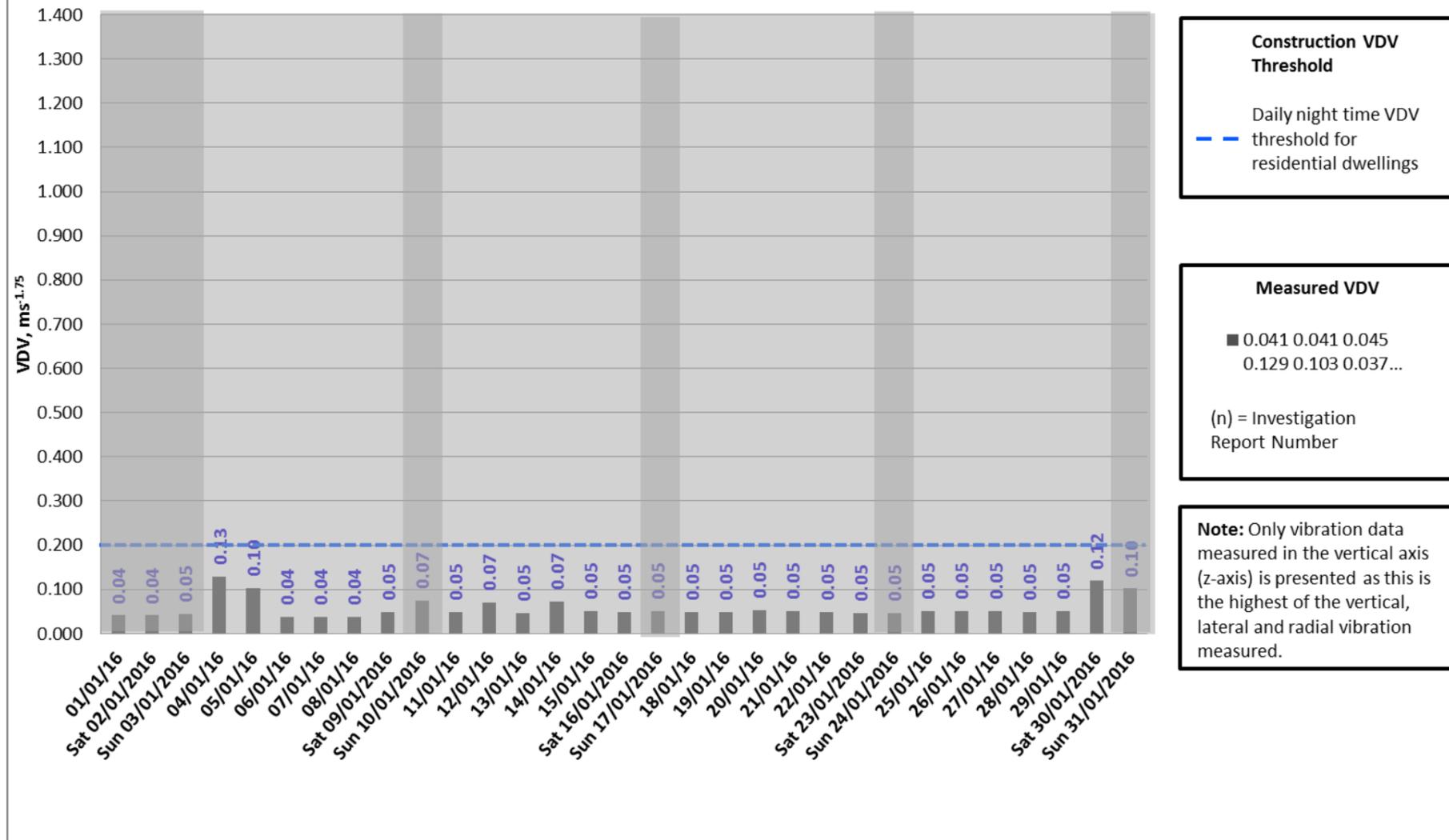
Measured VDV

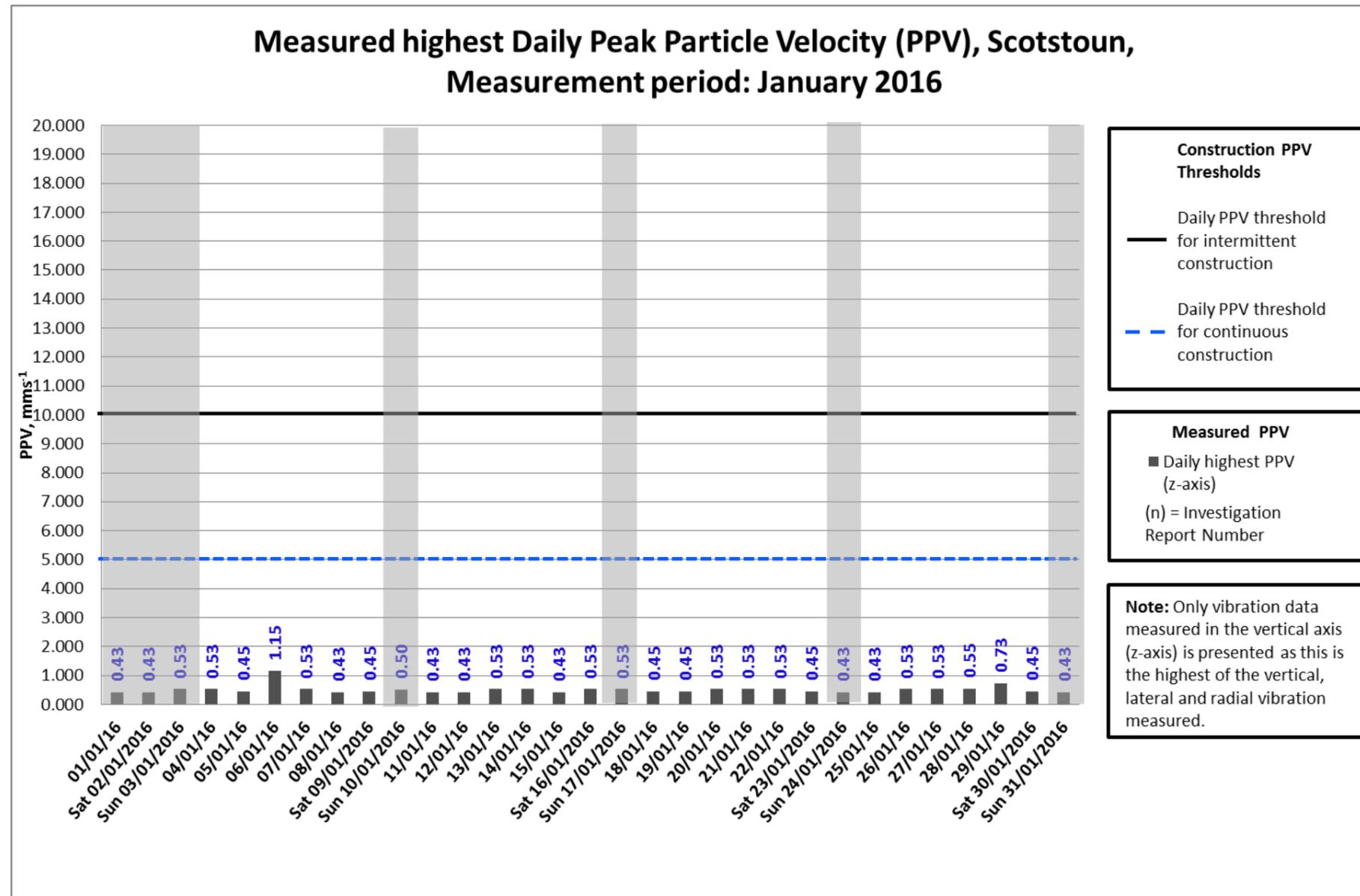
■ 01/01/16 Sat
■ 02/01/2016 Sun...

(n) = Investigation Report Number

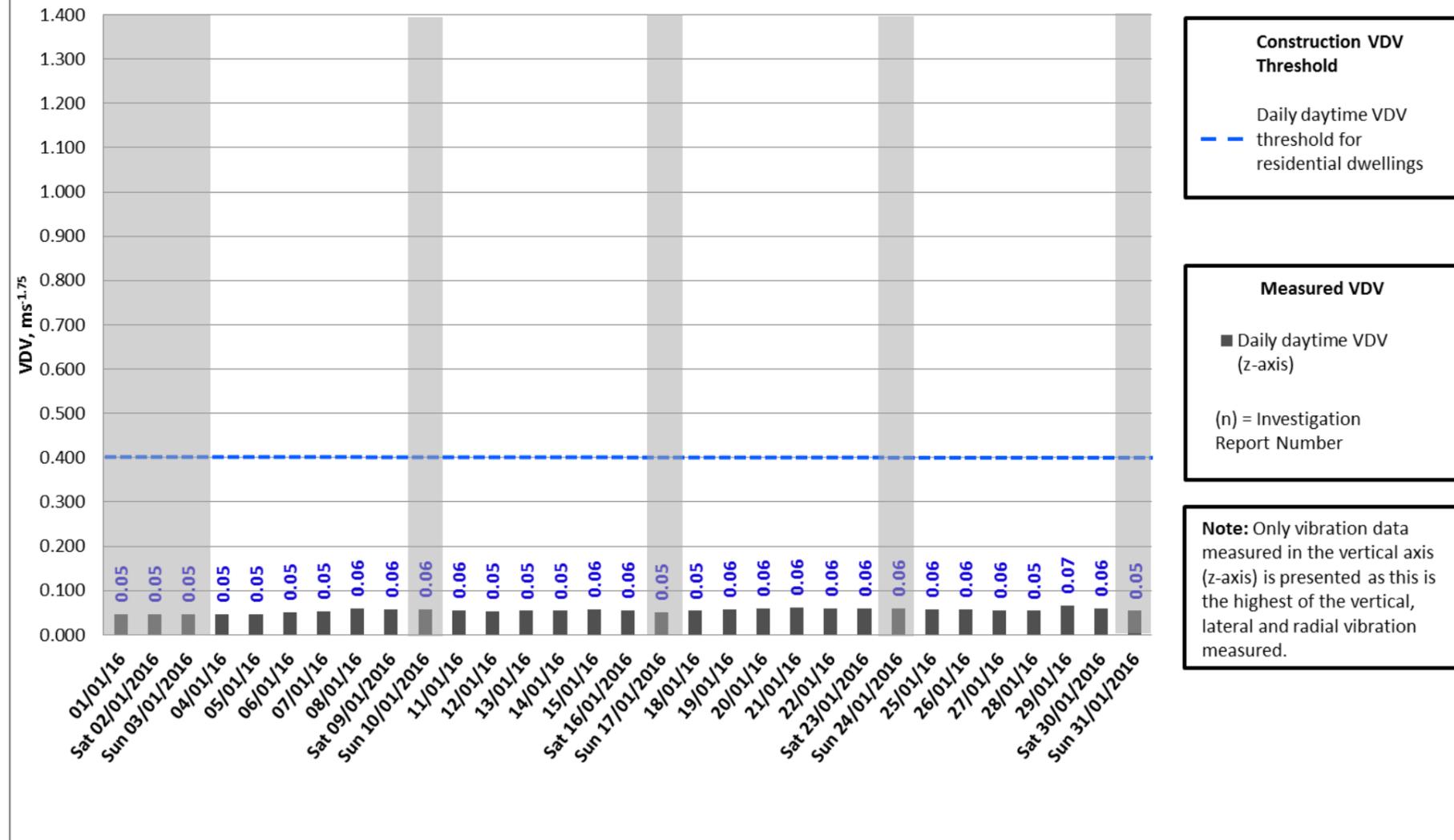
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), 5 Linn Mill, Measurement period: January 2016

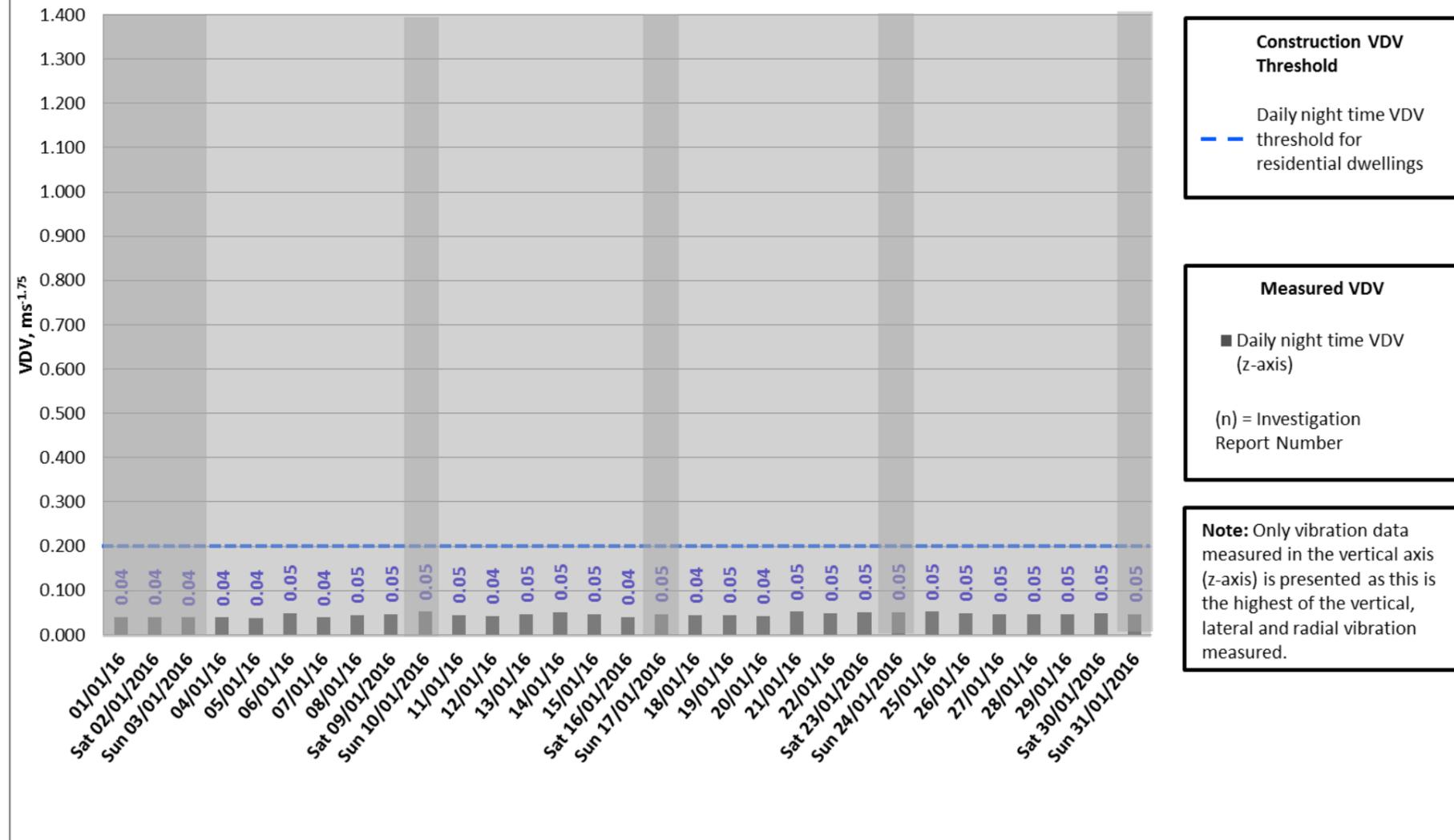




Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: January 2016



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



Construction VDV Threshold

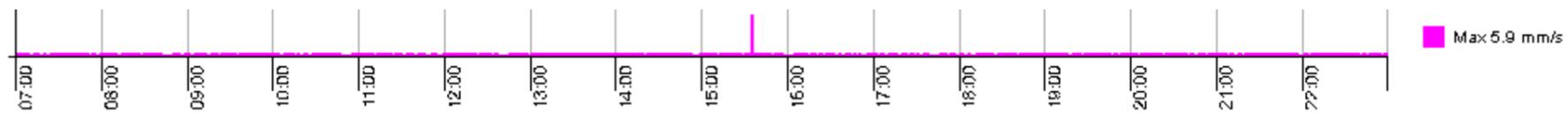
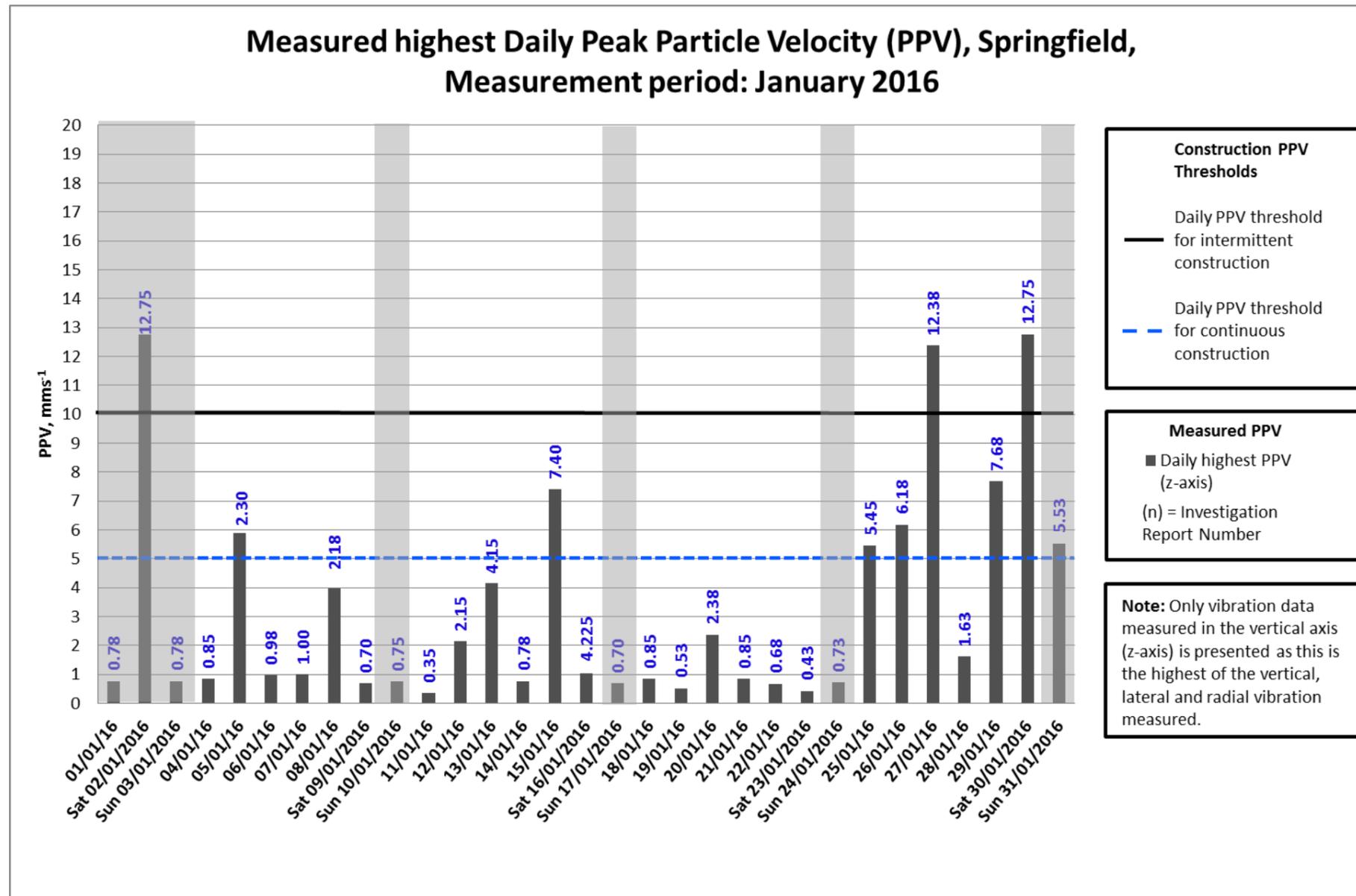
Daily night time VDV threshold for residential dwellings

Measured VDV

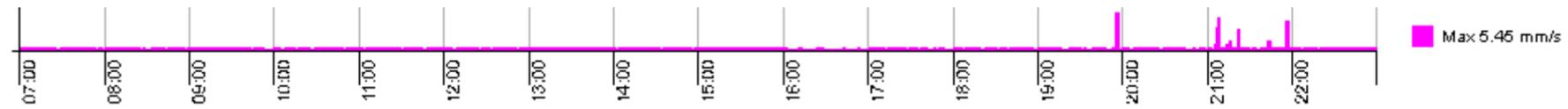
■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

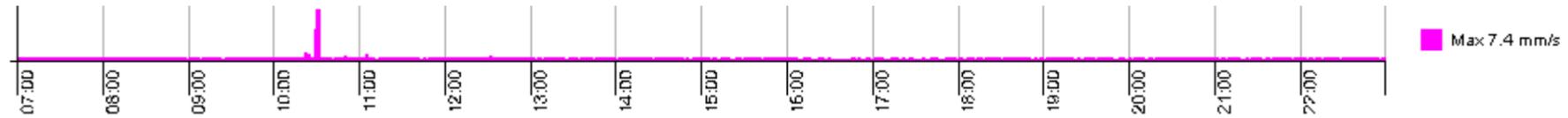
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



Exceedance on the 5th of January was caused by monitor maintenance by the environmental department.

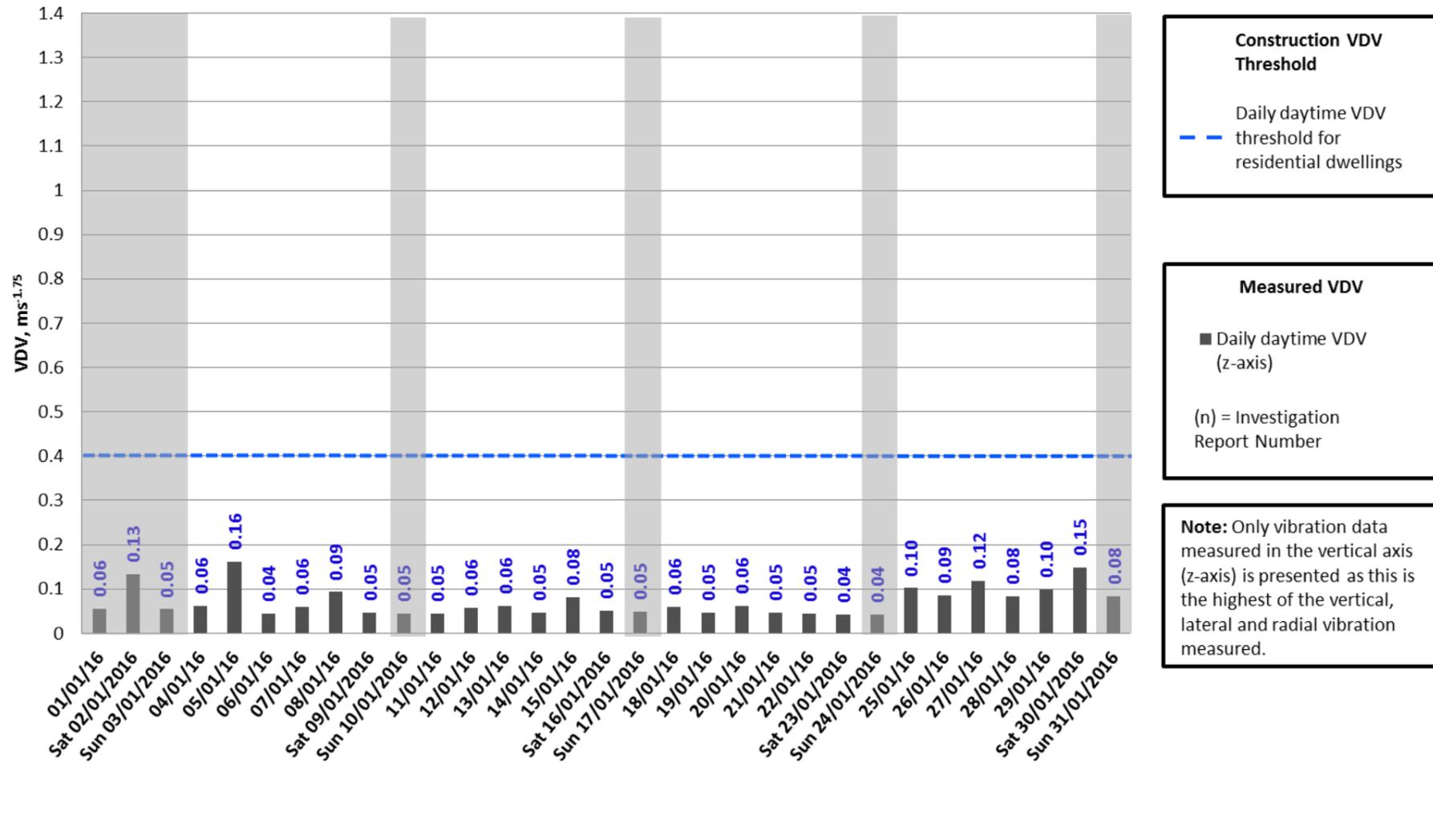


Exceedances on the 25th and 31st of January were out with normal working hours for construction related activities on road networks. Due to this it is highly unlikely that the source of the vibration levels recorded was from construction works, but more likely to have been caused by localised activity close to the monitor (graph above taken from data acquired on 25/01/2016).



Exceedances on the 15th, 26th, 27th, 29th and 30th of January have been investigated and found to be isolated events that are highly unlikely to have been caused by construction related activities, but more likely to have been caused by localised activity close to the monitor (graph above taken from data acquired on 15/01/2016)

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Springfield, Measurement period: January 2016



Construction VDV Threshold

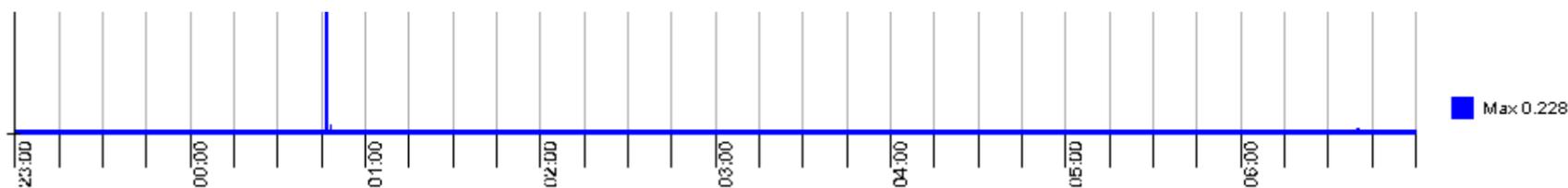
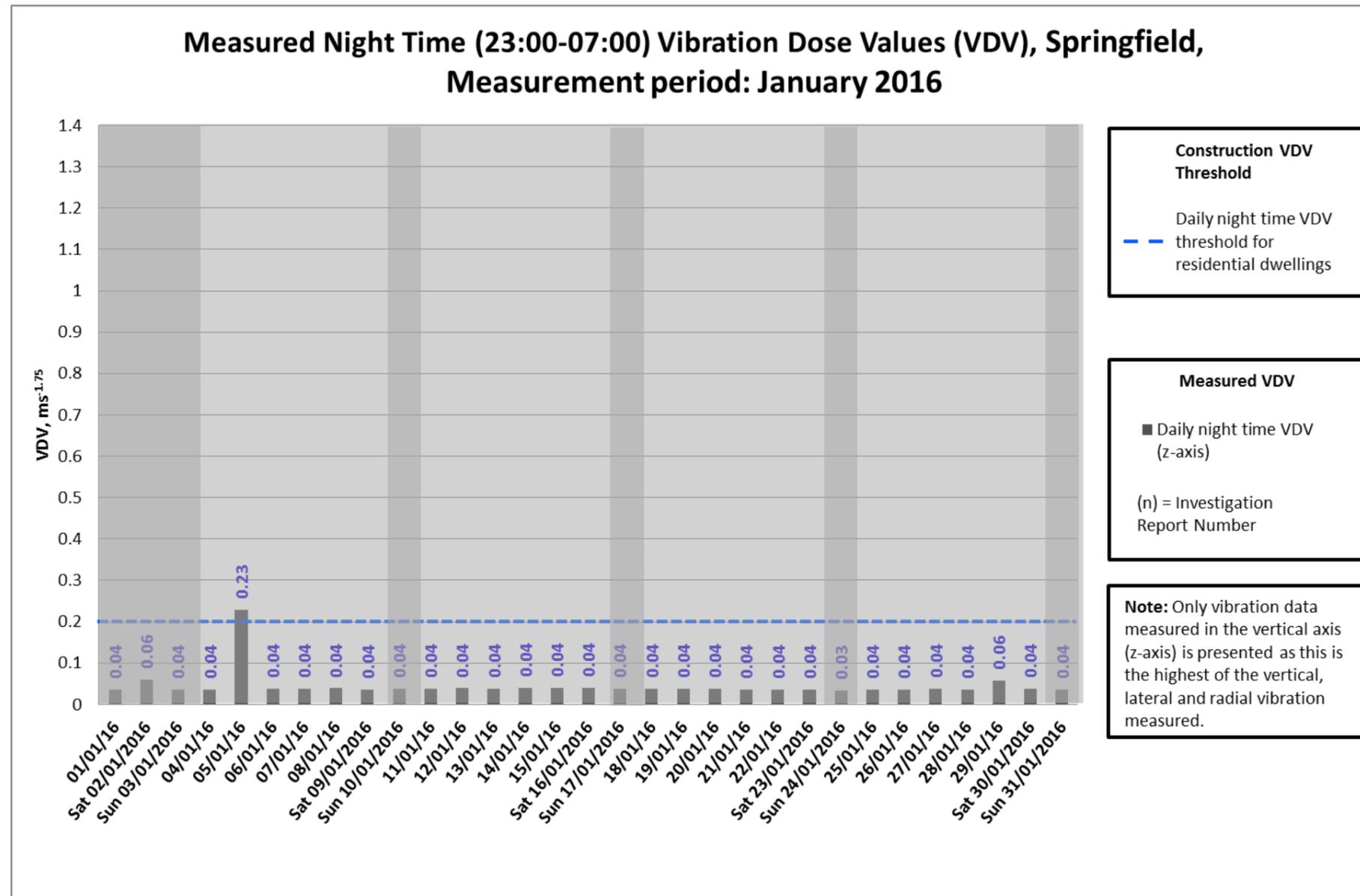
Daily daytime VDV threshold for residential dwellings

Measured VDV

■ Daily daytime VDV (z-axis)

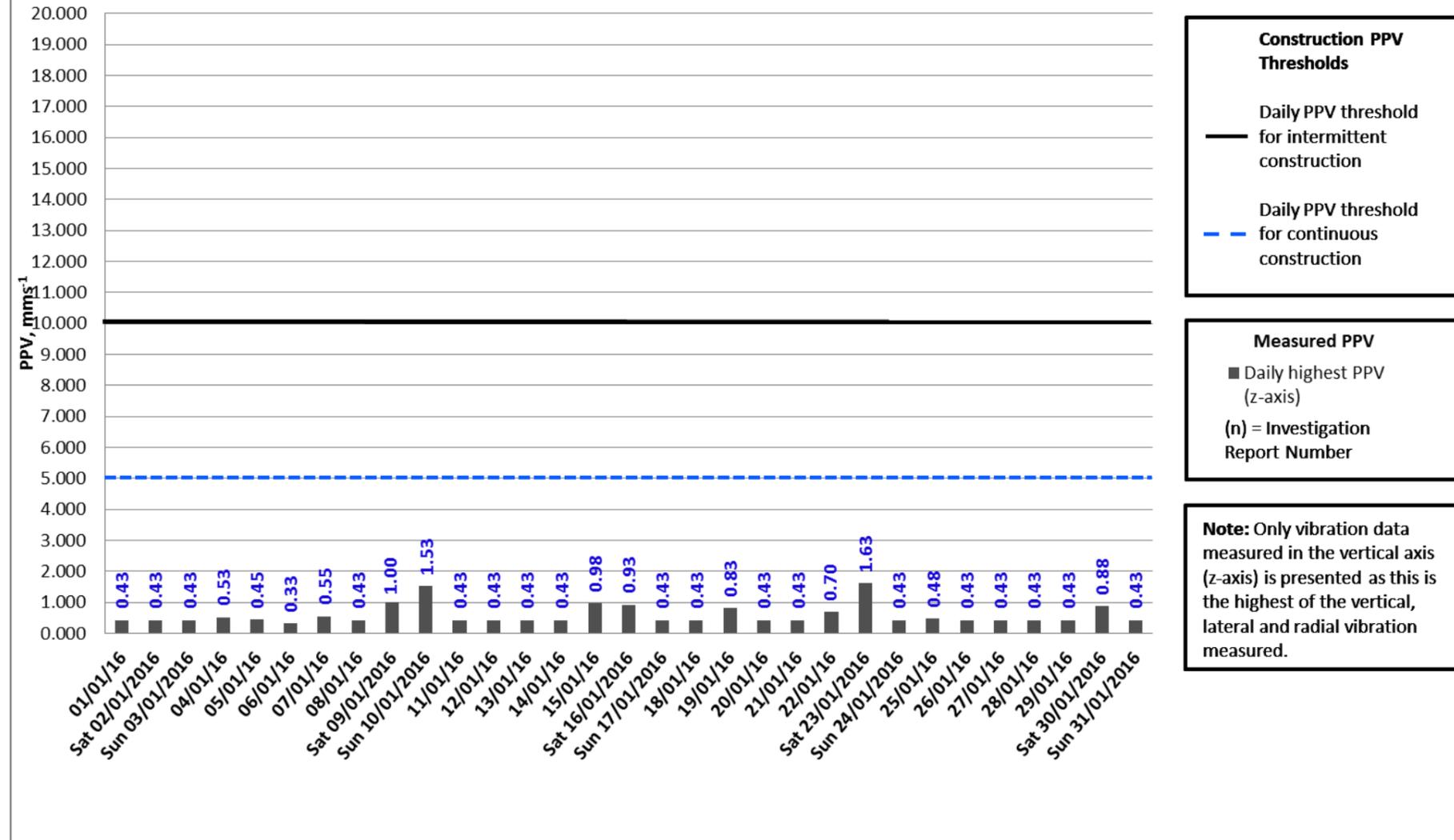
(n) = Investigation Report Number

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.



Exceedance on the 5th of January was caused out with normal working hours for construction related works on road networks. Due to this it is highly unlikely that the source of the vibration levels was from construction works, but more likely to have been caused by localised activity close to the monitor.

Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na Grian, Measurement period: January 2016



Construction PPV Thresholds

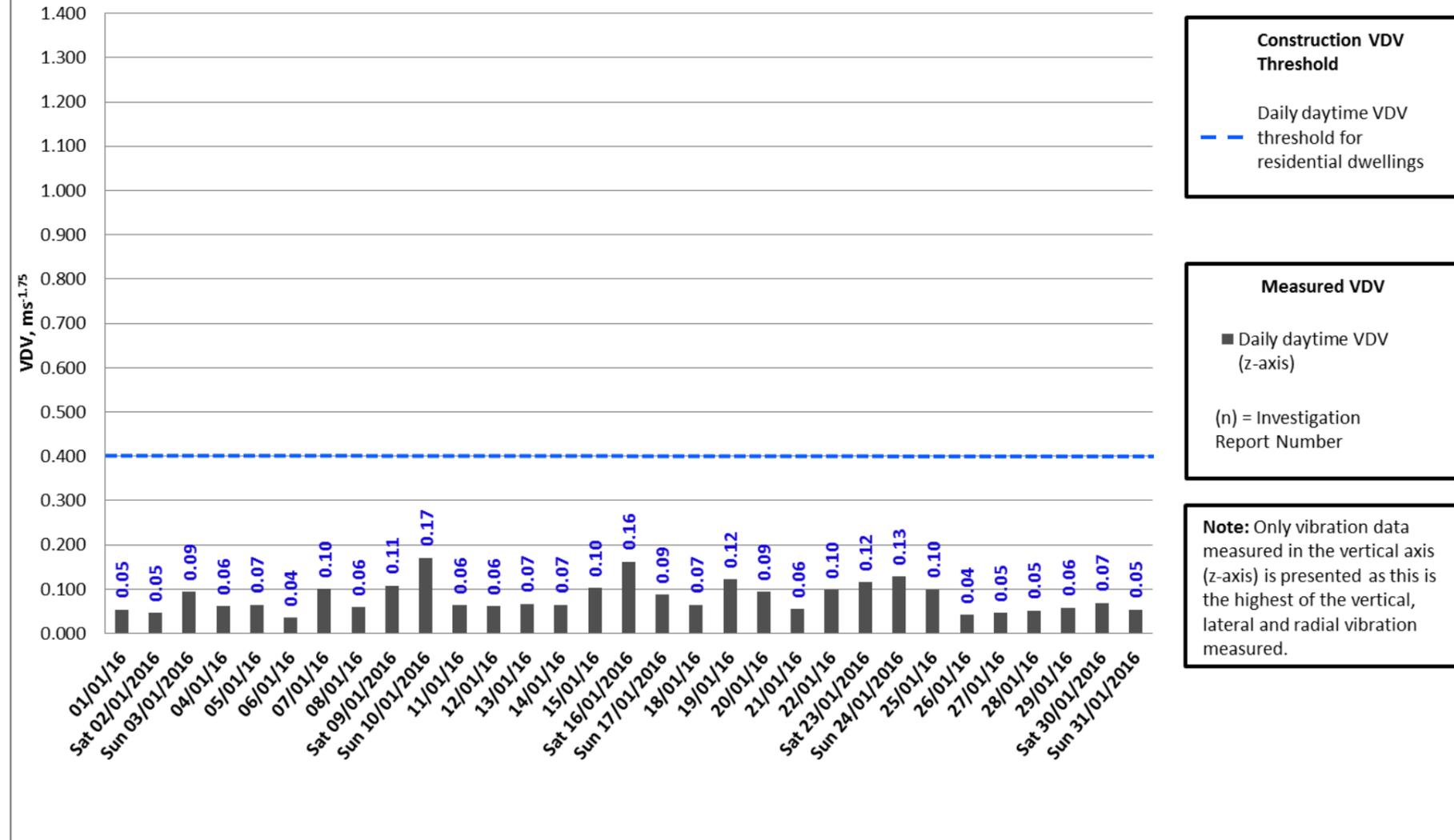
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

Measured PPV

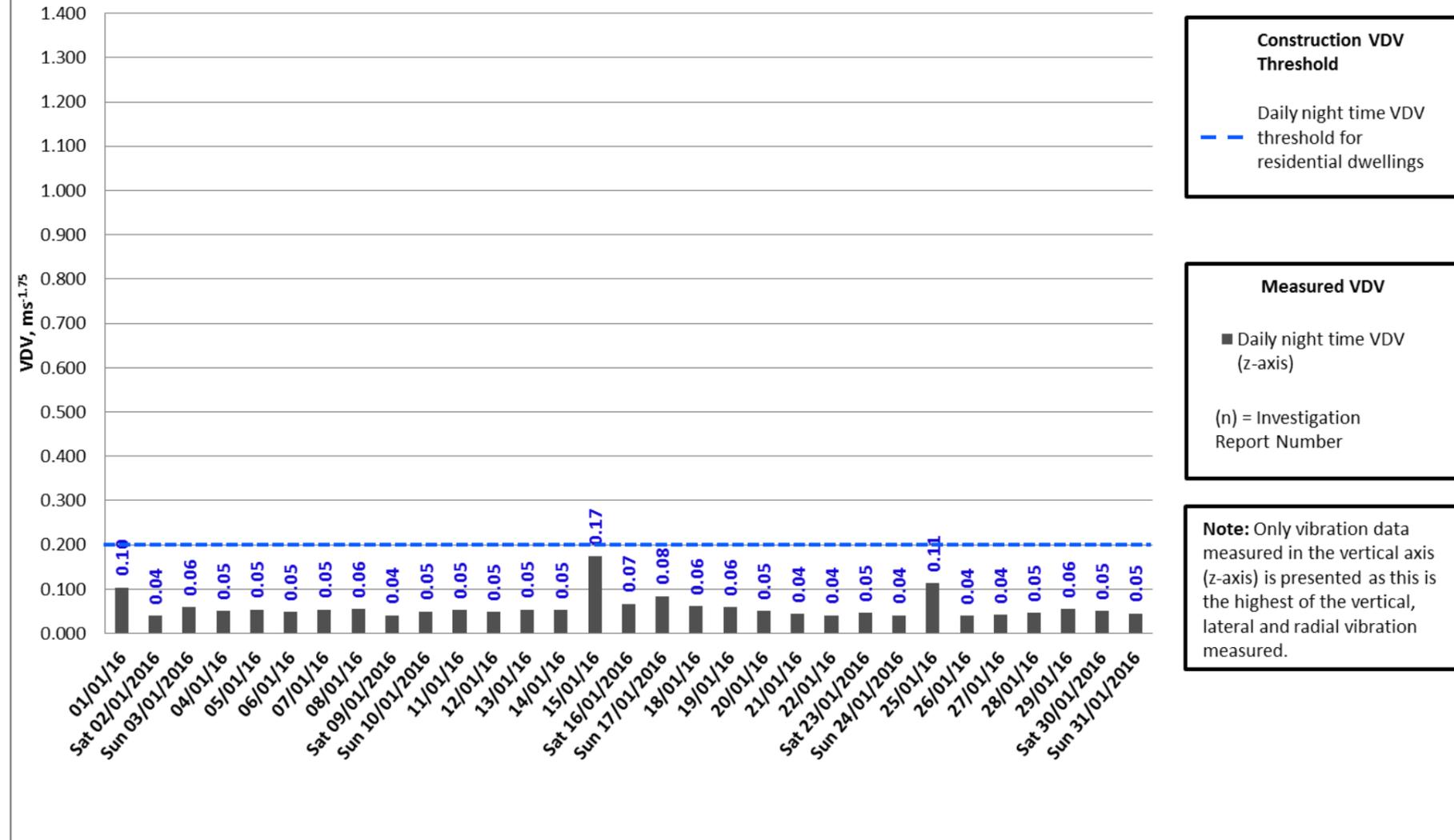
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

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.

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: January 2016



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: January 2016



Construction VDV Threshold

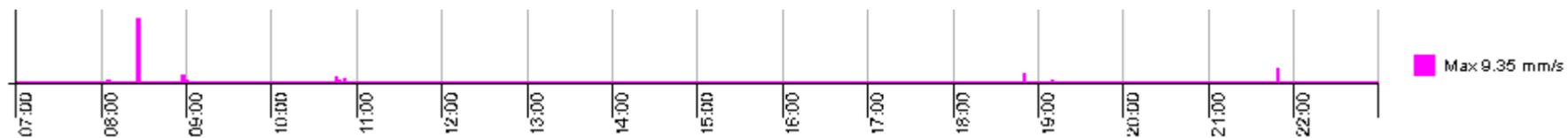
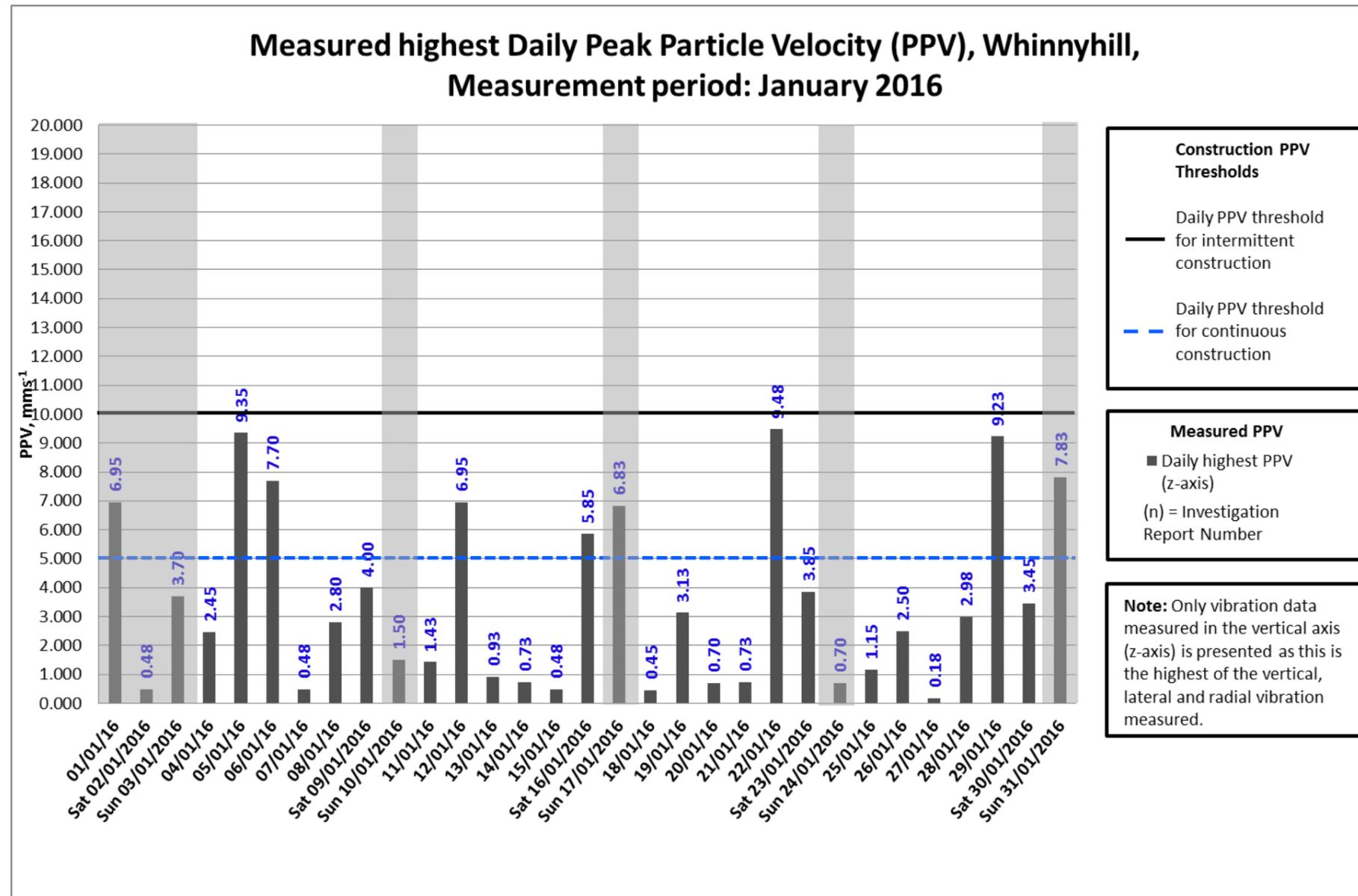
Daily night time VDV threshold for residential dwellings

Measured VDV

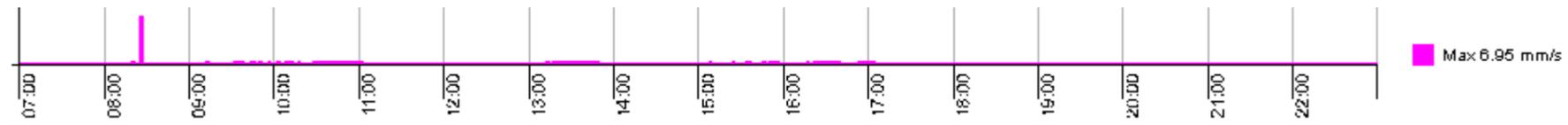
■ Daily night time VDV (z-axis)

(n) = Investigation Report Number

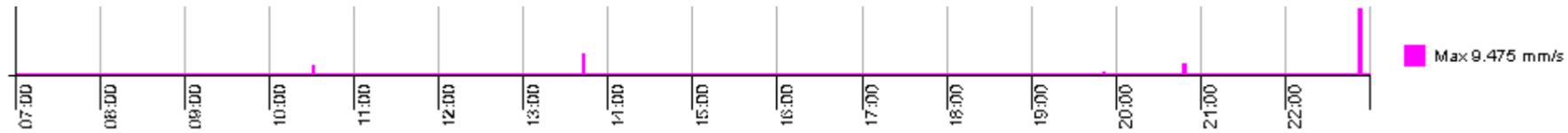
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



Exceedance on the 5th of January was caused by monitor maintenance by the environmental department.

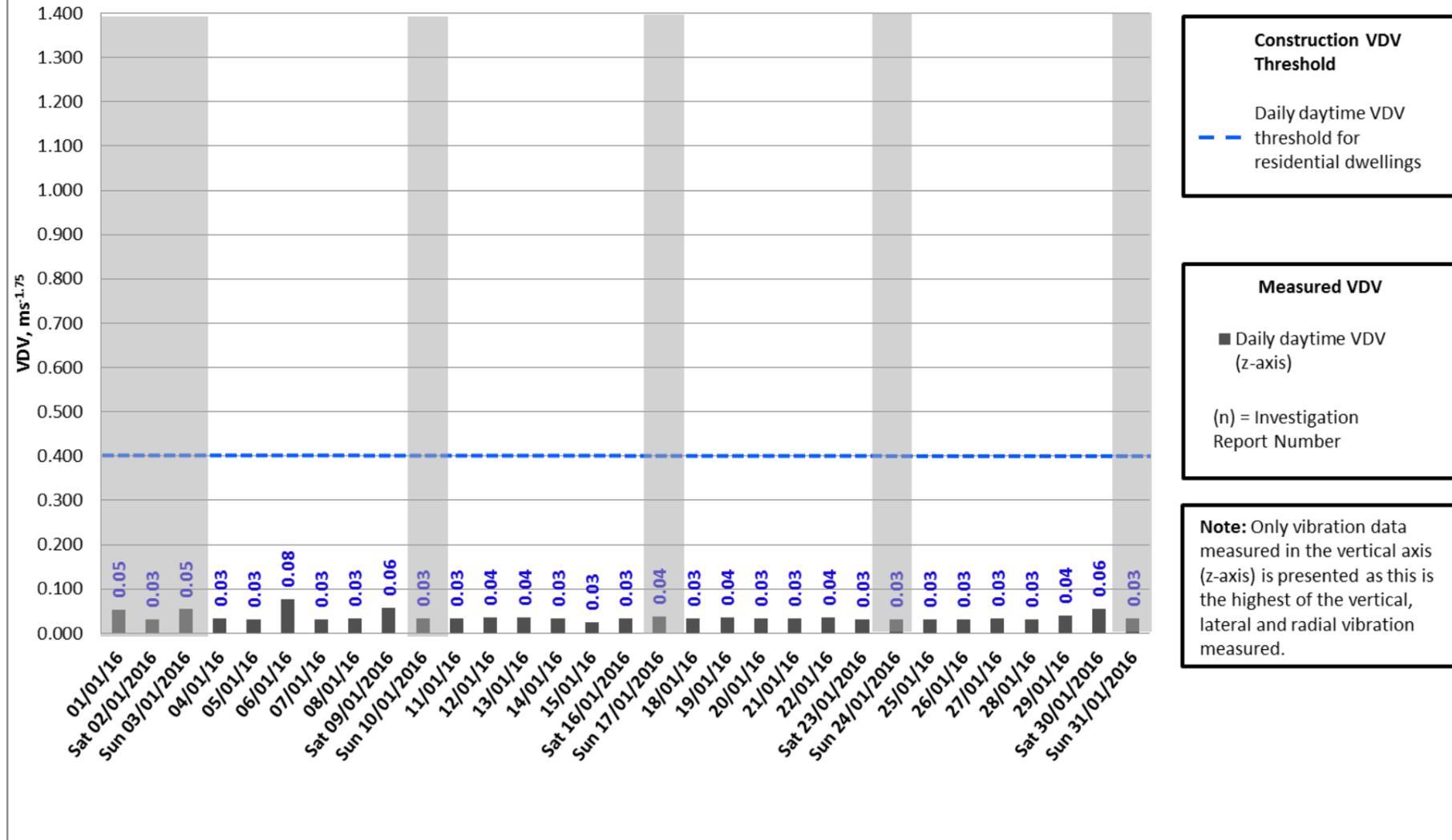


Exceedances on the 6th, 12th, 16th and 29th of January were found to be intermittent isolated events that are highly unlikely to have been caused by construction related activities (graph above taken from data acquired on 12/01/2016)



Exceedances on the 17th, 22nd and 31 have been found to be out with construction working hours and are highly unlikely to have been caused by construction related activities. These exceedances are more likely to have been caused by localised activities close to the monitor (graph above taken from data acquired on 22/01/2016).

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Whinnyhill, Measurement period: January 2016



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

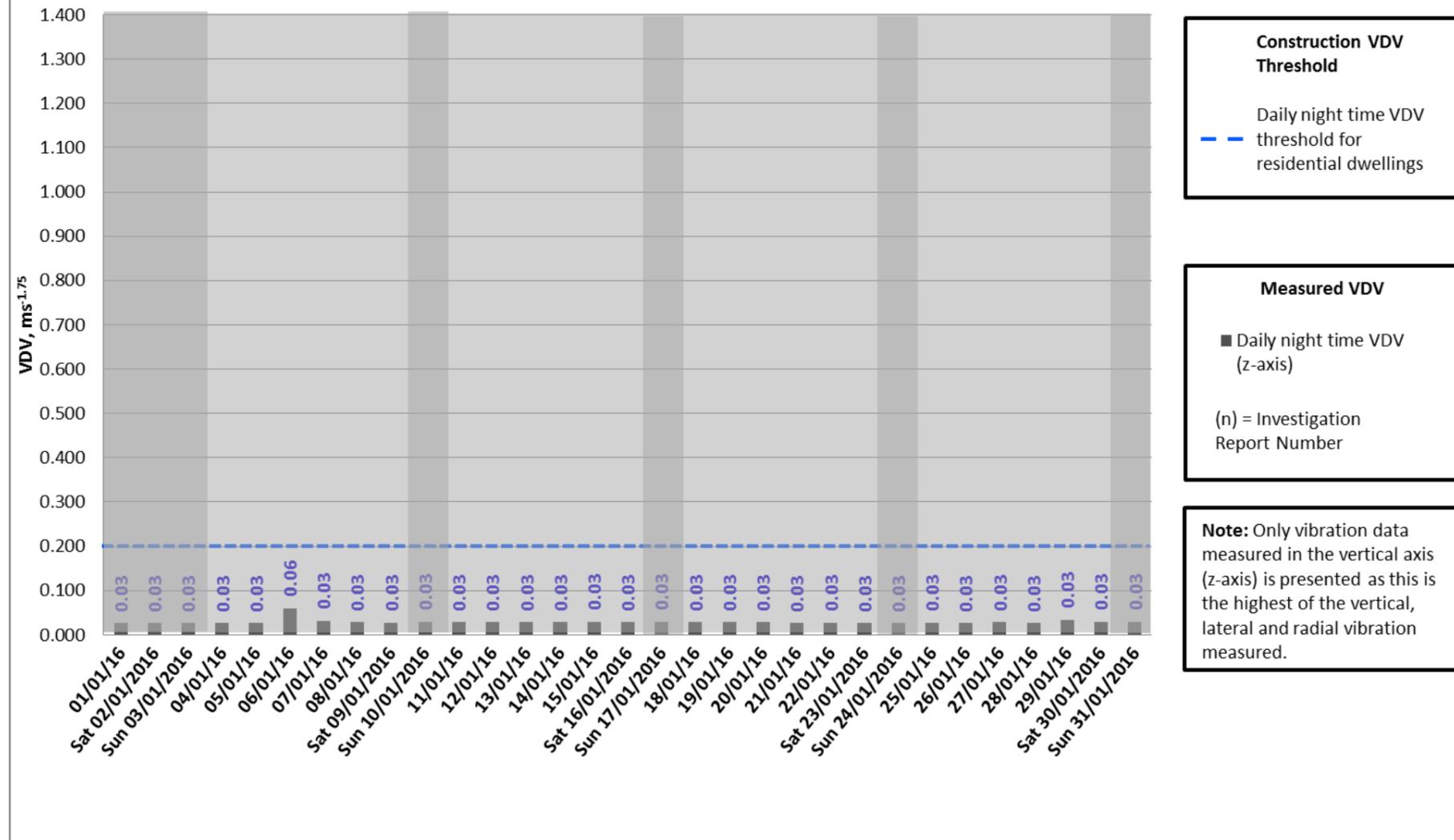
Measured VDV

■ 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), Whinnyhill, Measurement period: January 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.