



Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project **FORTH REPLACEMENT CROSSING**

Document title

VIBRATION MONITORING REPORT
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Contents

- 1. Introduction**
- 2. Monitoring Summary**
- 3. Conclusion**

Appendices:

Appendix A: Vibration Assessments from Relevant PCNVs

Appendix B: PPV and VDV Graphs

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 February 2014. 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

February 2014

Location	PPV Exceedance		VDV Exceedance	
	Continuous (5 mm.s ⁻¹)	Intermittent (10 mm.s ⁻¹)	Day (0.4 m.s ^{-1.75})	Night (0.2 m.s ^{-1.75})
Linn Mill	0	0	1	5
Butlaw Fisheries	0	1	0	0
Clufflat Brae	3	0	0	0
Dundas Home Farm	0	0	0	3
Echline	5	0	0	0
Inchgarvie Lodge	0	0	0	0
Scotstoun	0	0	0	0
Springfield	1	3	1	1
Tigh-Na-Grian	0	0	0	0
Whinnyhill	6	0	0	1

- 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⁻¹ for continuous construction (e.g. piling), and 10 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 m.s⁻² and the time period over which the VDV is measured is in seconds. This yields V DVs in 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. Due to the distances between the work areas and any sensitive receptors, none of the exceedances in VDV levels can be associated with the use of vibratory rollers or whacker plates.
- 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 as a result of monitoring device errors.

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 do not represent levels 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 February 2014
M1	Whinny Hill	Network	<ul style="list-style-type: none"> • Surfacing, excavation, grouting and top soil batters • Crushing works <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • North Tower rebar, formwork & concreting works • Pier N1 de-stressing wells, cleaning of cofferdam
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • South Tower rebar, formwork & concreting works • Pier S1 de-stressing wells works • Pier S3 cofferdam construction • Pier S5 rebar, formwork & concreting works • Preparation of rebar prefabrication area at S5 causeway • Concreting and fixing rebar at S6 • Society Road TARMAC coring • Bearing installation at S7
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork & concreting works • South Tower rebar, formwork & concreting works • Pier S1 de-stressing wells works • Pier S3 cofferdam construction • Pier S5 rebar, formwork & concreting works • Preparation of rebar prefabrication area at S5 causeway • Concreting and fixing rebar at S6 • Society Road TARMAC coring • Bearing installation at S7 • Launch – install plates to props, king post works and structural steel works
M11	Linn Mill	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Pier S5 rebar, formwork & concreting works • Preparation of rebar prefabrication area at S5 causeway • Concreting and fixing rebar at S6 • Bearing installation at S7 <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M13	Clufflat Brae	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Society Road TARMAC coring <p>N.B. No night time or Sunday daytime construction</p>

			in vicinity.
M14	Springfield	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M15	Echline Field	Network	<ul style="list-style-type: none"> • Launch – install plates to props, king post works and structural steel works • Gyrotory – cut batters/shaping rock • A904 tie in road works, including verge fill, kerbing and placing/trimming of type 1 sub-base for footpath <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M16	Scotstoun	Network	<ul style="list-style-type: none"> • Utilities works • Structure works <p>N.B. No night time or Sunday daytime construction in vicinity.</p>
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> • Utility works • Fill south bund/landscape <p>N.B. No night time or Sunday daytime construction in vicinity.</p>

Table 2 lists the main construction activities undertaken in the locality of each of the vibration monitors during the period of February 2014.

Table 3: PCNV Predicted PPV & VDV Levels

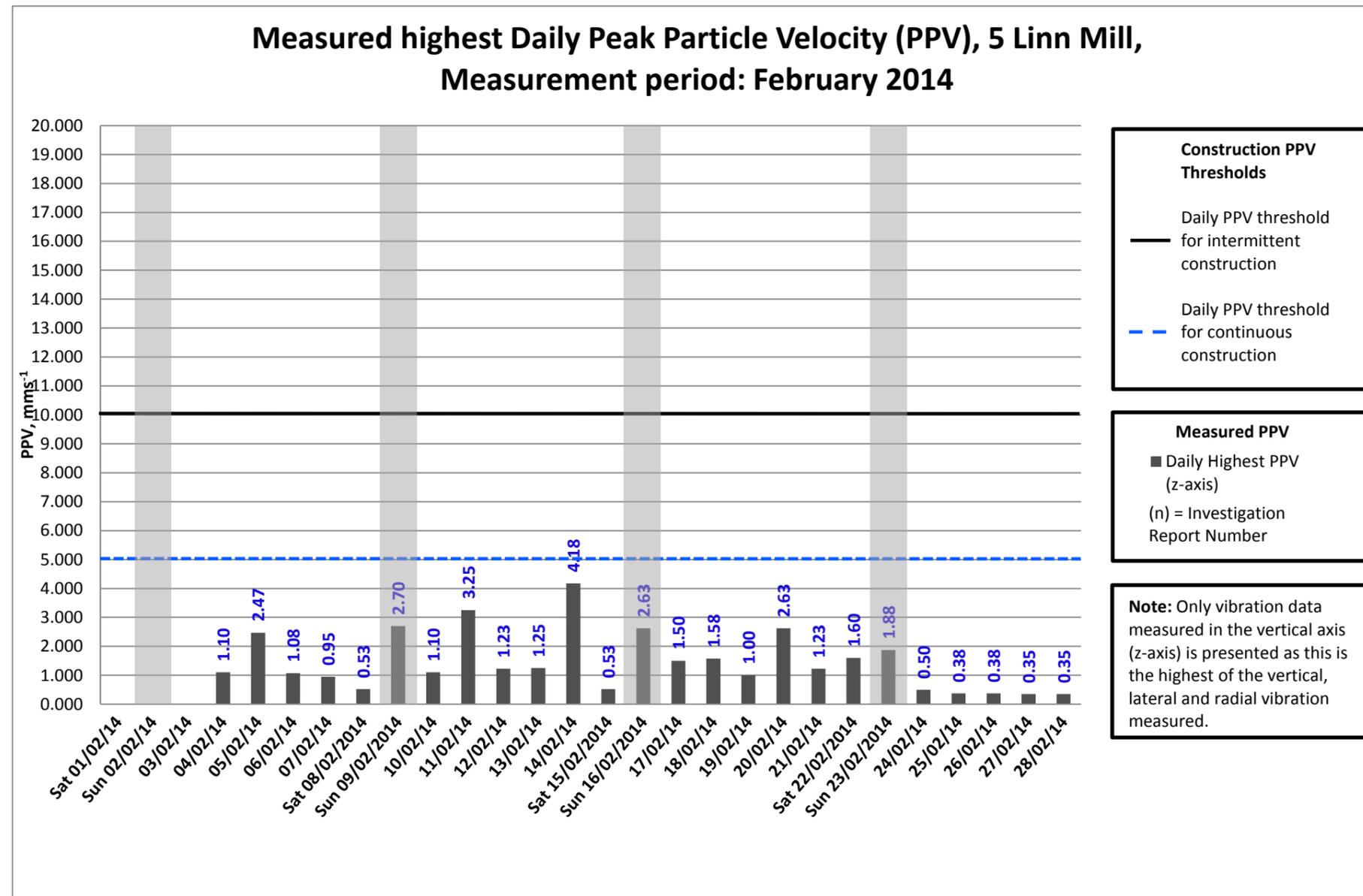
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker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

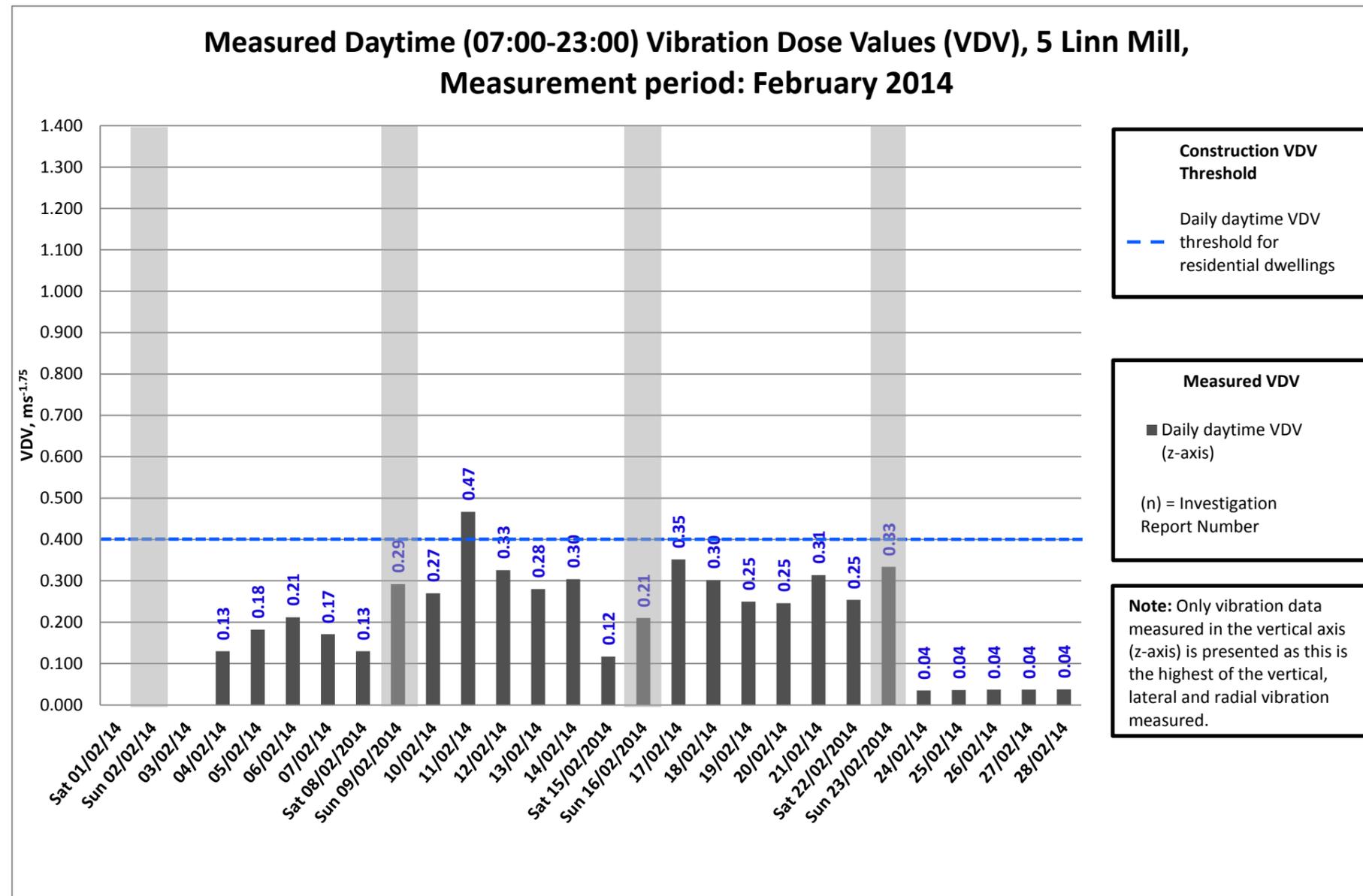
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s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



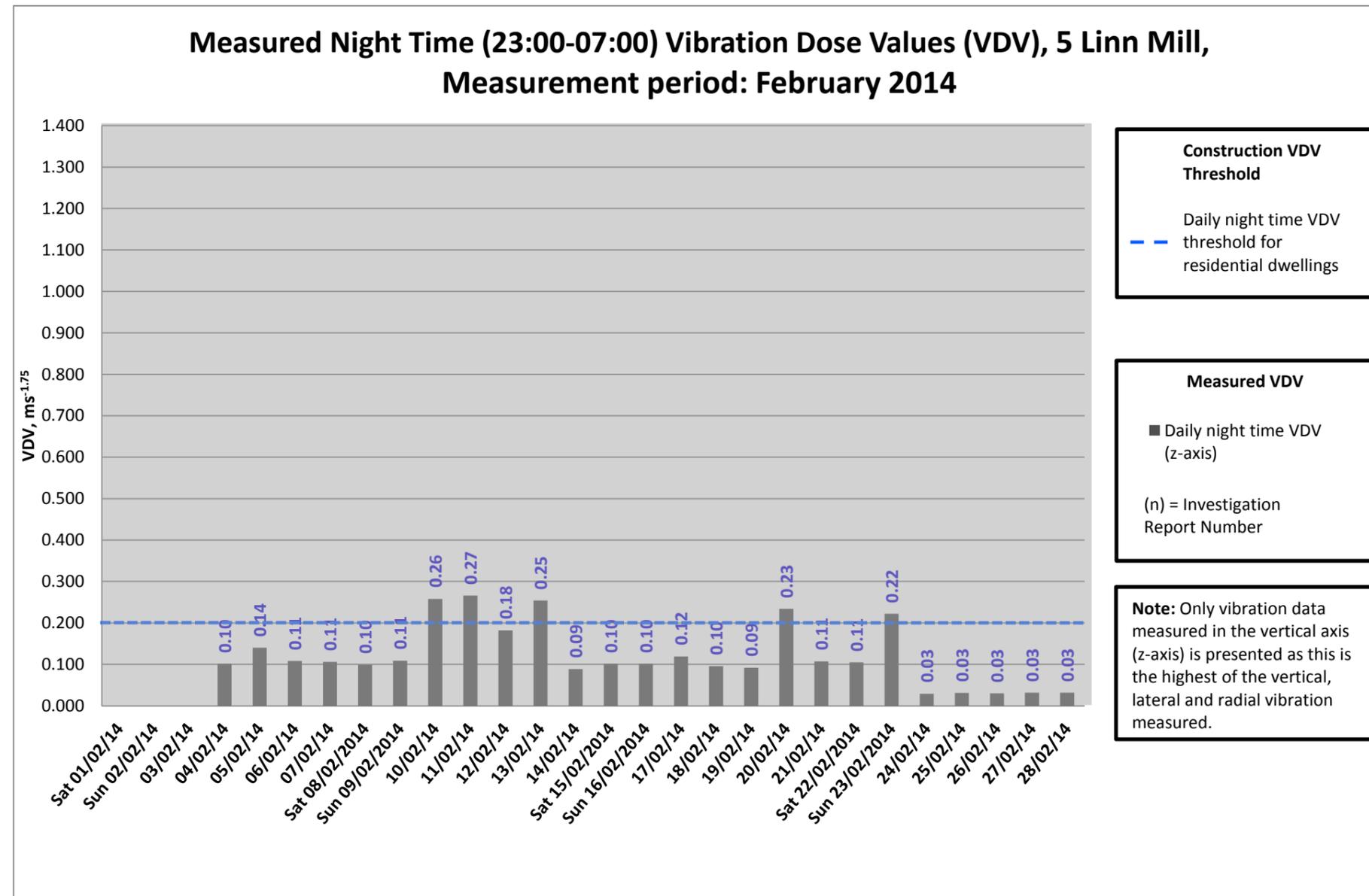
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Linn Mill monitor on Sundays.
- Data is missing for the period 01/02/14 – 03/02/14 due to device error.



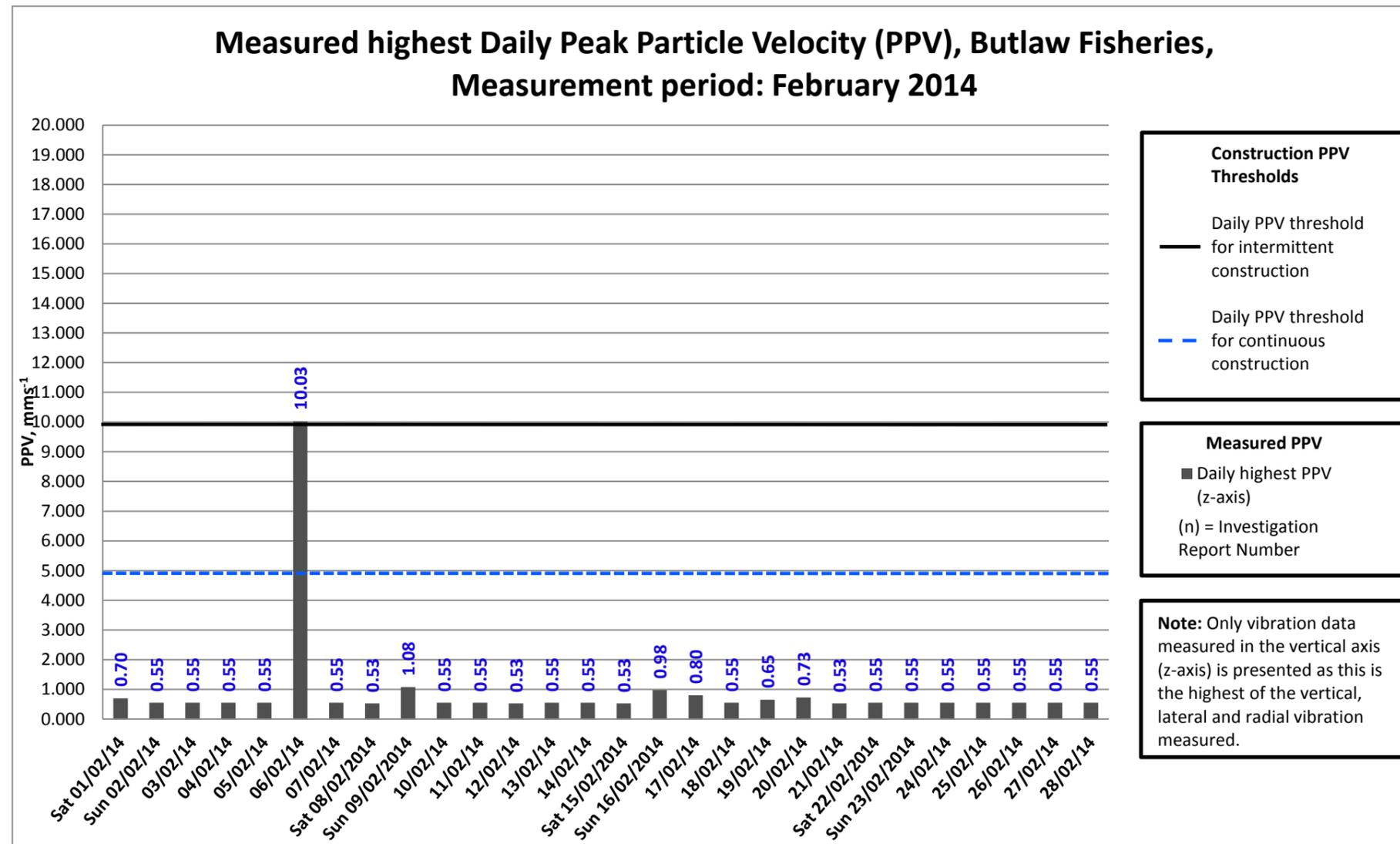
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Linn Mill monitor on Sundays.
- Data is missing for the period 01/02/14 – 03/02/14 due to device error.
- The VDV on 11/02/14 has been investigated. It is extremely unlikely that this particular level was generated as a result of FCBC construction, as the only works to be conducted in the vicinity of the monitor on this date in question were rebar, formwork & concreting works at Piers S5 and S6 and steel work assembly at the South Launch area. None of these works involved the use of any vibration inducing plant and were a minimum of 160m (worst case) from the monitor.



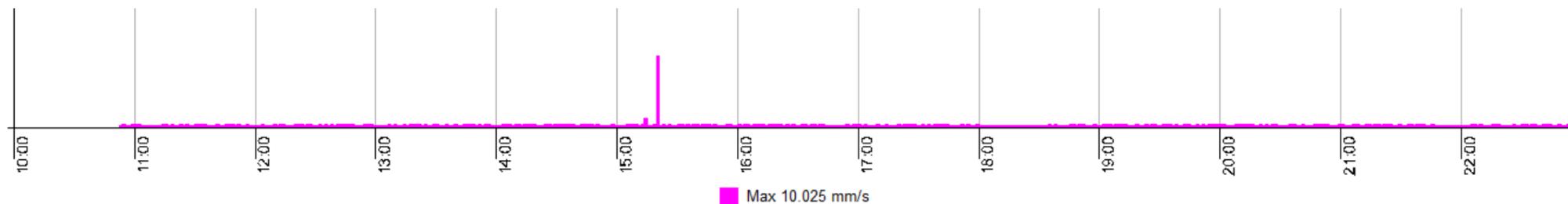
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Linn Mill vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.

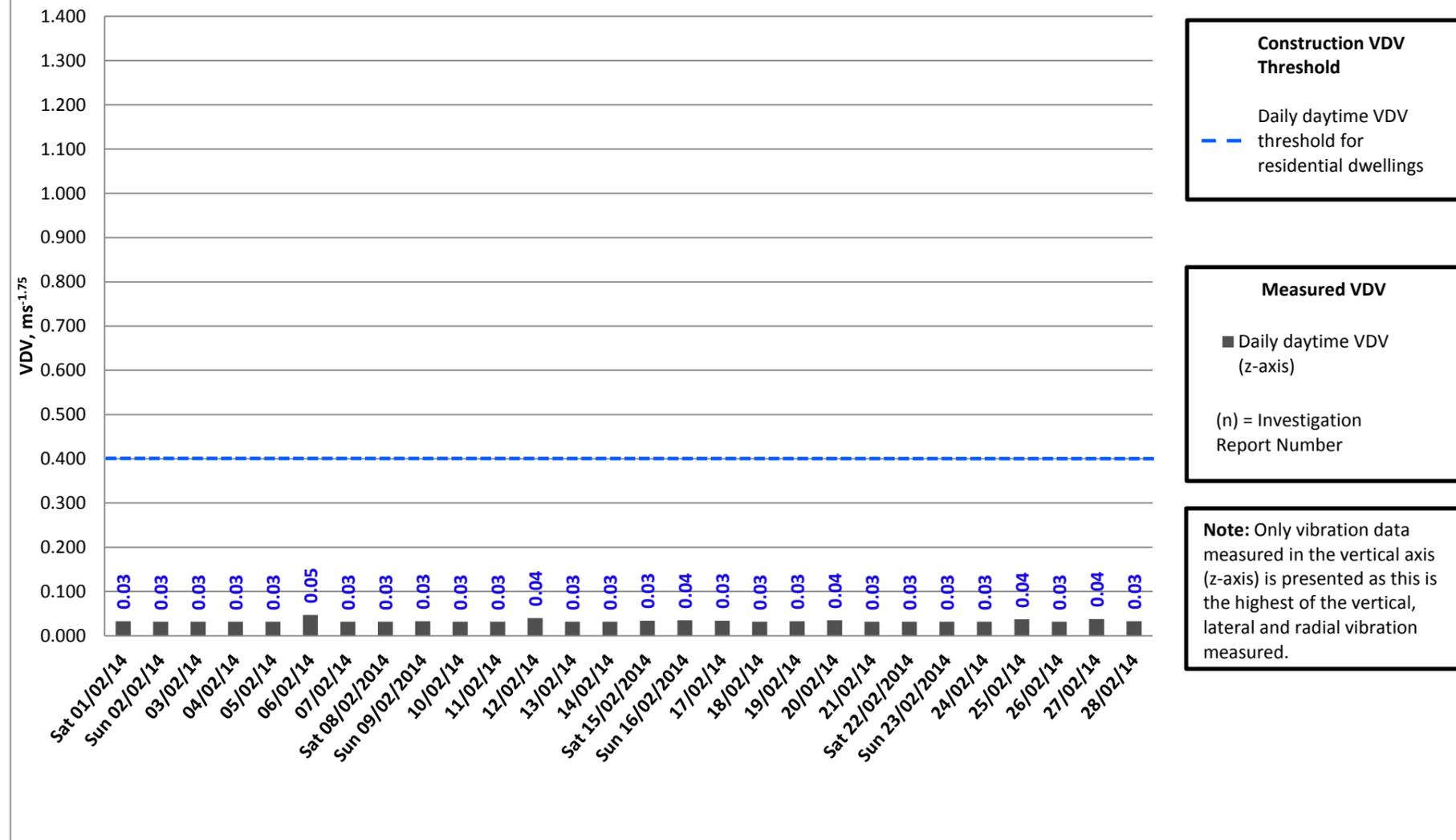


Notes:

- The PPV value on 06/02/14 has been investigated, and has been seen to be individual, isolated events within each period (see Vibrock PPV graph below). It is extremely unlikely that this particular level was generated as a result of FCBC construction, as the only vibration inducing works to be conducted in the vicinity of the monitor on this date were impact piling works for Pier S3 cofferdam construction (which would display a succession of repeated impulses). These works were conducted over 350m from the monitor and were also conducted intermittently throughout the month. Other works conducted in the vicinity of the monitor on this date were Pier S5 rebar, formwork & concreting works and preparation of rebar prefabrication area at the S5 causeway. None of these works involved the use of any vibration inducing plant and were a minimum of 180m (worst case) from the monitor.



**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw Fisheries,
 Measurement period: February 2014**



Construction VDV Threshold

— Daily daytime VDV threshold for residential dwellings

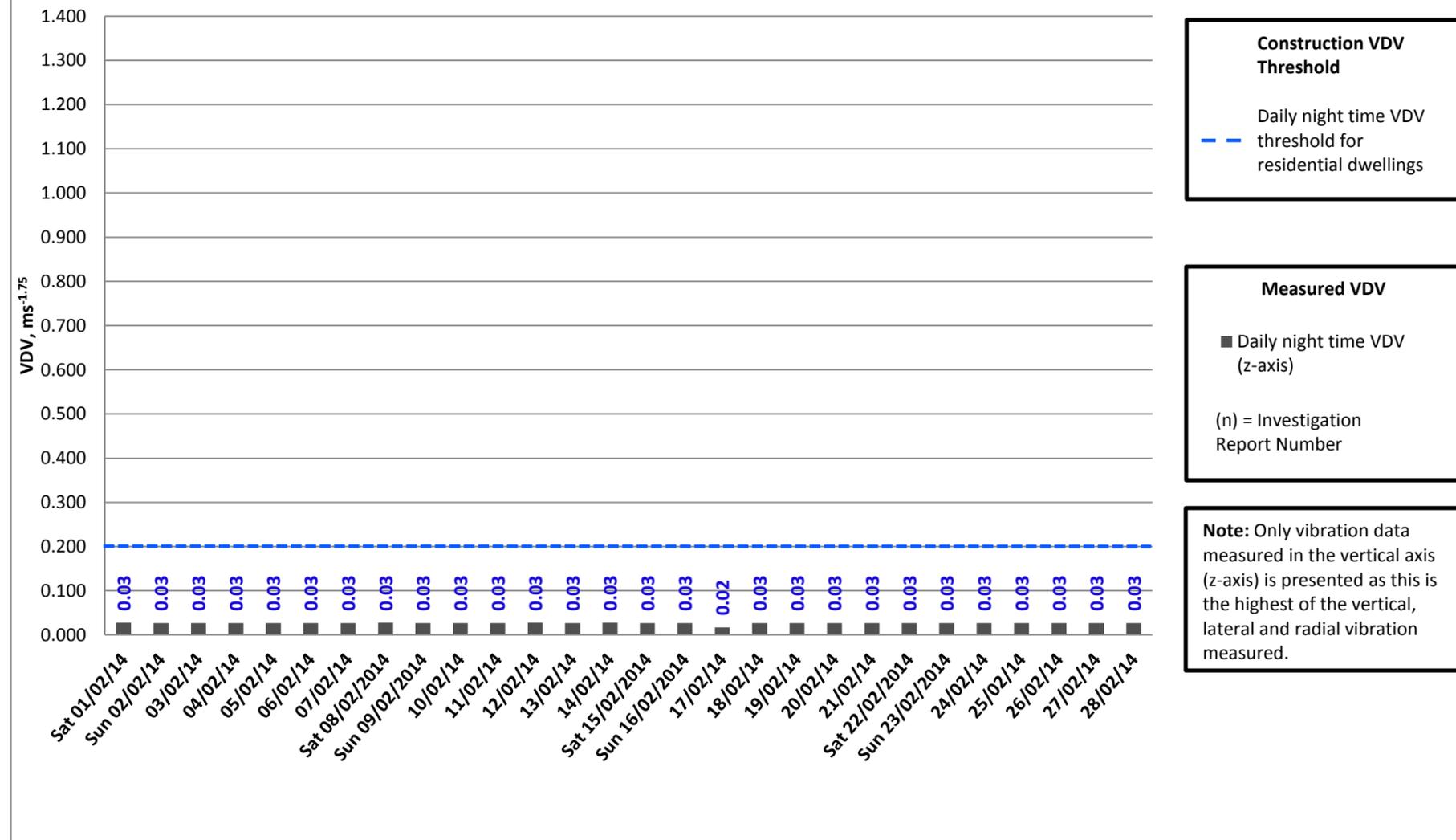
Measured VDV

■ 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 Fisheries, Measurement period: February 2014



Construction VDV Threshold

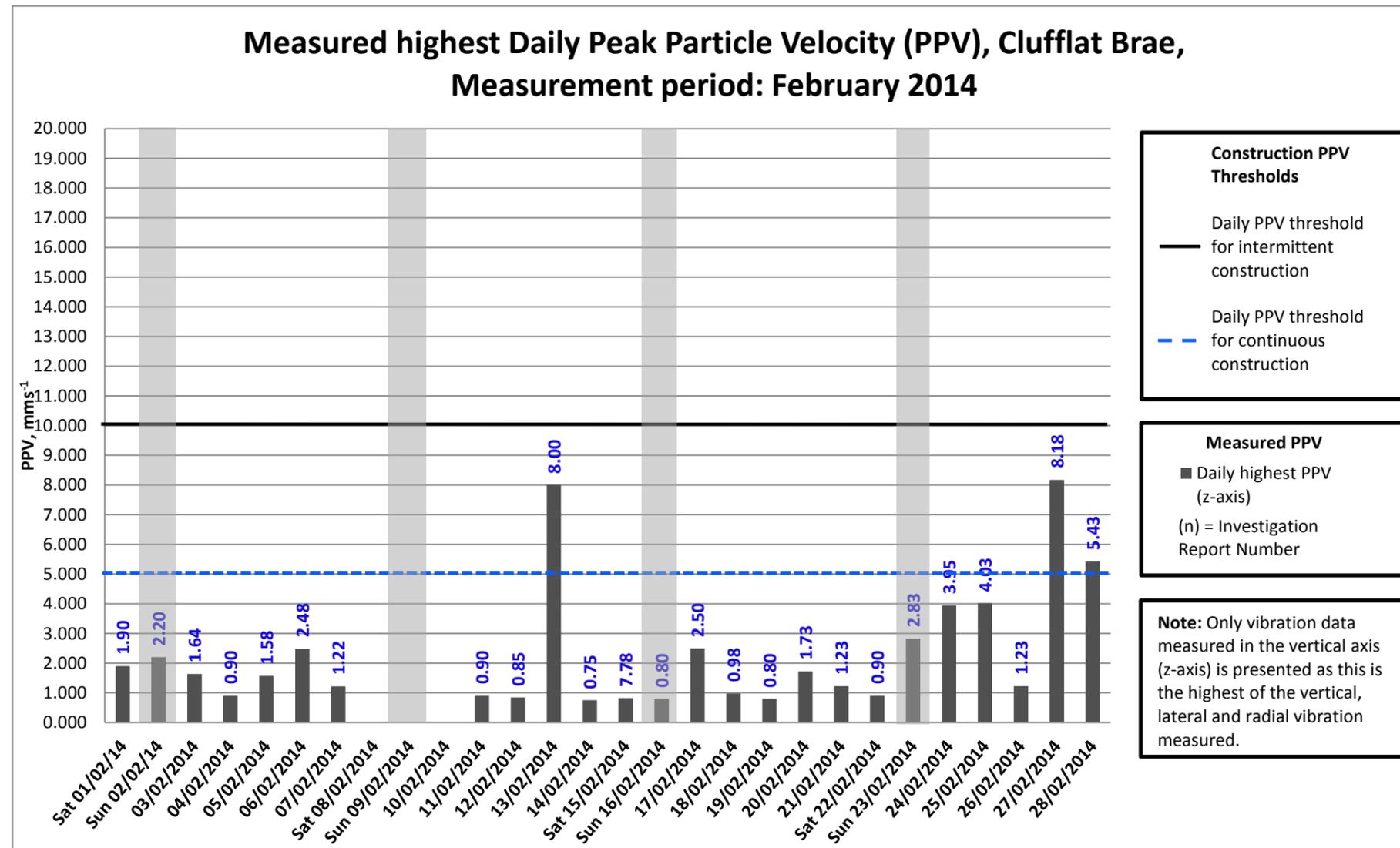
Daily night time VDV threshold for residential dwellings

Measured VDV

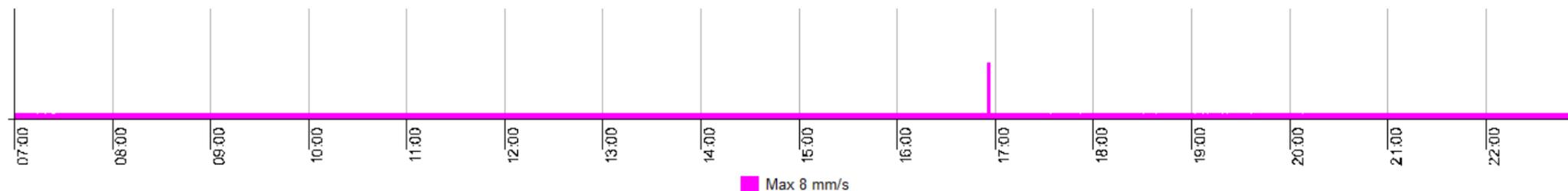
■ Daily night time VDV (z-axis)

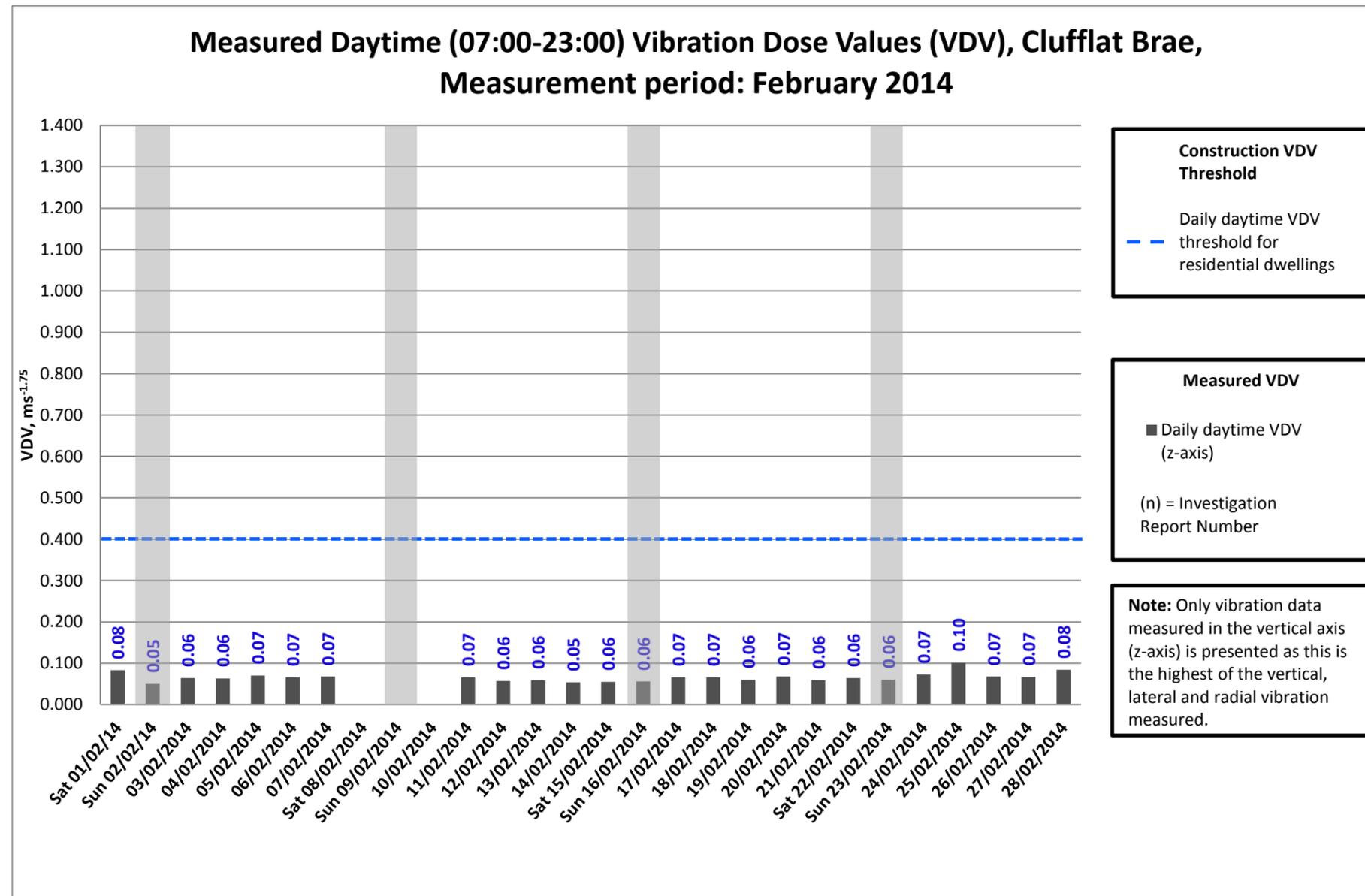
(n) = Investigation Report Number

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.



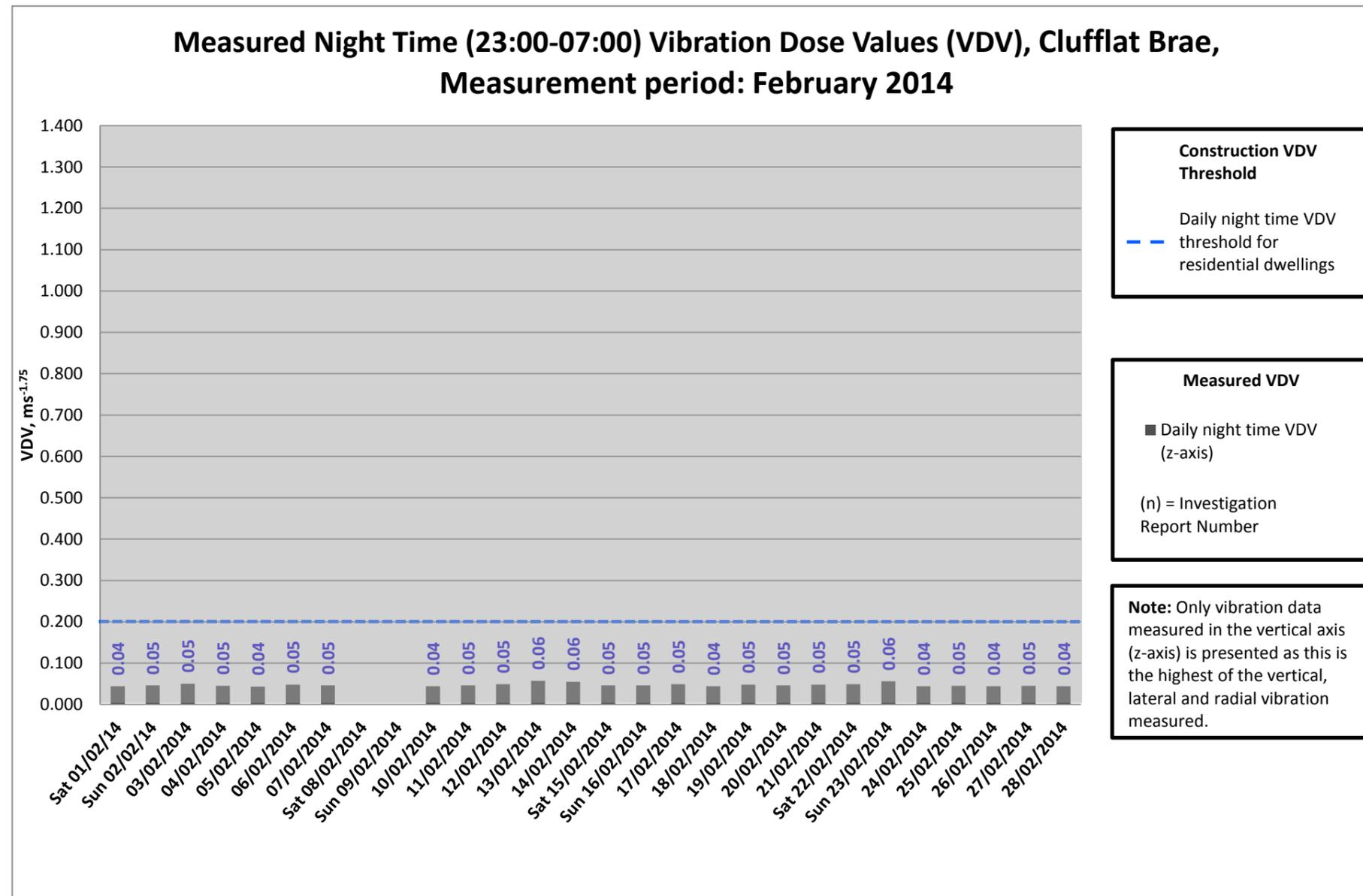
- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Clufflat Brae monitor on Sundays.
 - Data is missing for the period 08/02/14 – 10/02/14 due to device error.
 - The PPV values on 13/02/14, 27/02/14 & 28/02/14 have all been investigated, and have been seen to be individual, isolated events within the period (see Vibrock PPV graph below from 13/02/14), all of which are within the intermittent threshold of 10mm/s.





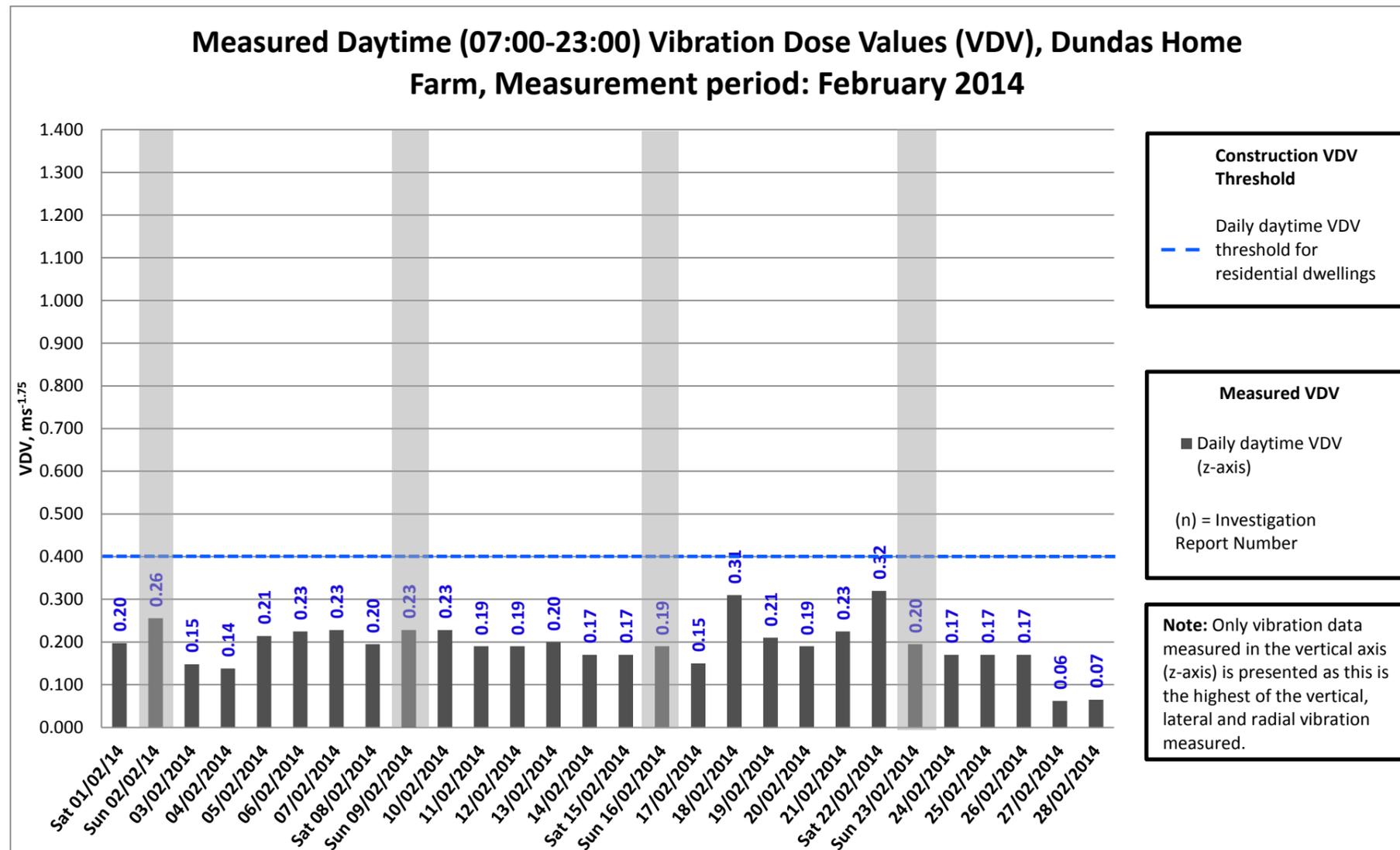
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Clufflat Brae monitor on Sundays.
- Data is missing for the period 08/02/14 – 10/02/14 due to device error.



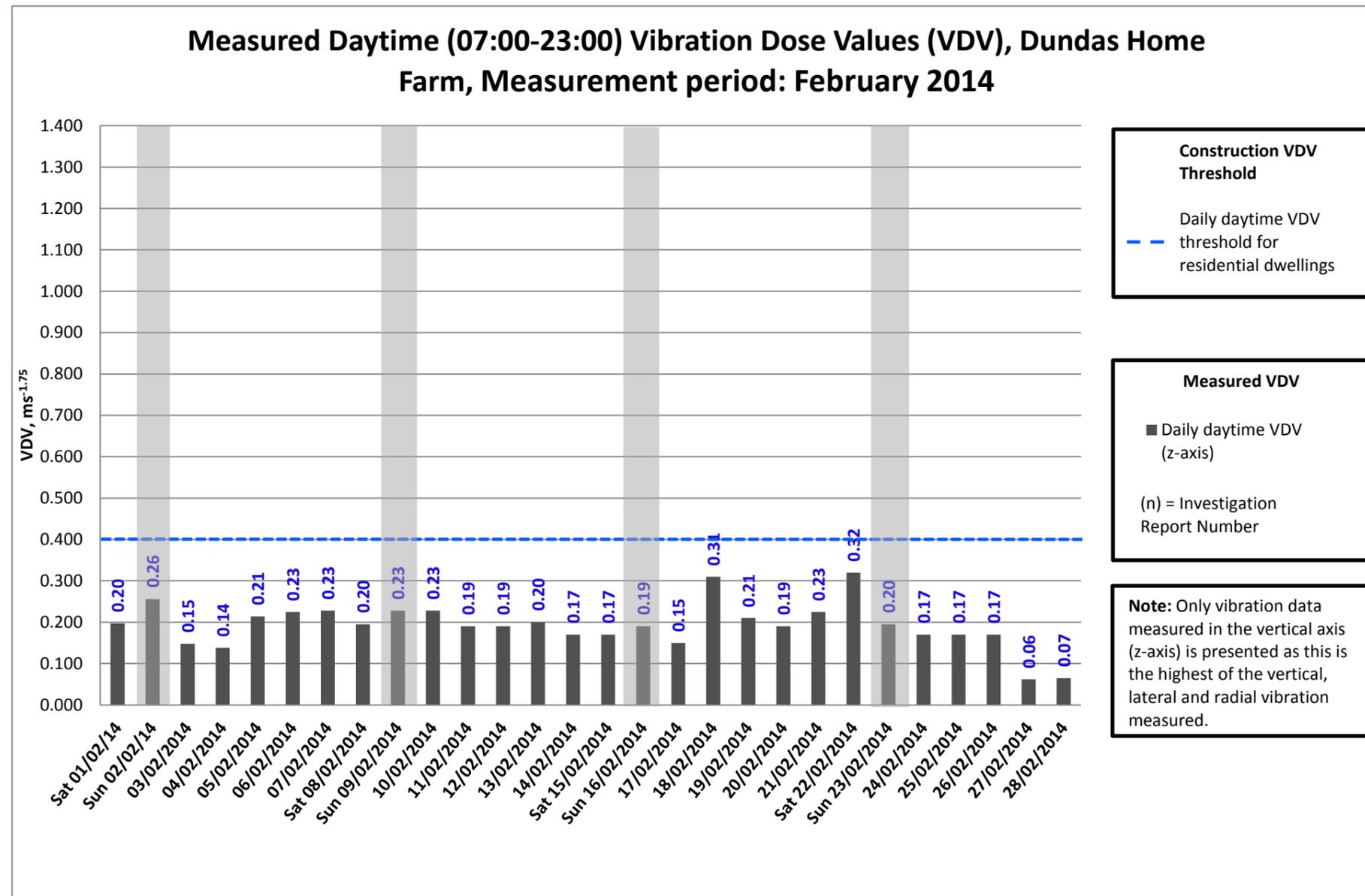
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Clufflat Brae vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.



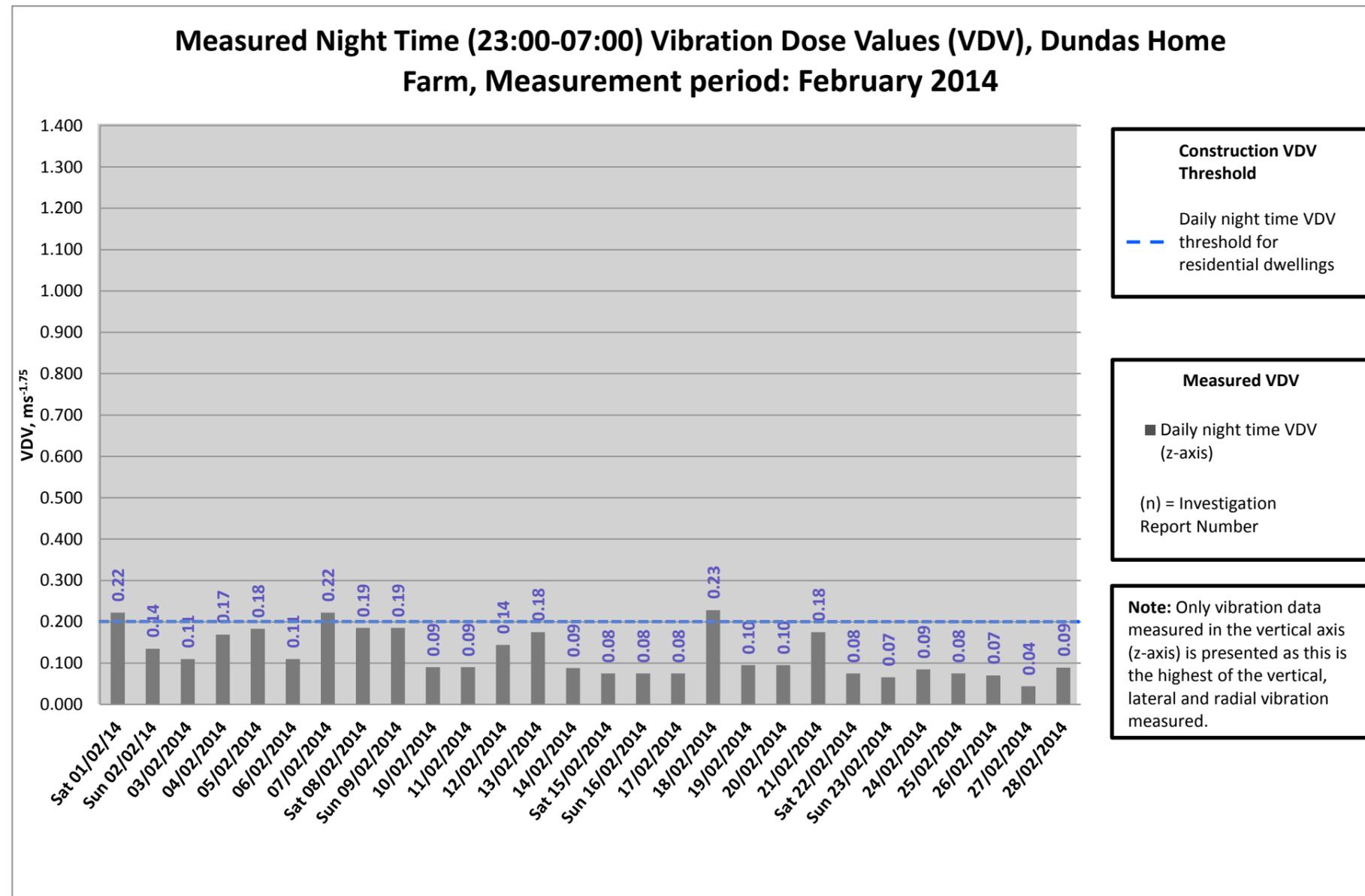
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Dundas monitor on Sundays.



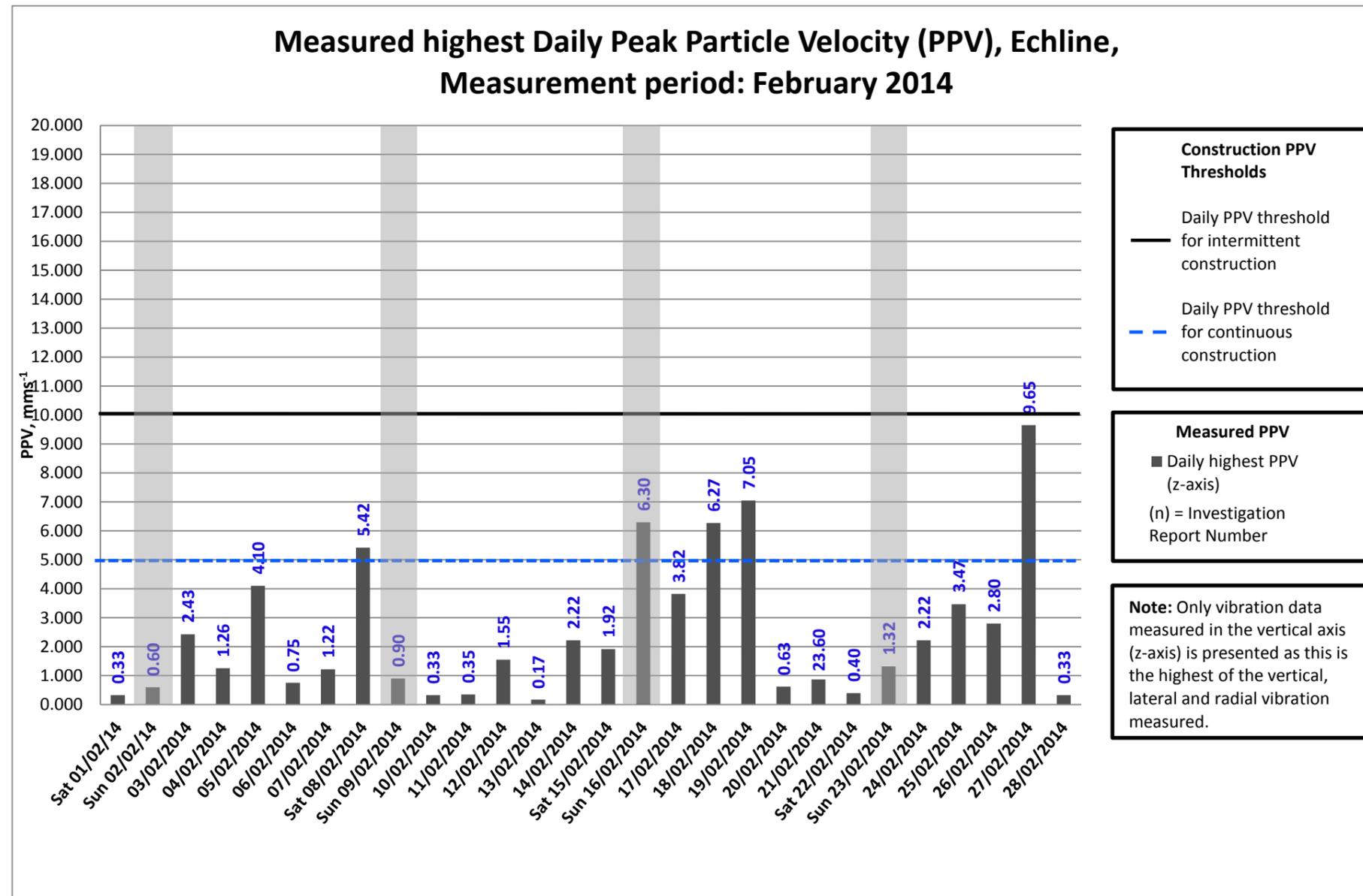
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Dundas monitor on Sundays.



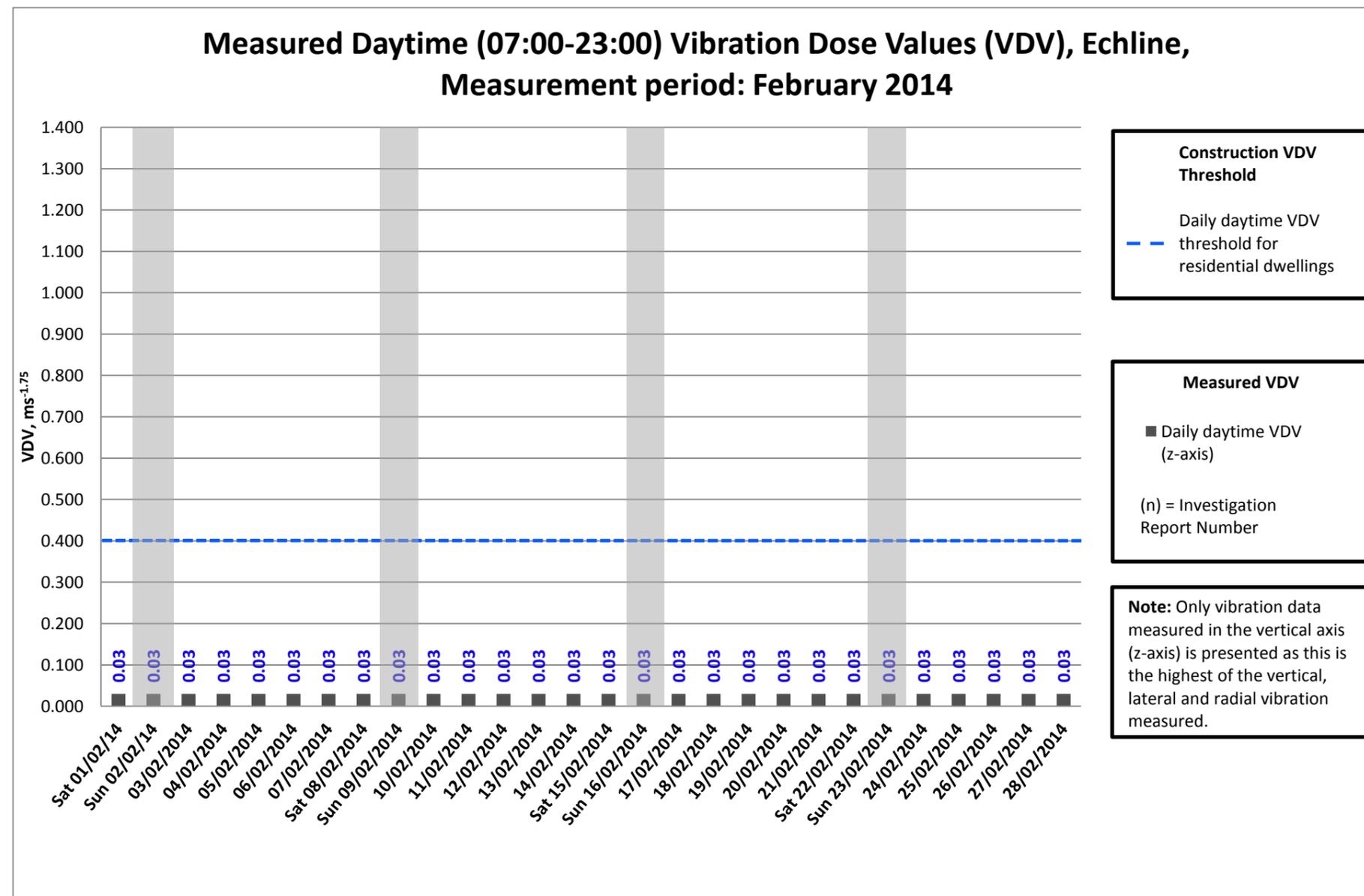
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas Home Farm vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.



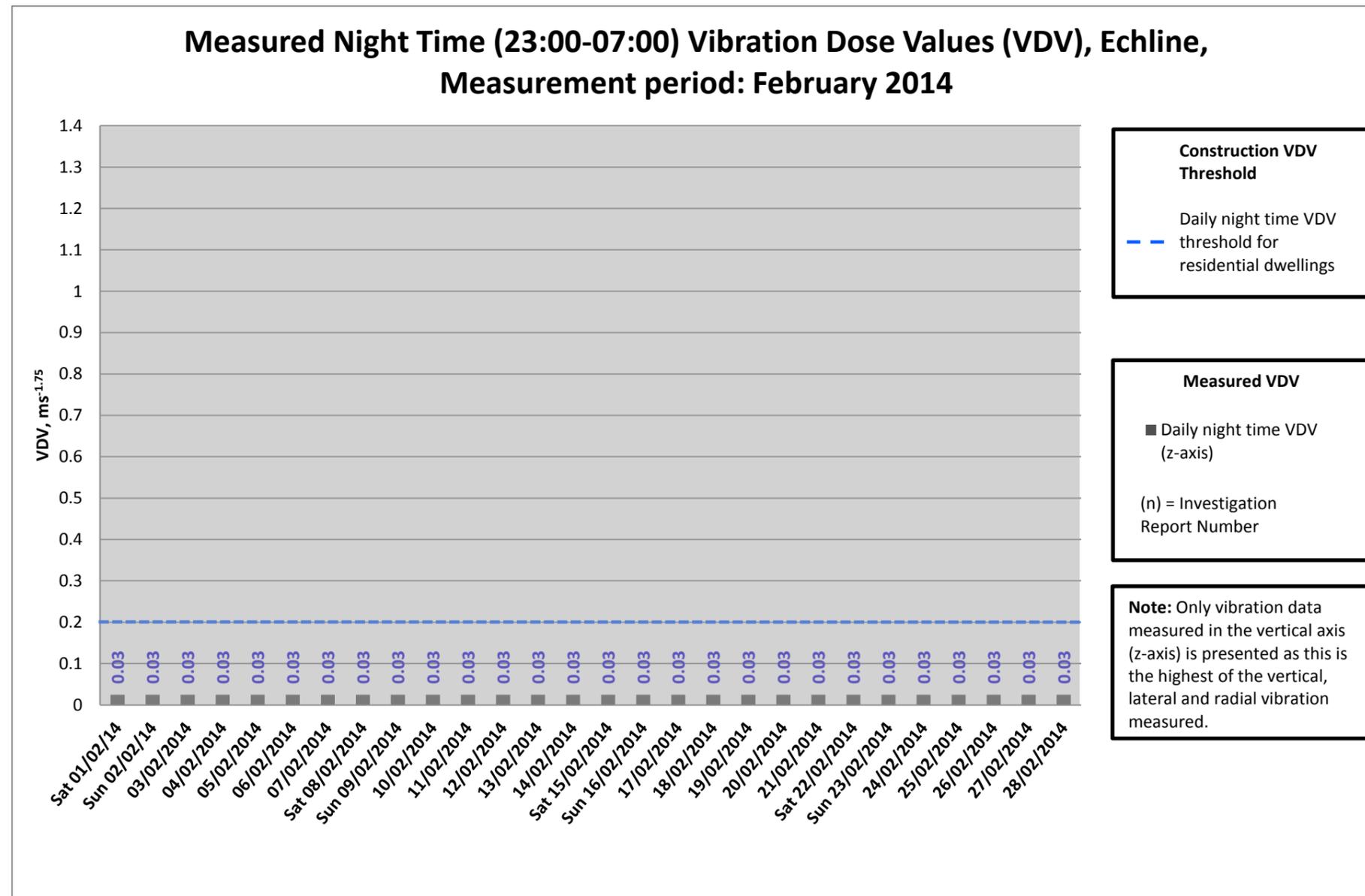
Notes

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Echline monitor on Sundays.
- The PPV values on 08/02/14, 18/02/14, 19/02/14 & 27/02/14 have all been investigated, and have been seen to be individual, isolated events within the period, all of which are within the intermittent threshold of 10mm/s.



Notes:

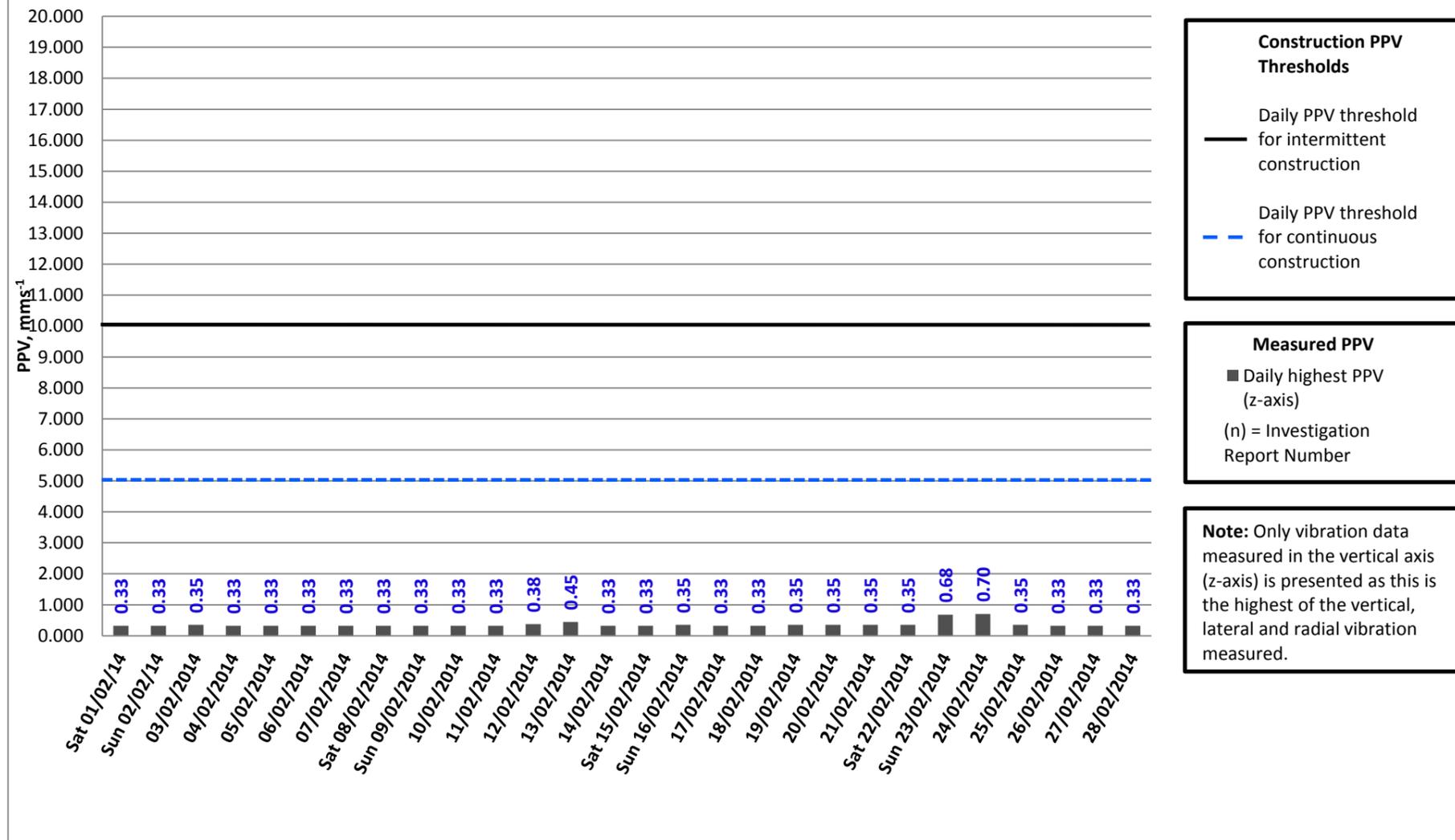
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Echline monitor on Sundays.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Echline vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.

Measured highest Daily Peak Particle Velocity (PPV), Inchgarvie Lodge, Measurement period: February 2014



Construction PPV Thresholds

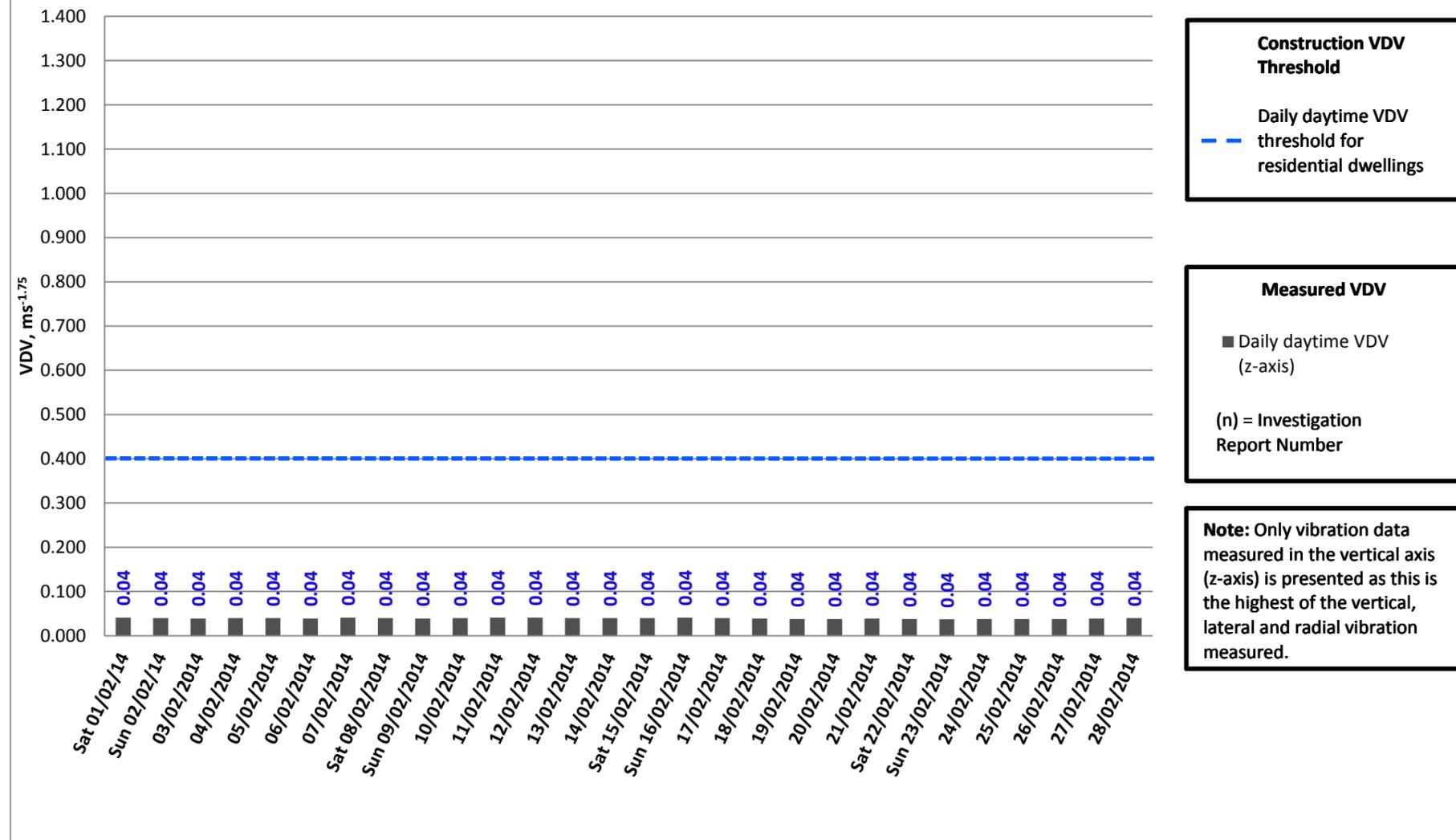
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

Measured PPV

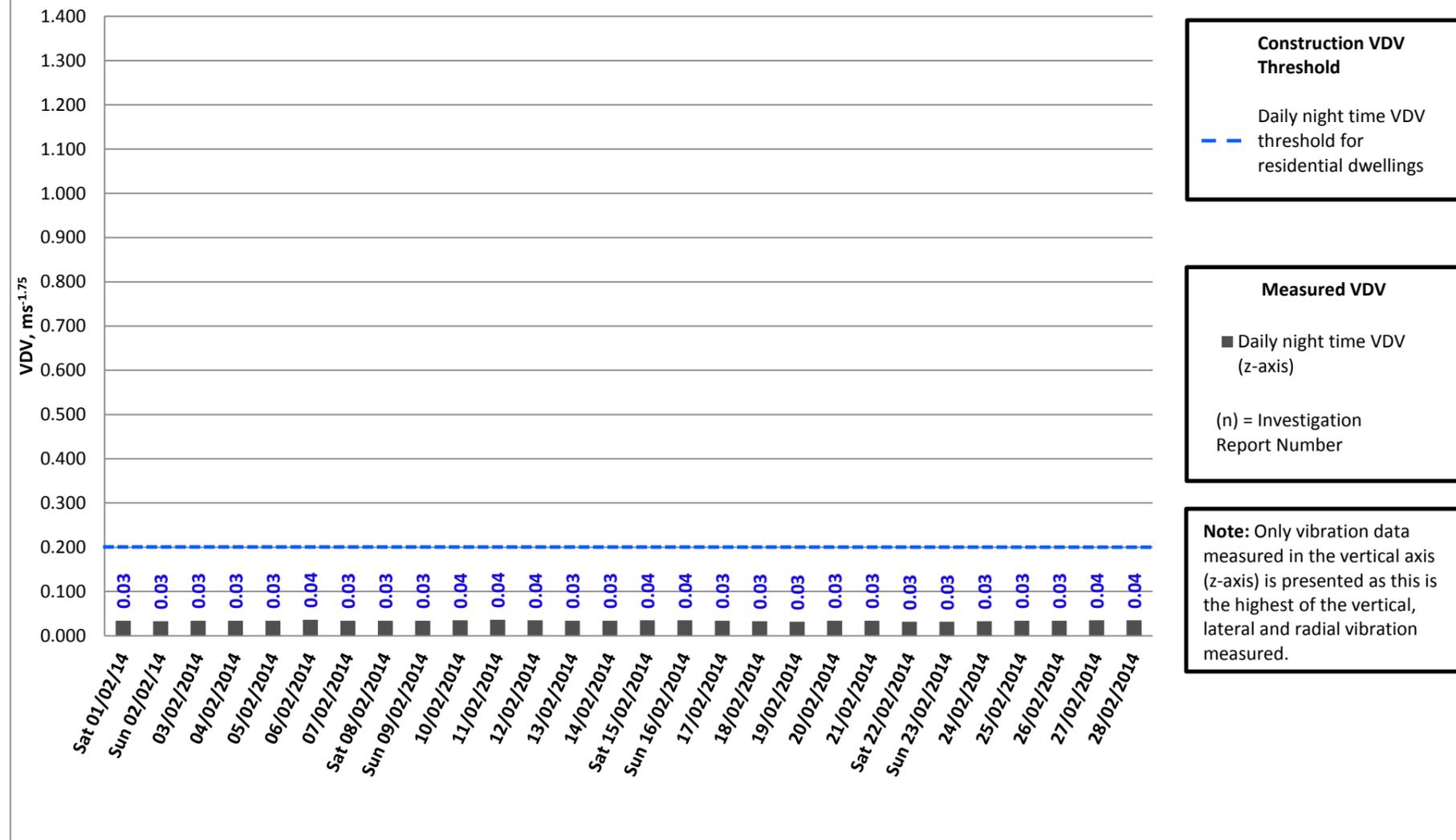
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

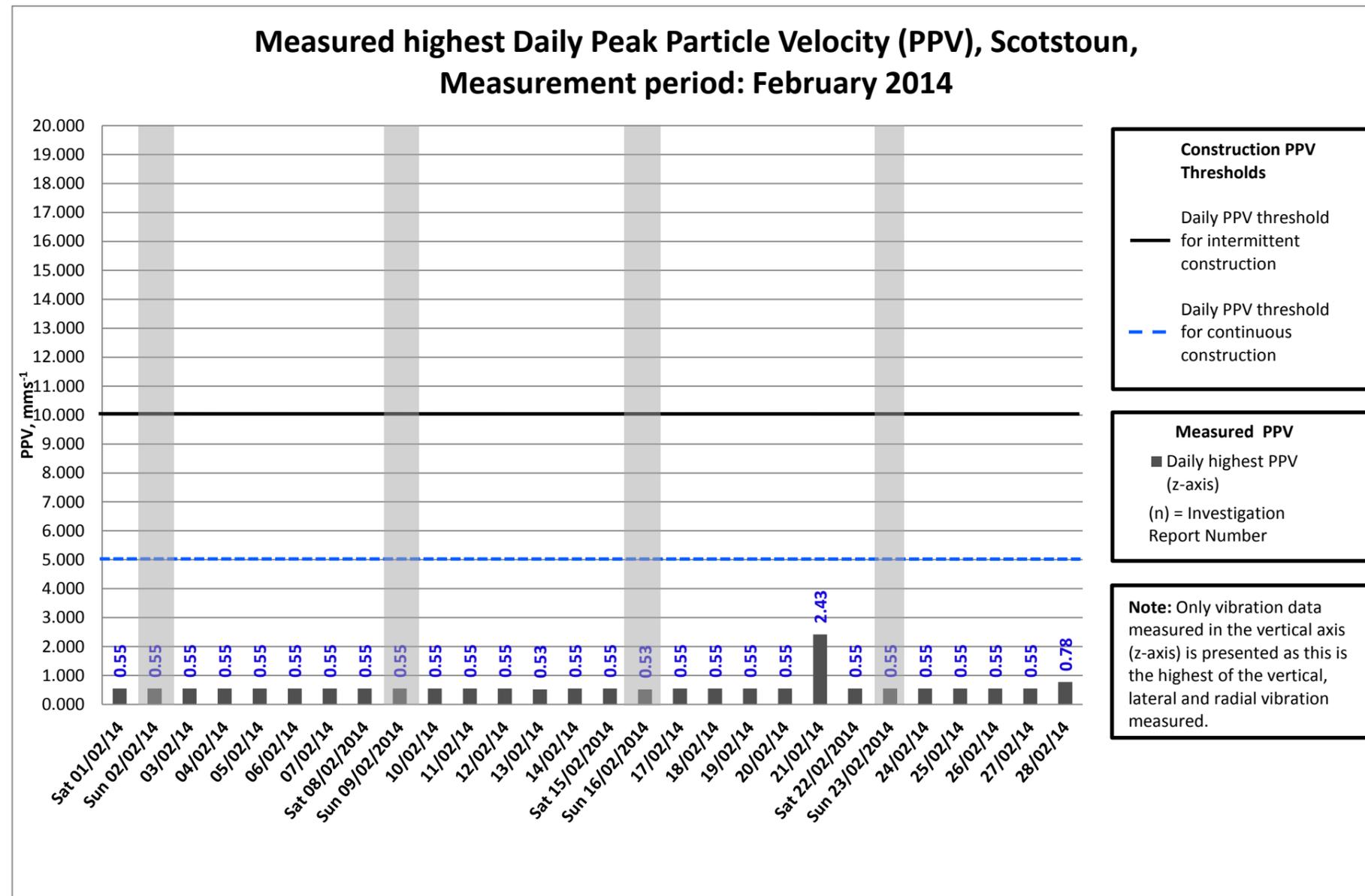
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: February 2014



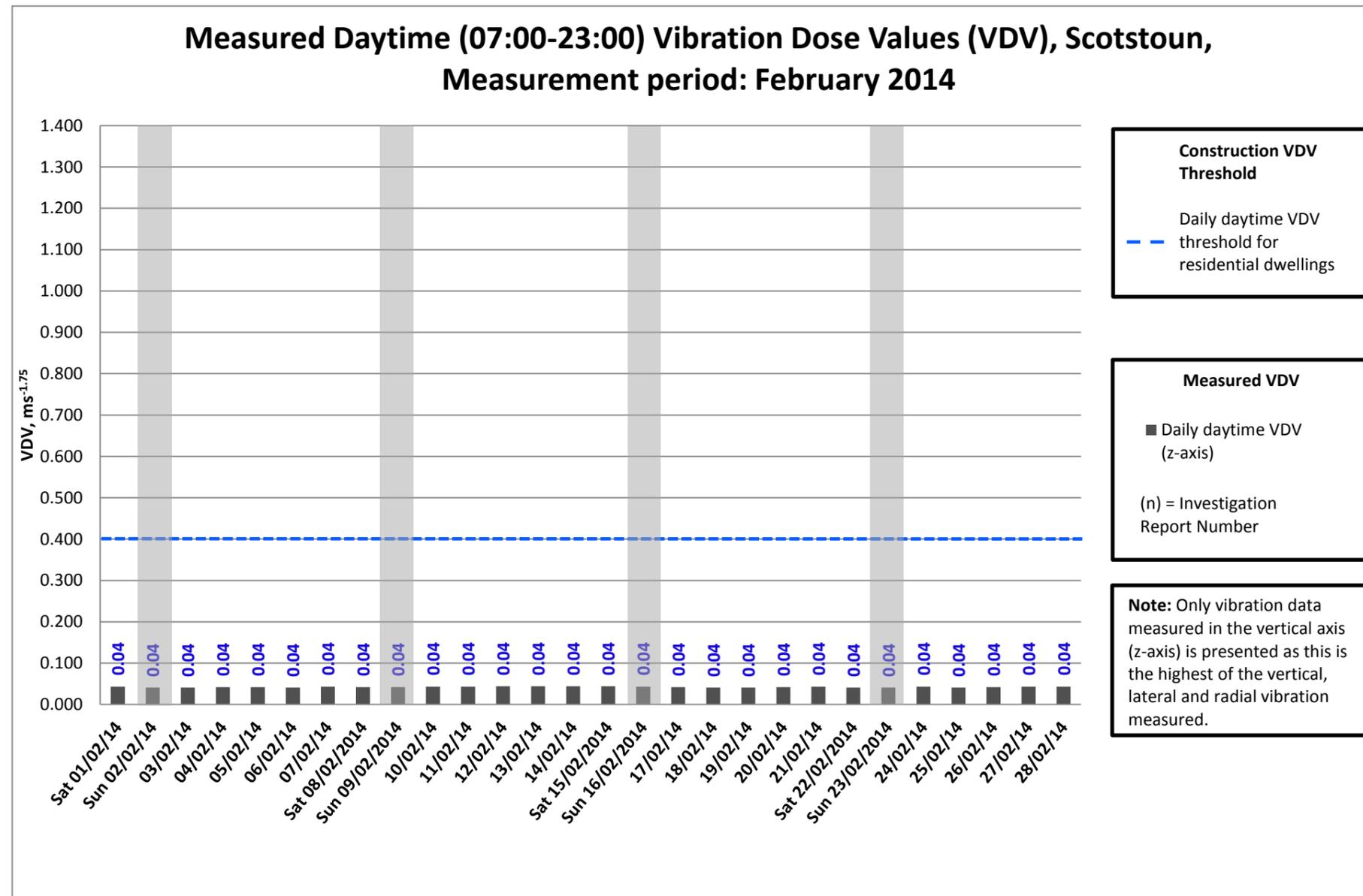
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: February 2014





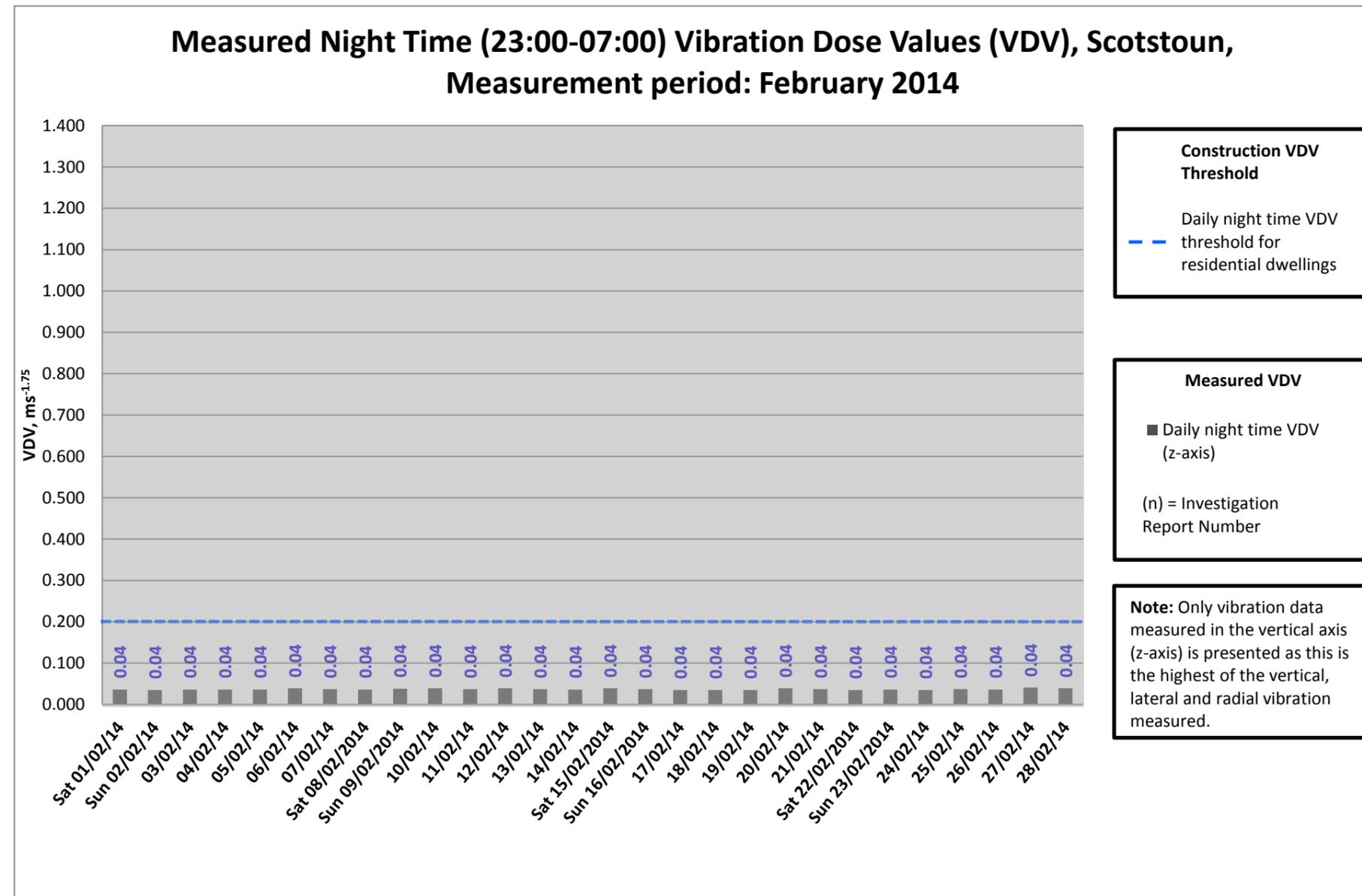
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Scotstoun monitor on Sundays.



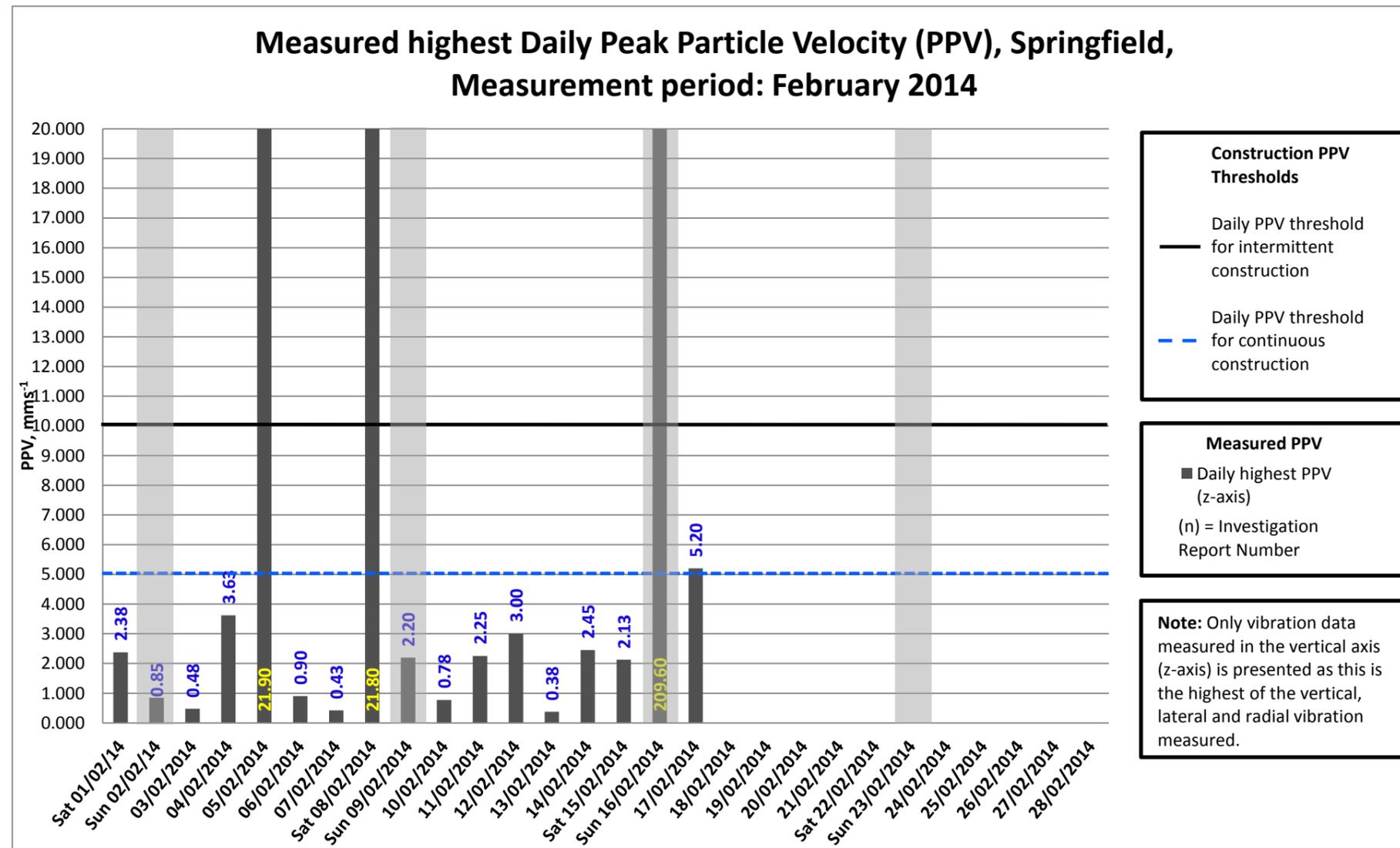
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Scotstoun monitor on Sundays.



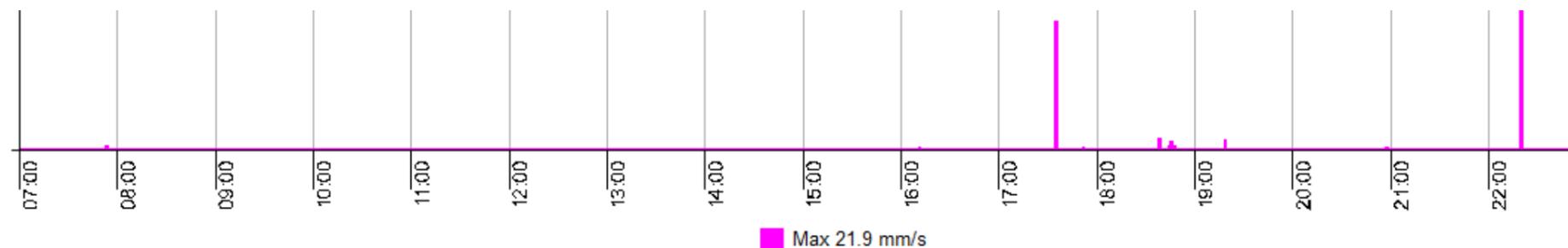
Notes:

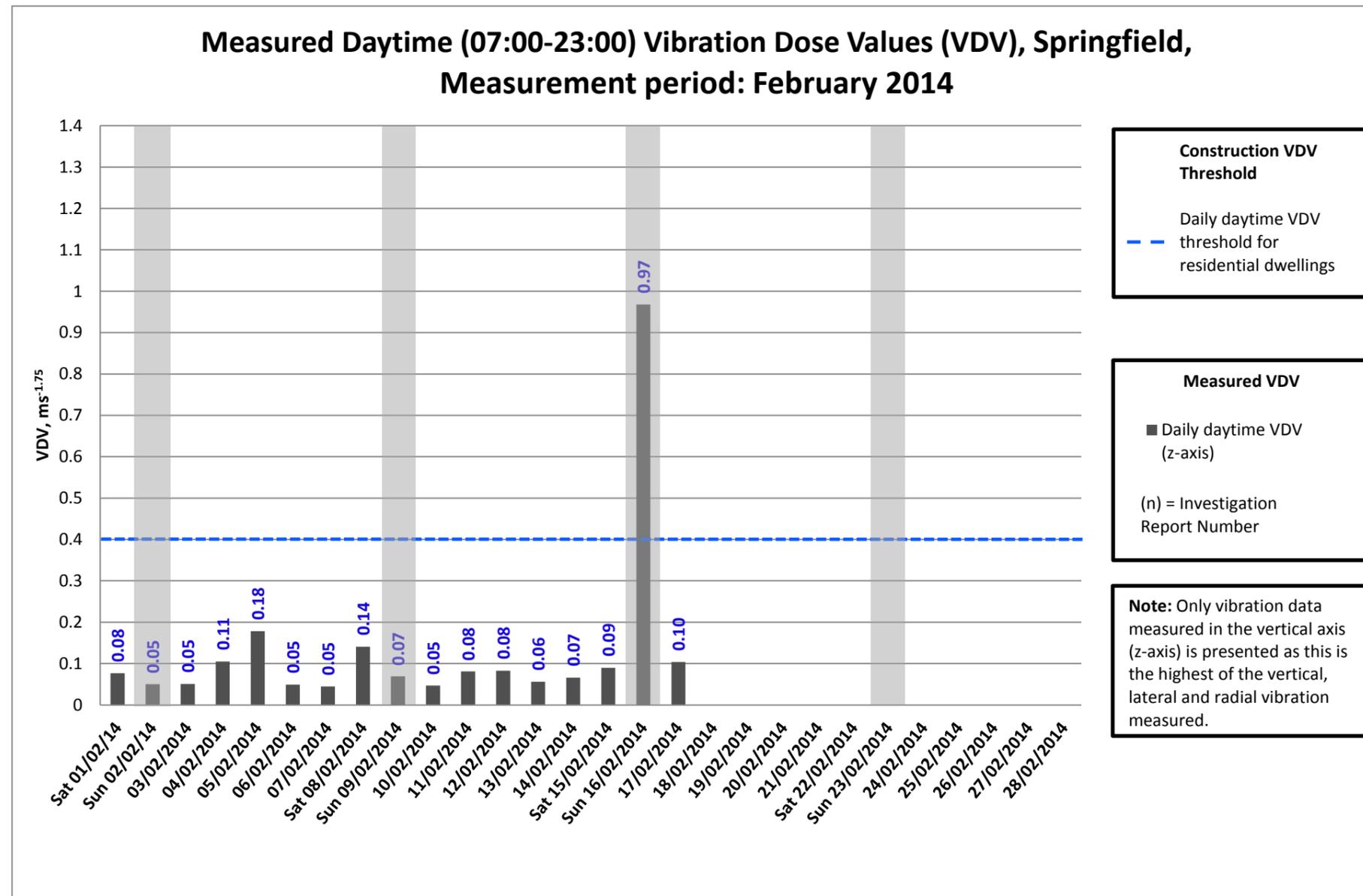
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Scotstoun vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.



Notes:

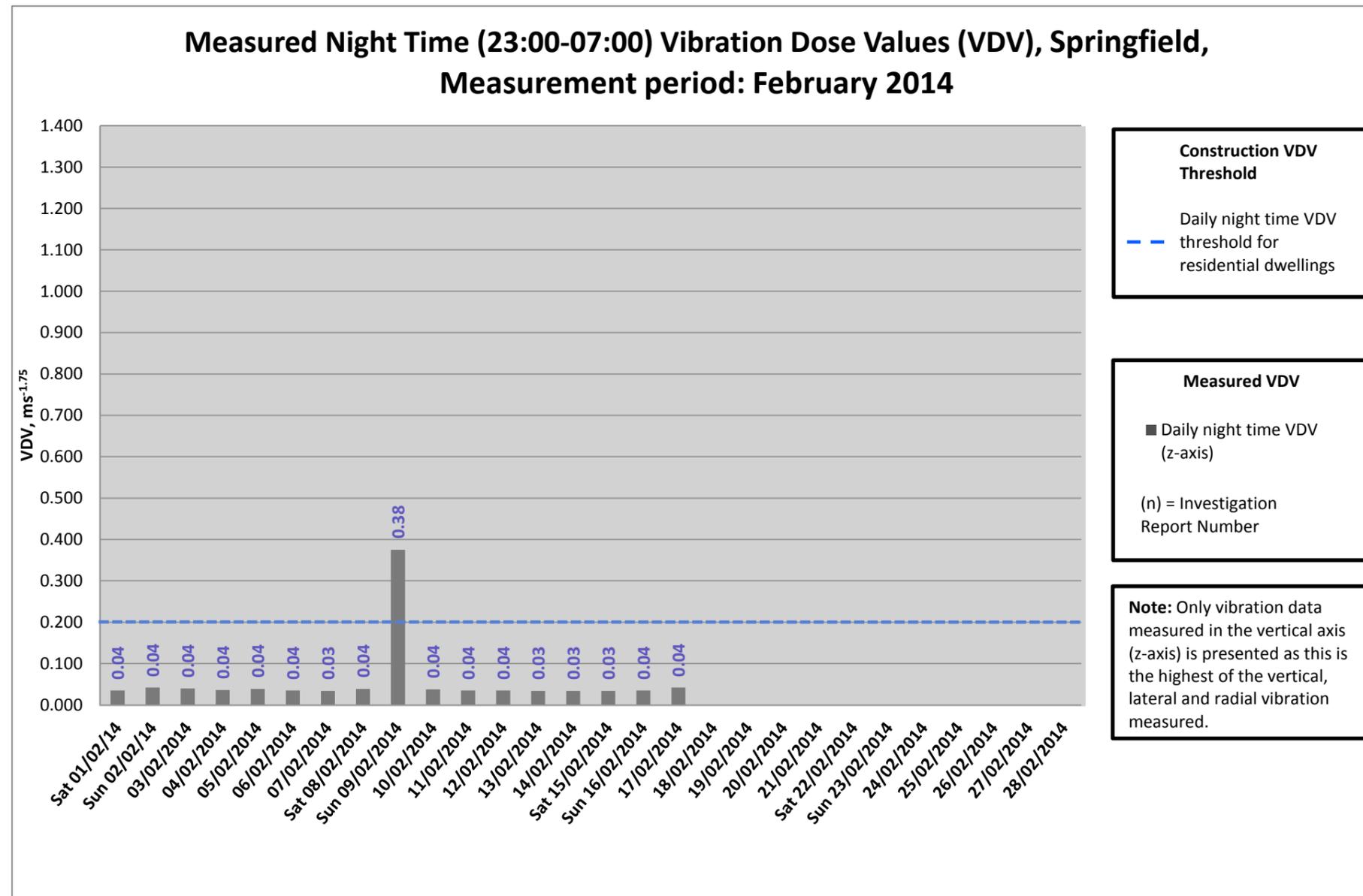
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Springfield monitor on Sundays.
- Data is missing for the period 18/02/14 – 28/02/14 as the device was removed in order for private construction activities to be conducted at the property.
- The PPV values on 05/02/14, 08/02/14 & 17/02/14 have been investigated, and have been seen to be individual, isolated events within the period (see Vibrock PPV graph below from 05/02/14), one of which is within the intermittent threshold of 10mm/s. Furthermore, it is highly unlikely that these exceedances resulted from FCBC works as the only works conducted in the vicinity of the monitor on these dates was cutting batters work at the Gyratory and A904 tie in road works, neither of which involved the use of any vibration inducing plant.





Notes:

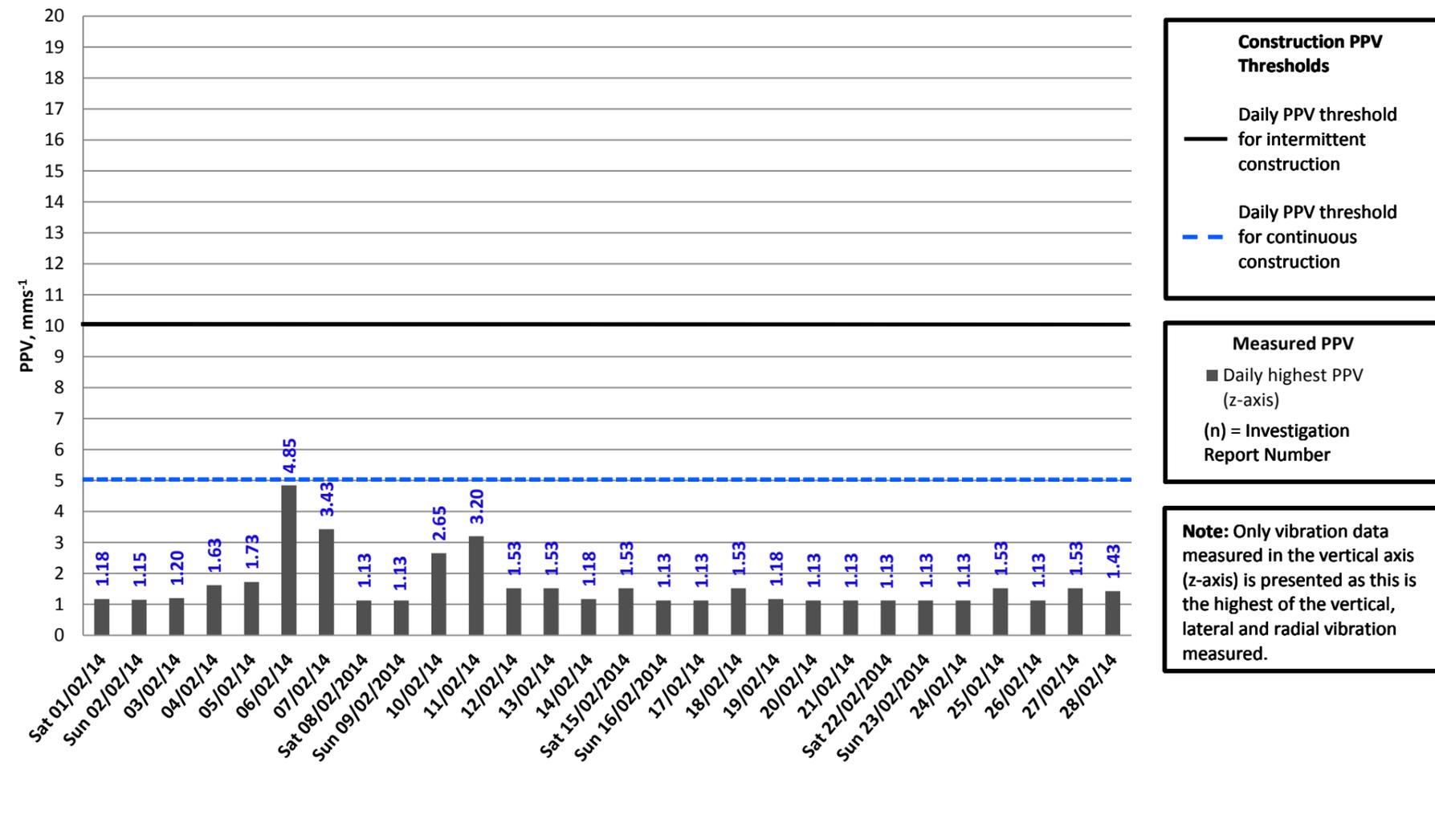
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Springfield monitor on Sundays.
- Data is missing for the period 18/02/14 – 28/02/14 as the device was removed in order for private construction activities to be conducted at the property.



Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.
- Data is missing for the period 18/02/14 – 28/02/14 as the device was removed in order for private construction activities to be conducted at the property.

Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na Grian, Measurement period: February 2014



Construction PPV Thresholds

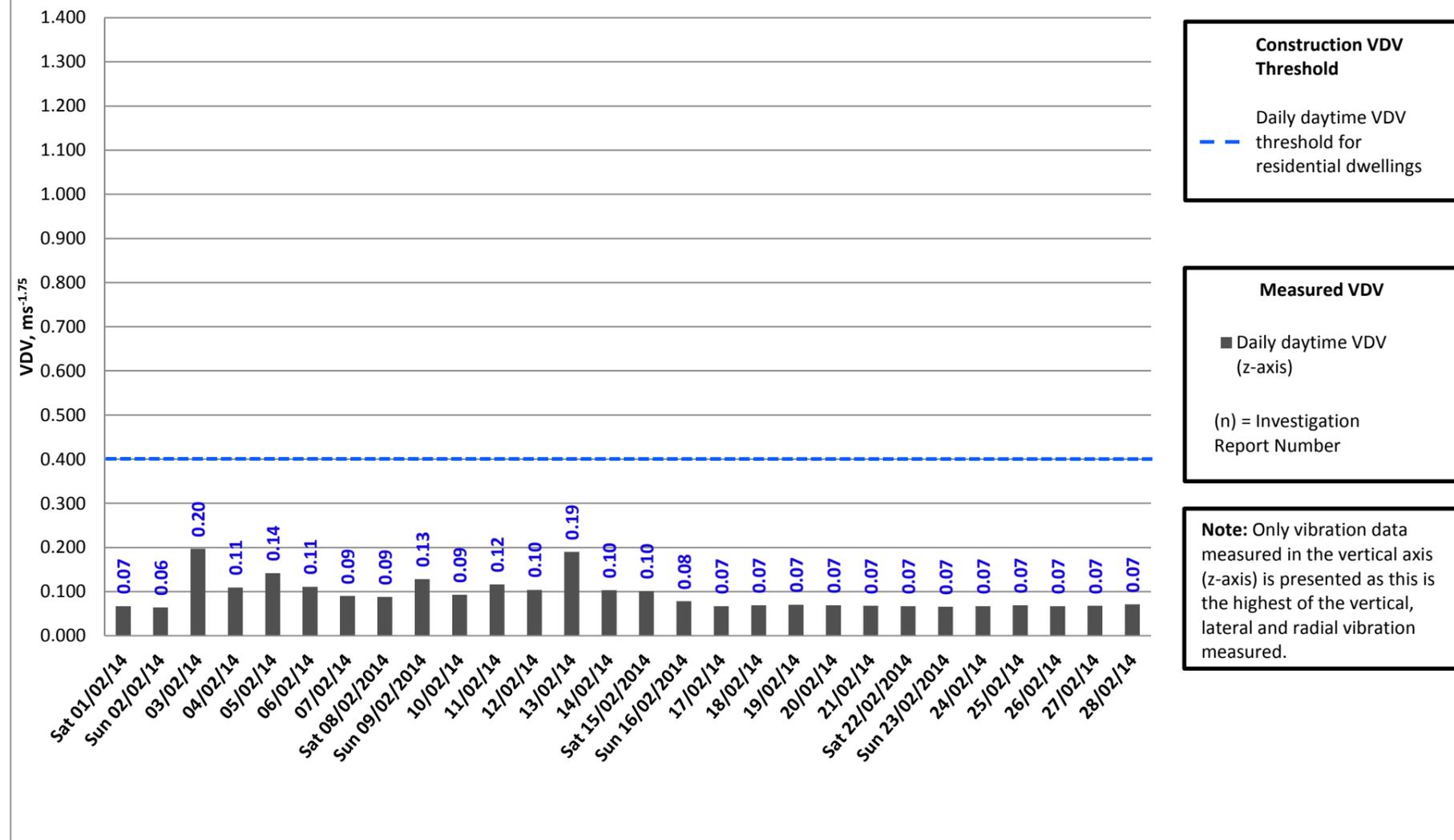
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

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: February 2014**



Construction VDV Threshold

— Daily daytime VDV threshold for residential dwellings

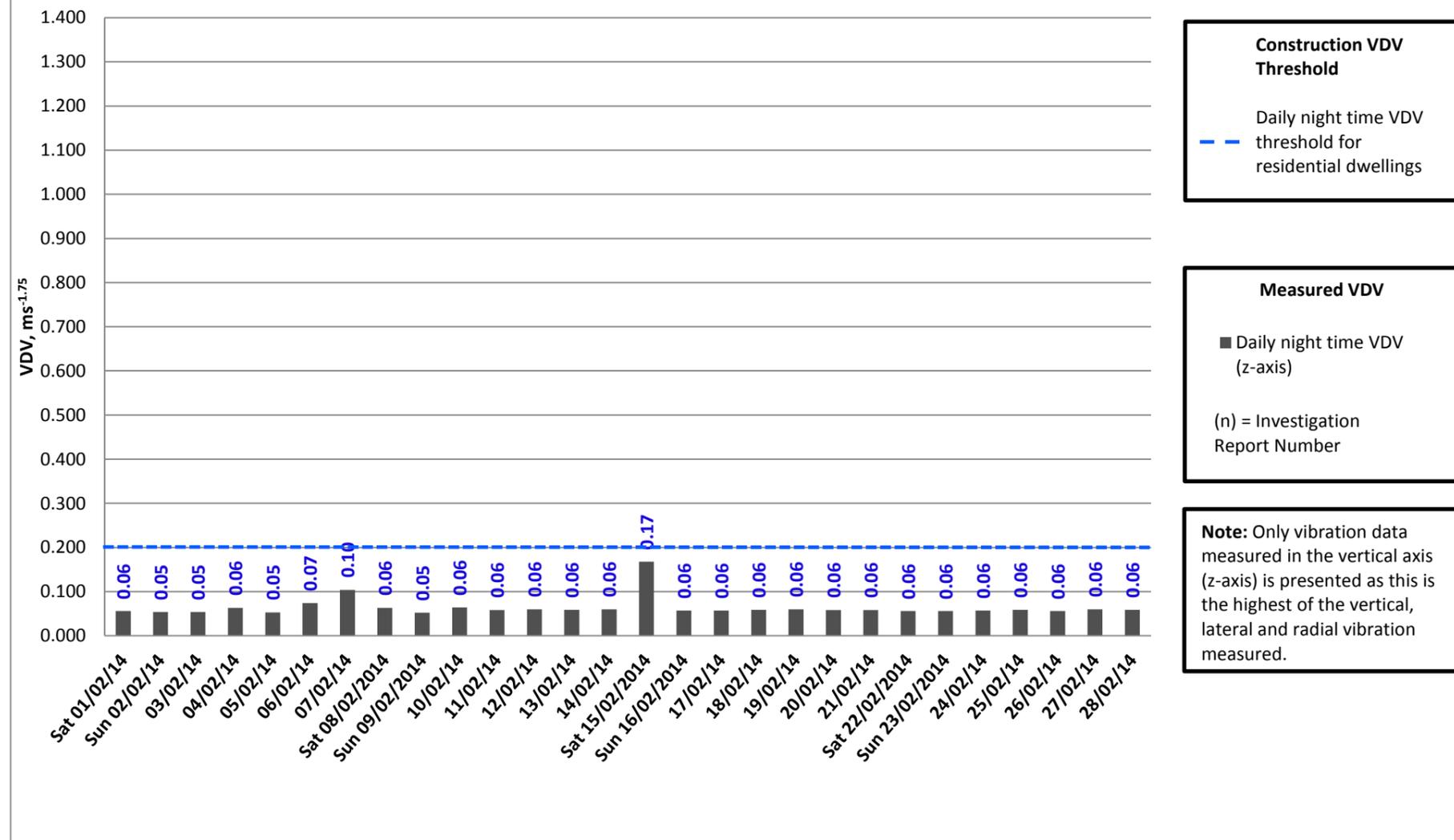
Measured VDV

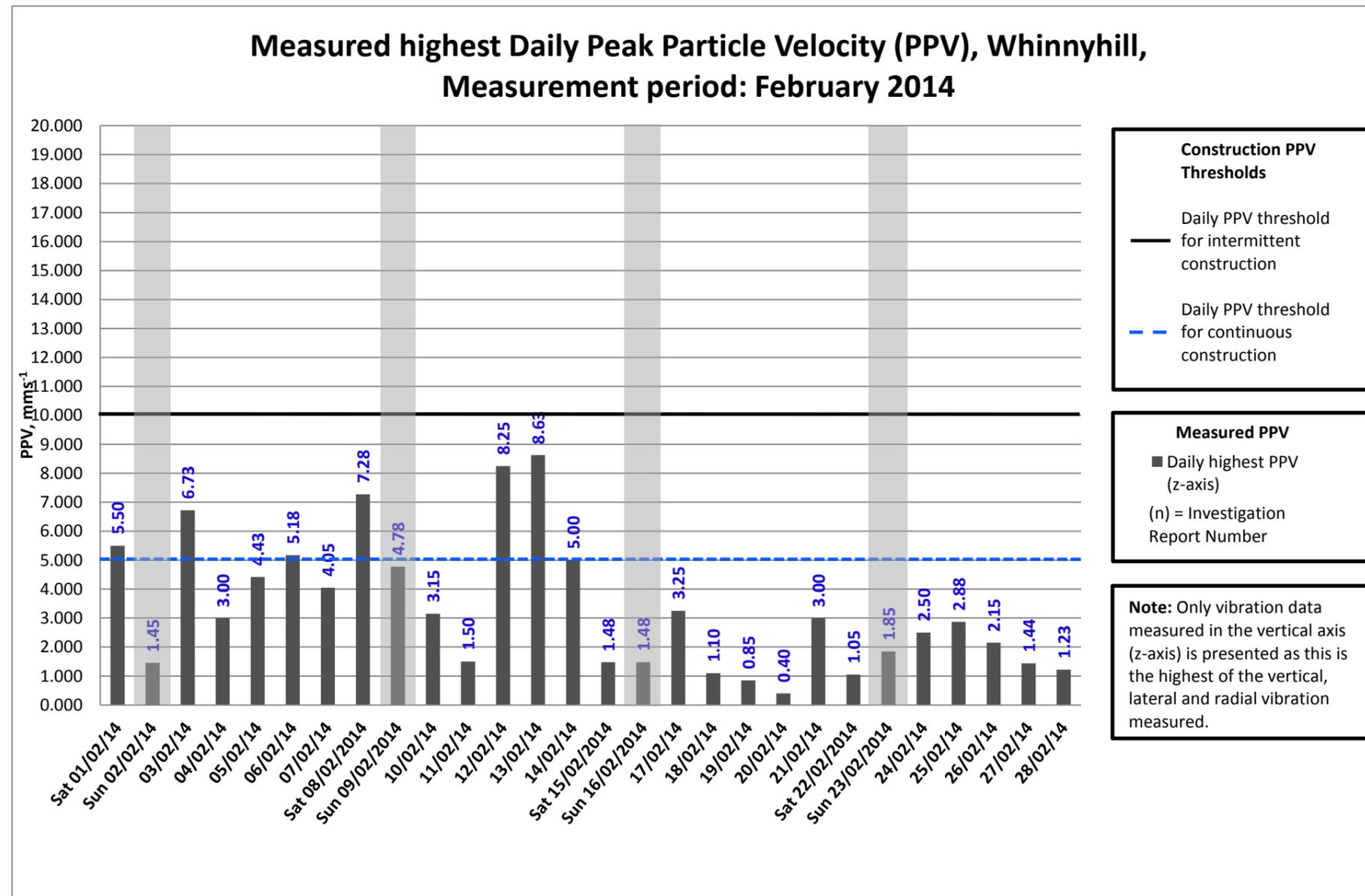
■ Daily daytime VDV (z-axis)

(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.

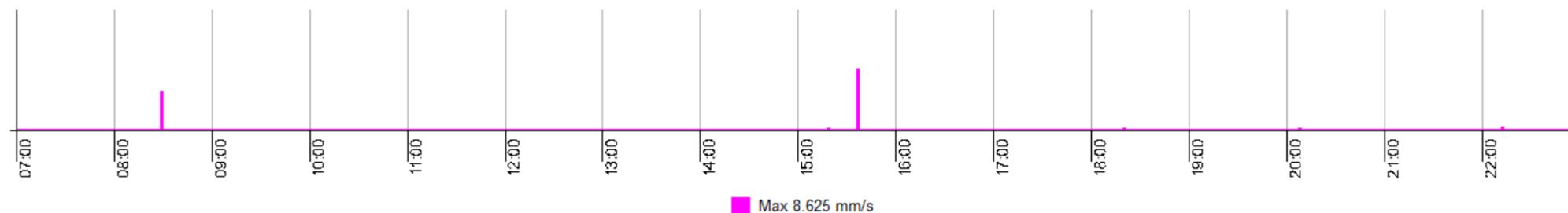
**Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Tigh-Na Grian,
 Measurement period: February 2014**

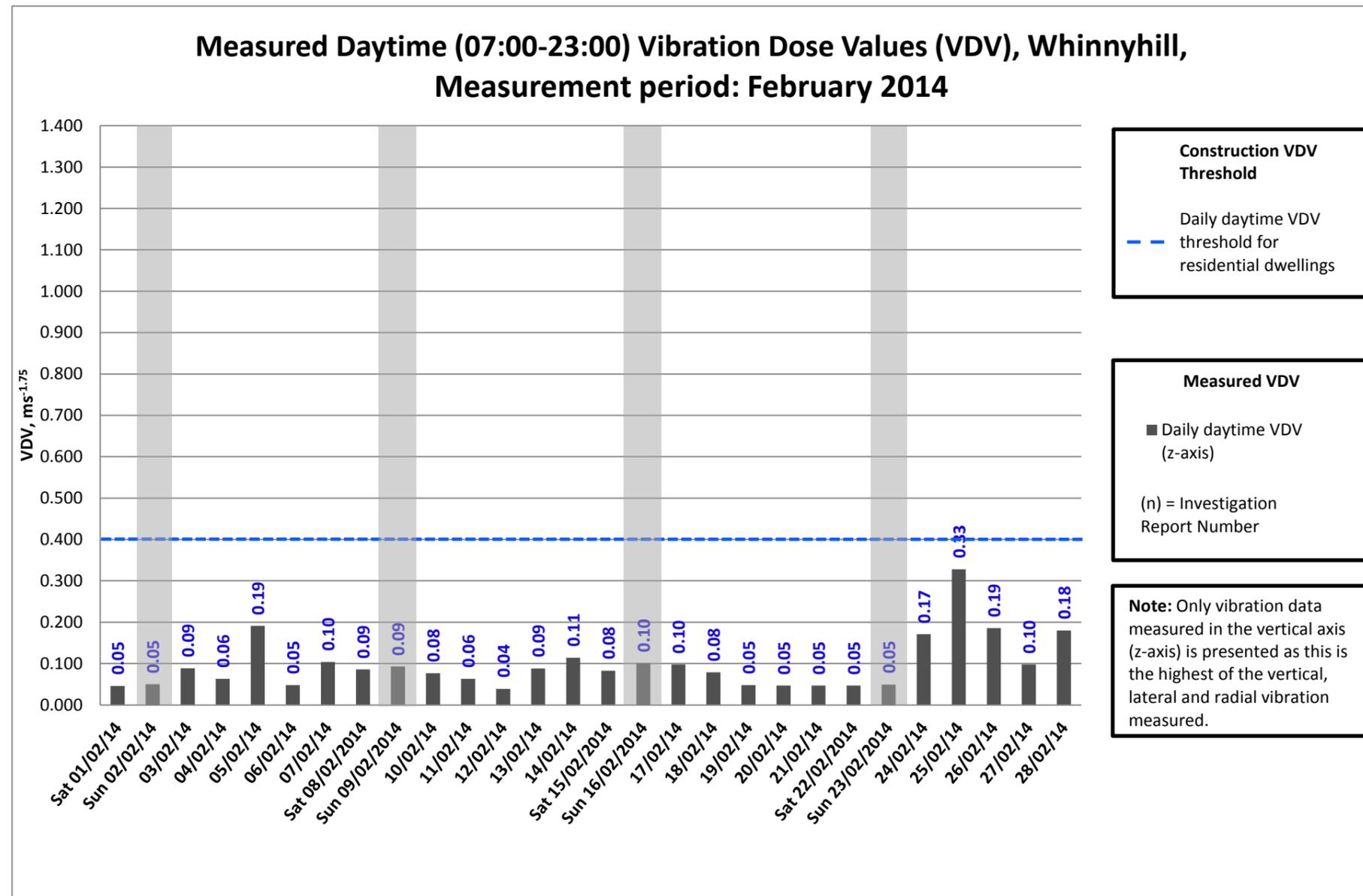




Notes:

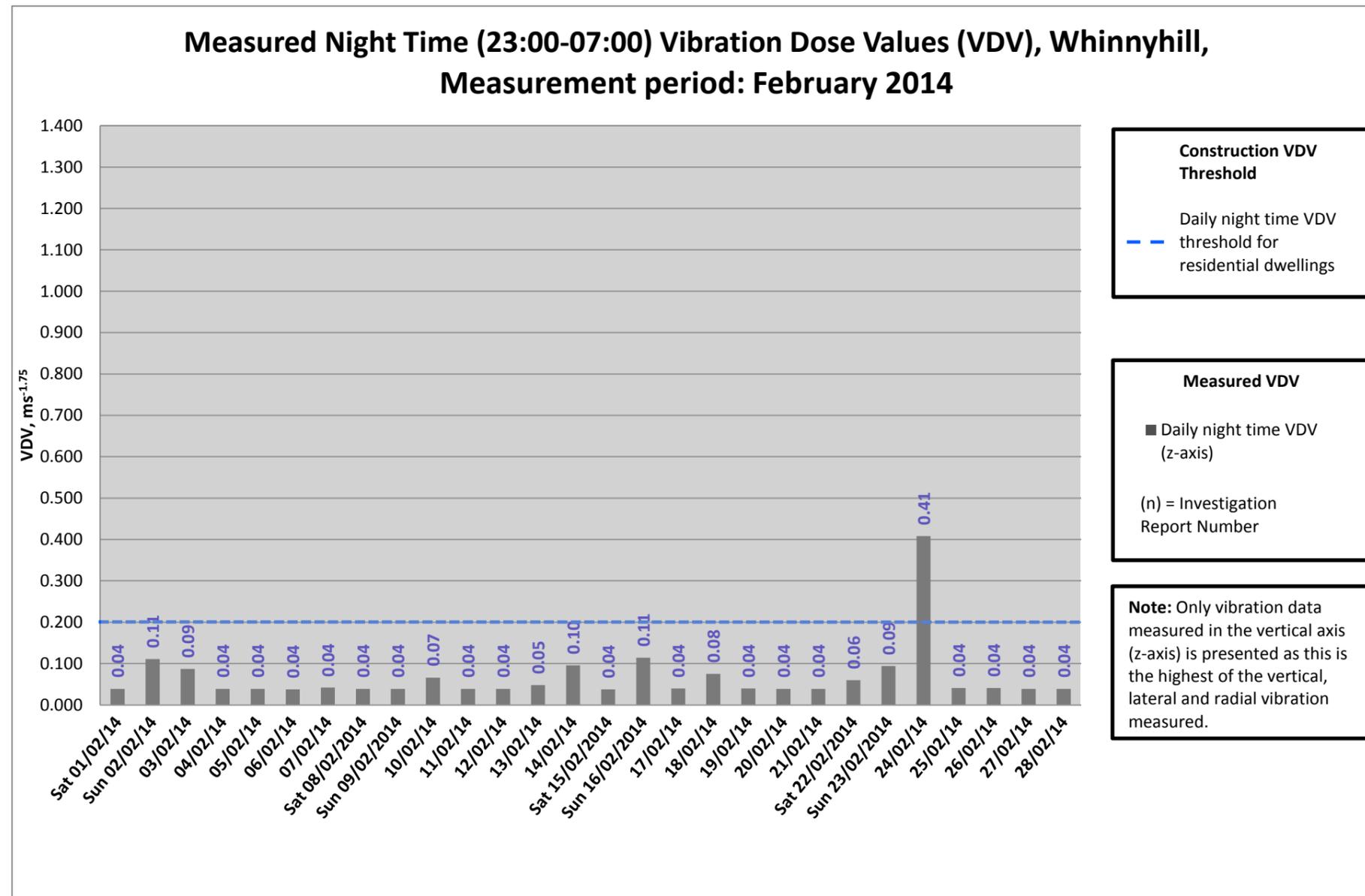
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Whinnyhill monitor on Sundays.
- The PPV values 01/02/14, 03/02/14, 06/02/14, 08/02/14, 12/02/14 & 13/02/14, and have all been investigated and have seen to be individual, isolated events within each period (see Vibrock PPV graph below from 13/02/14), all of which are within the intermittent threshold of 10mm/s.





Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted in the vicinity of the Whinnyhill monitor on Sundays.



- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Whinnyhill vibration monitor throughout the month of February 2014. This graph is included for illustrative purposes only.