



Contractor



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Project **FORTH REPLACEMENT CROSSING**

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VIBRATION MONITORING REPORT
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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 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, footsteps or 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 vibration, and damage resulting solely from well-controlled construction and demolition vibration is rare. There are many other mechanisms that 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 of FCBC construction-related vibration is highly unlikely.
- 2.5.** The number of threshold exceedances at the various vibration monitoring stations during the relevant period are shown in Table 1 below.

Table 1: Number of exceedances of thresholds set out in the CoCP

September 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 m.s ^{-1.75})	<i>Night</i> (0.2 m.s ^{-1.75})
Linn Mill	1	0	0	0
Butlaw Fisheries	2	1	1	0
Clufflat Brae	13	11	0	0
Dundas Home Farm	1	0	0	0
Echline	0	0	0	0
Inchgarvie Lodge	3	7	1	0
Scotstoun	0	0	0	0
Springfield	8	21	0	0
Tigh-Na-Grian	0	0	0	0
Whinnyhill	13	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 of the 3 axis that are 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 $\text{m.s}^{-1.75}$.
- 2.10.** The vibration dose value (VDV), a cumulative measurement of the vibration level received over an 8-hour (night time) or 16-hour (day time) 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 suggested 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 at all locations. These occurred due to calibration of the vibration monitors.



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.



APPENDIX A – MONITORING LOCATIONS & VIBRATION ASSESSMENTS FROM RELEVANT PCNVs

Table 2: Monitoring Locations

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During September 2016
M1	Whinny Hill	Network	<ul style="list-style-type: none"> • Earthworks/Fill placement • Hope Street roadworks • FT03 & FT04 works • FT19 Works • FT09/10 works • Main carriageway Roadworks • Rock breaking / crushing • Gantry installation
M3	Tigh-Na-Grian	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works • North Tower rebar, formwork, concreting works deck section lifts and stay cable installation works • AVN Rebar and concrete works
M7	Butlaw Fisheries	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation works • South Tower rebar, formwork, concreting works deck section lifts and stay cable installation works • Pier S2 works • AVS rebar & concrete deck works
M10	Inchgarvie Lodge	Crossing	<ul style="list-style-type: none"> • Central Tower rebar, formwork, concreting works deck section lifts and stay cable installation • South Tower rebar, formwork, concreting works deck section lifts and stay cable installation • Pier S2 works • AVS rebar & concrete deck works • South Abutment works • Main carriageway roadworks • Excavation of SUDS detention basin • Gantry installation
M11	Linn Mill	Network (close proximity to Crossing)	<ul style="list-style-type: none"> • AVS rebar & concrete deck works • Main carriageway roadworks • South Abutment works • Excavation of SUDS detention basin • Gantry installation
M13	Clufflat Brae	Crossing	<ul style="list-style-type: none"> • AVS rebar & concrete deck works • Main carriageway roadworks • South Abutment works • Gantry installation
M14	Springfield	Network	<ul style="list-style-type: none"> • AVS rebar & concrete deck works • Main carriageway roadworks • South abutment works • Gantry installation
M15	Echline	Network	<ul style="list-style-type: none"> • AVS rebar & concrete deck works • South abutment works • Main carriageway roadworks • Gantry installation • Access road works



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M16	Scotstoun	Network	<ul style="list-style-type: none"> • B800 North road works • ESQ11 works • Mainline roadworks • Gantry installation
M17	Dundas Home Farm	Network	<ul style="list-style-type: none"> • Utility works • B800 North roadworks • Mainline roadworks • Gantry installation

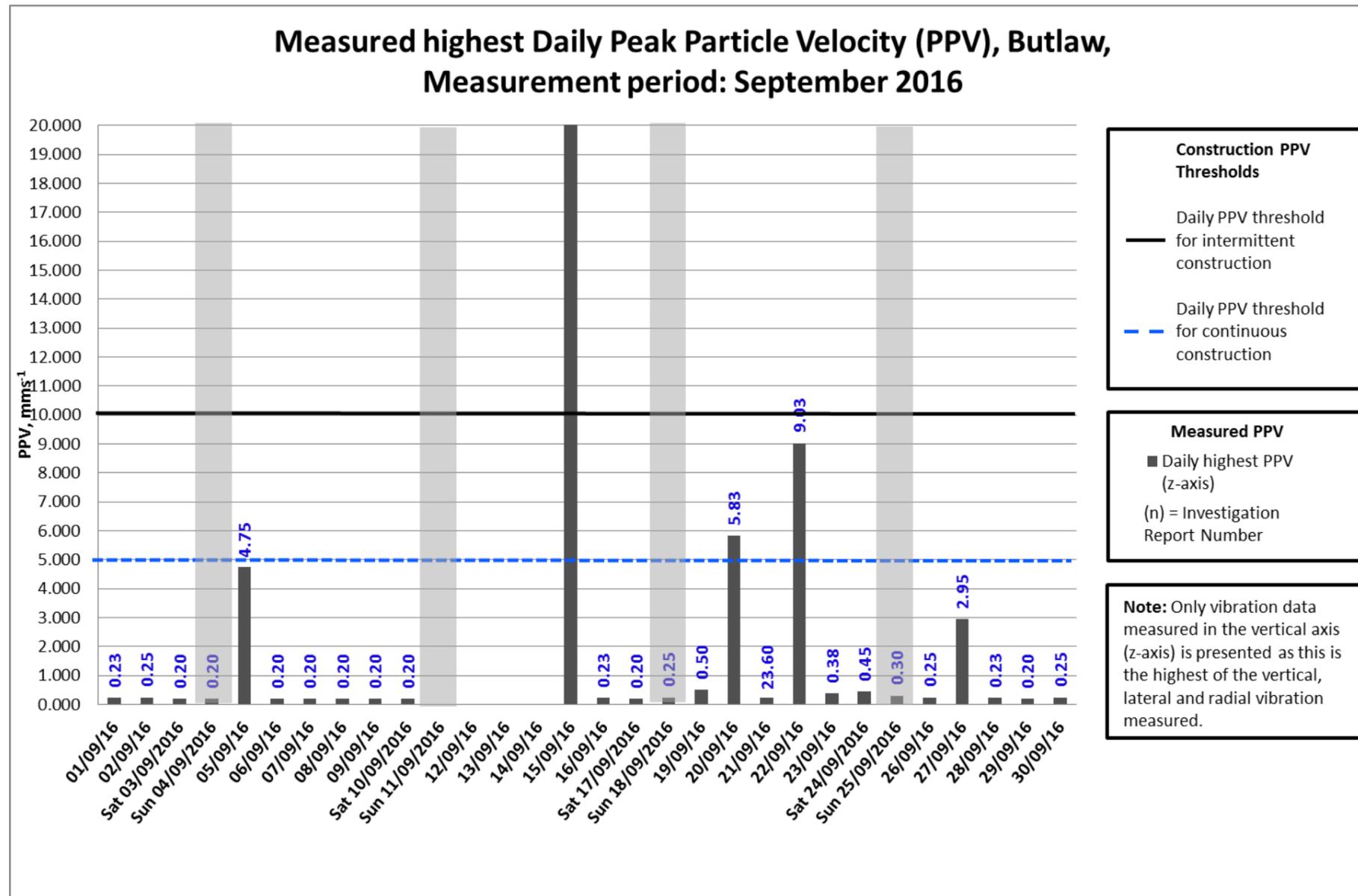
Table 3: PCNV Predicted PPV & VDV Levels

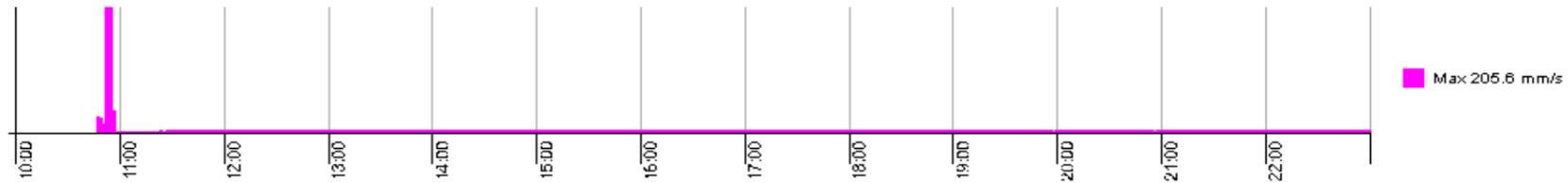
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	130	160	Roller/Whacker	0.44	0.23
Clufflat Brae	40	90	Roller/Whacker	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	Roller/Whacker	0.383	0.04

Notes on Table 3

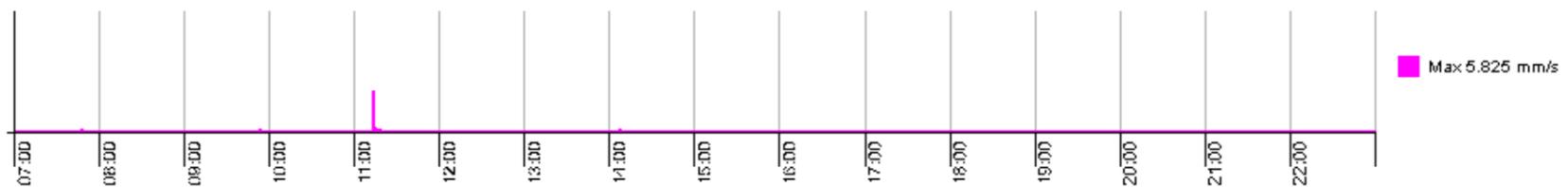
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 5m, 0.4mm/s @ 20m, 0.1mm/s @ 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

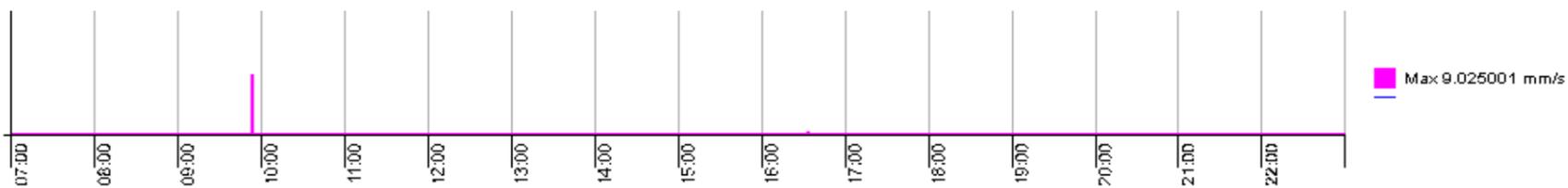




Exceedance on the 15th September has been investigated and found to be caused by the environmental department carrying out maintenance on the vibration monitor.



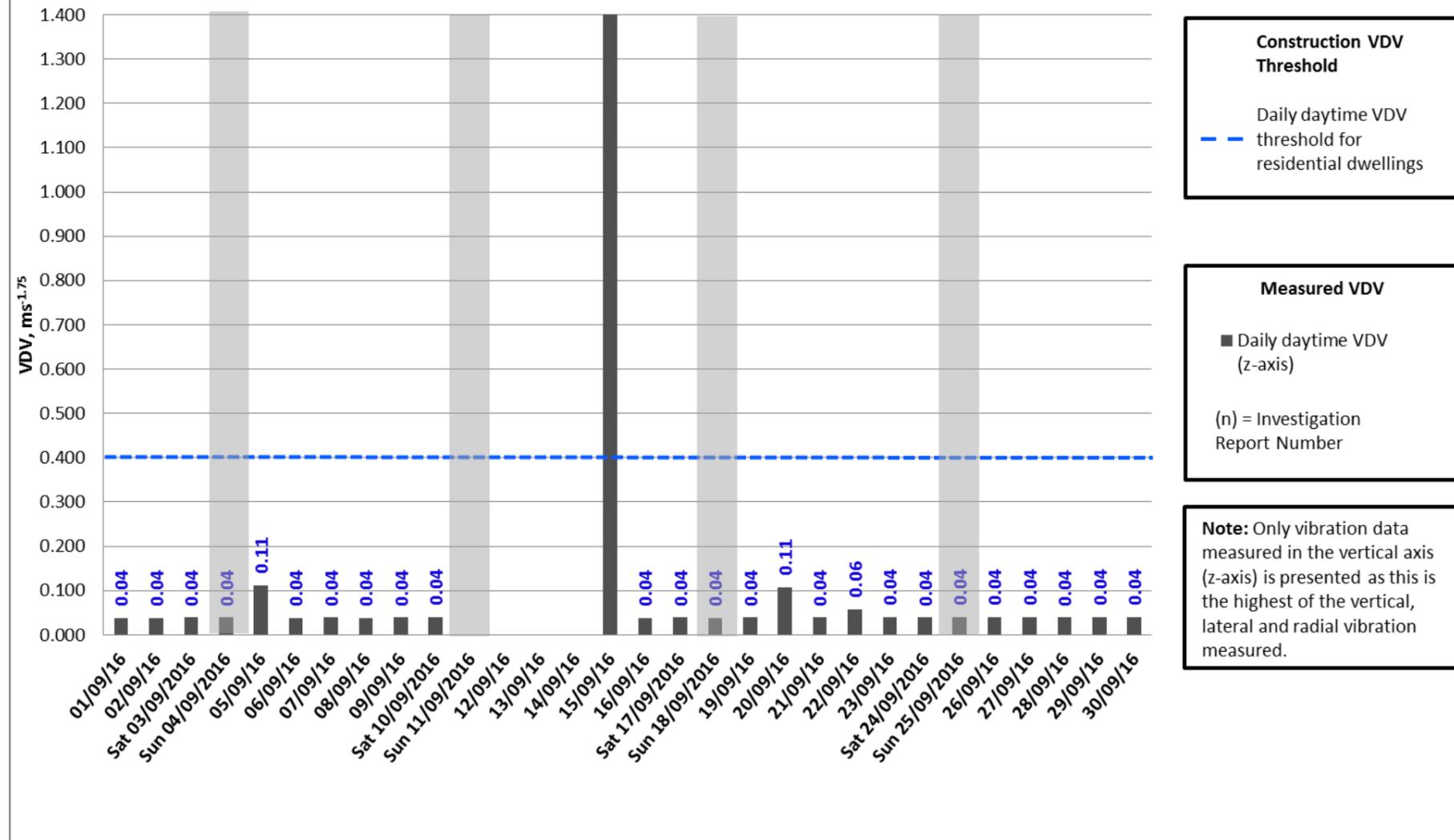
Exceedance on the 20th September has been investigated and found to be caused by the resident cutting the grass where the vibration is situated at approximately 11:15.



Exceedance on the 22nd September has been investigated and could not be determined.

Data missing on the 11th-14th September was caused by electrical issue with monitor.

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



Construction VDV Threshold

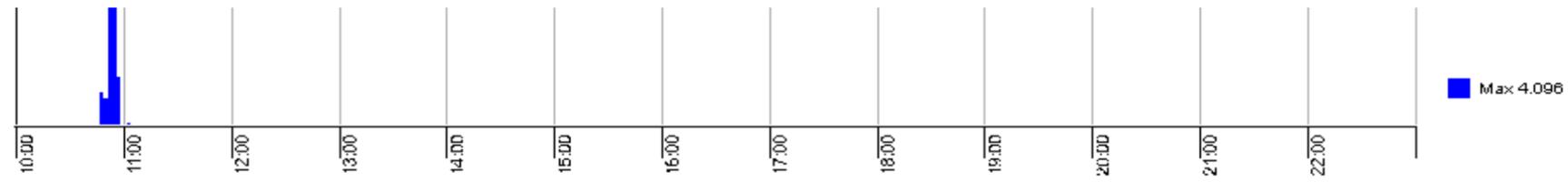
Daily daytime VDV threshold for residential dwellings

Measured VDV

■ Daily daytime VDV (z-axis)

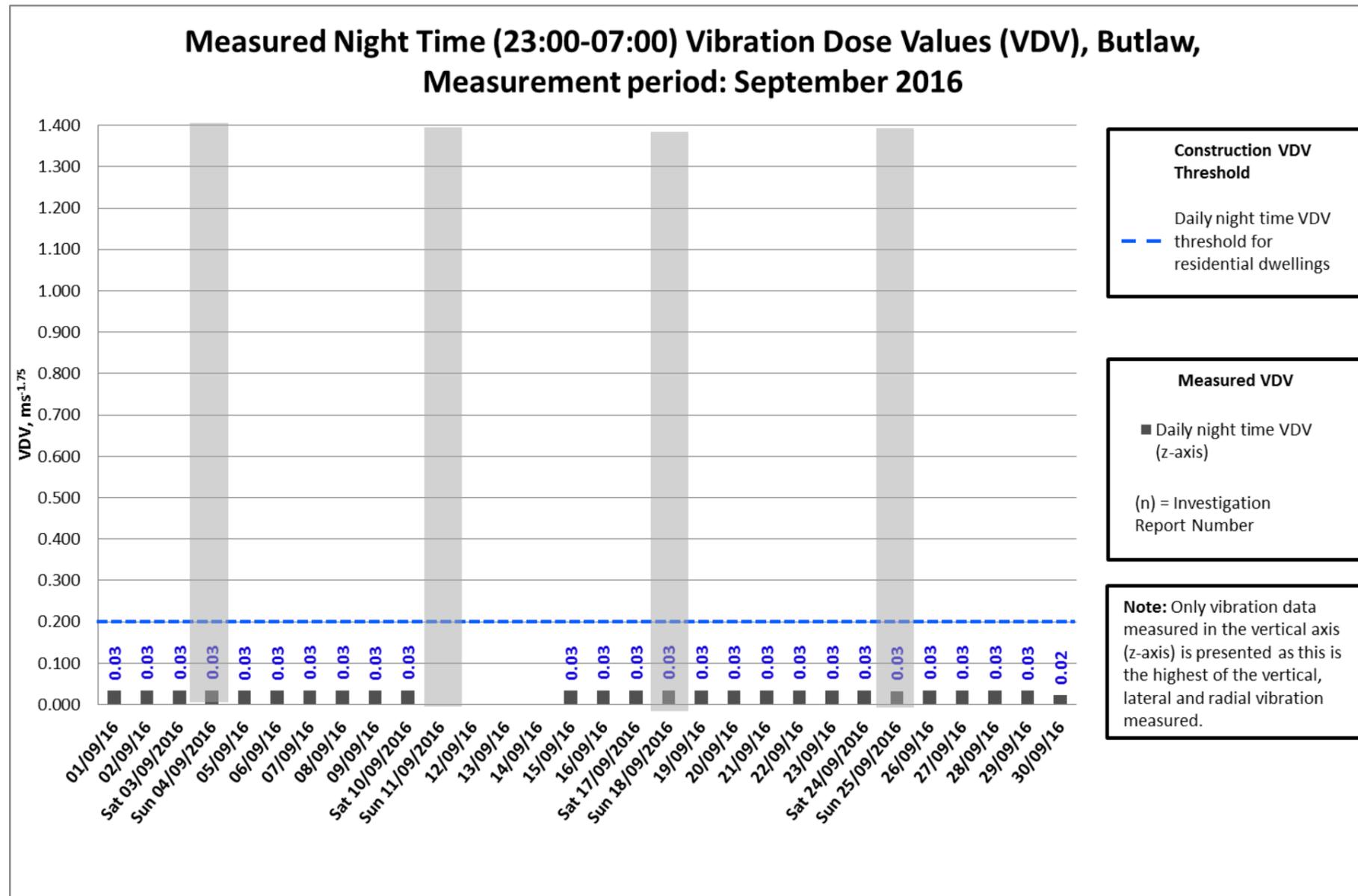
(n) = Investigation Report Number

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.



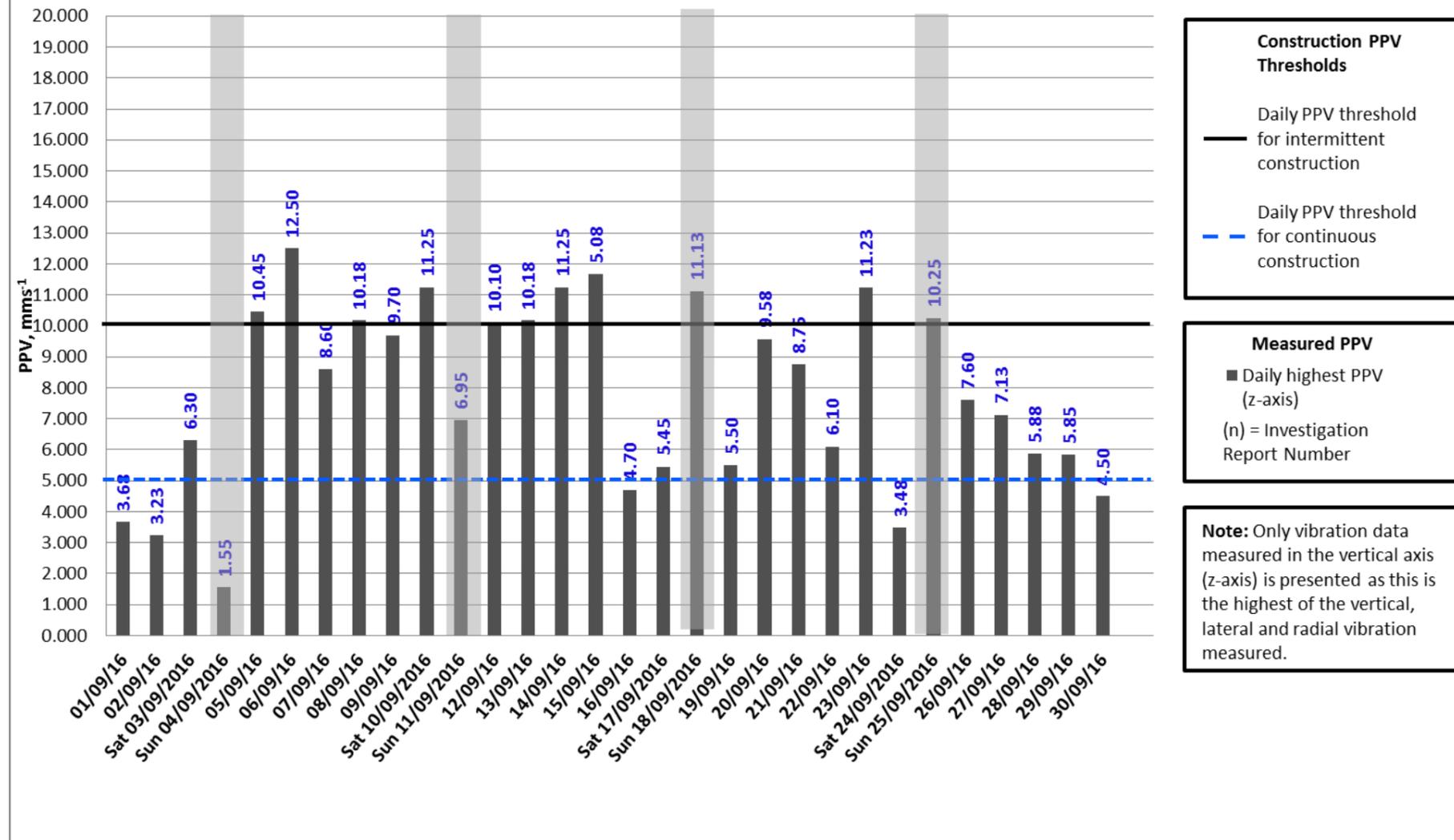
Exceedance on the 15th September has been investigated and found to be caused by the environmental department carrying out maintenance on the vibration monitor.

Data missing on the 11th-14th September was caused by electrical issue with monitor.



Data missing on the 11th-14th September was caused by electrical issue with monitor.

Measured highest Daily Peak Particle Velocity (PPV), Clufflat Brae, Measurement period: September 2016



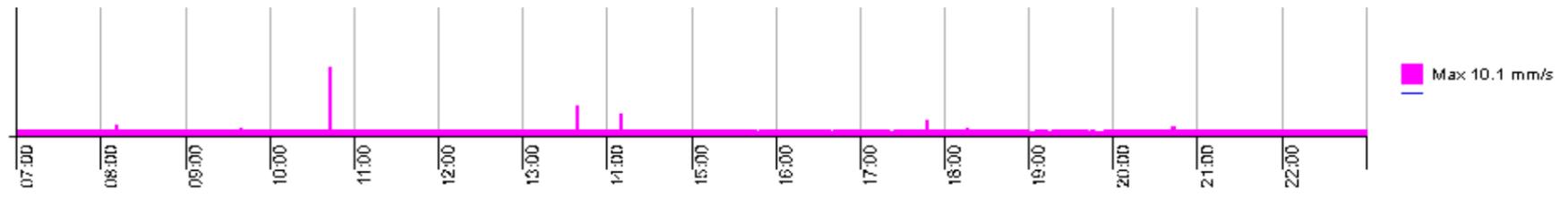
Construction PPV Thresholds

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

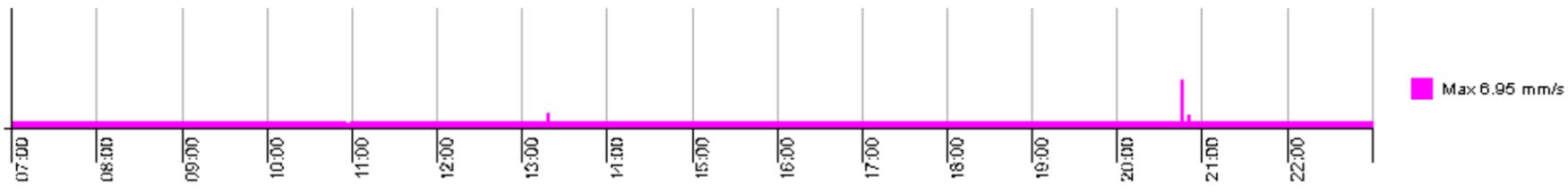
Measured PPV

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

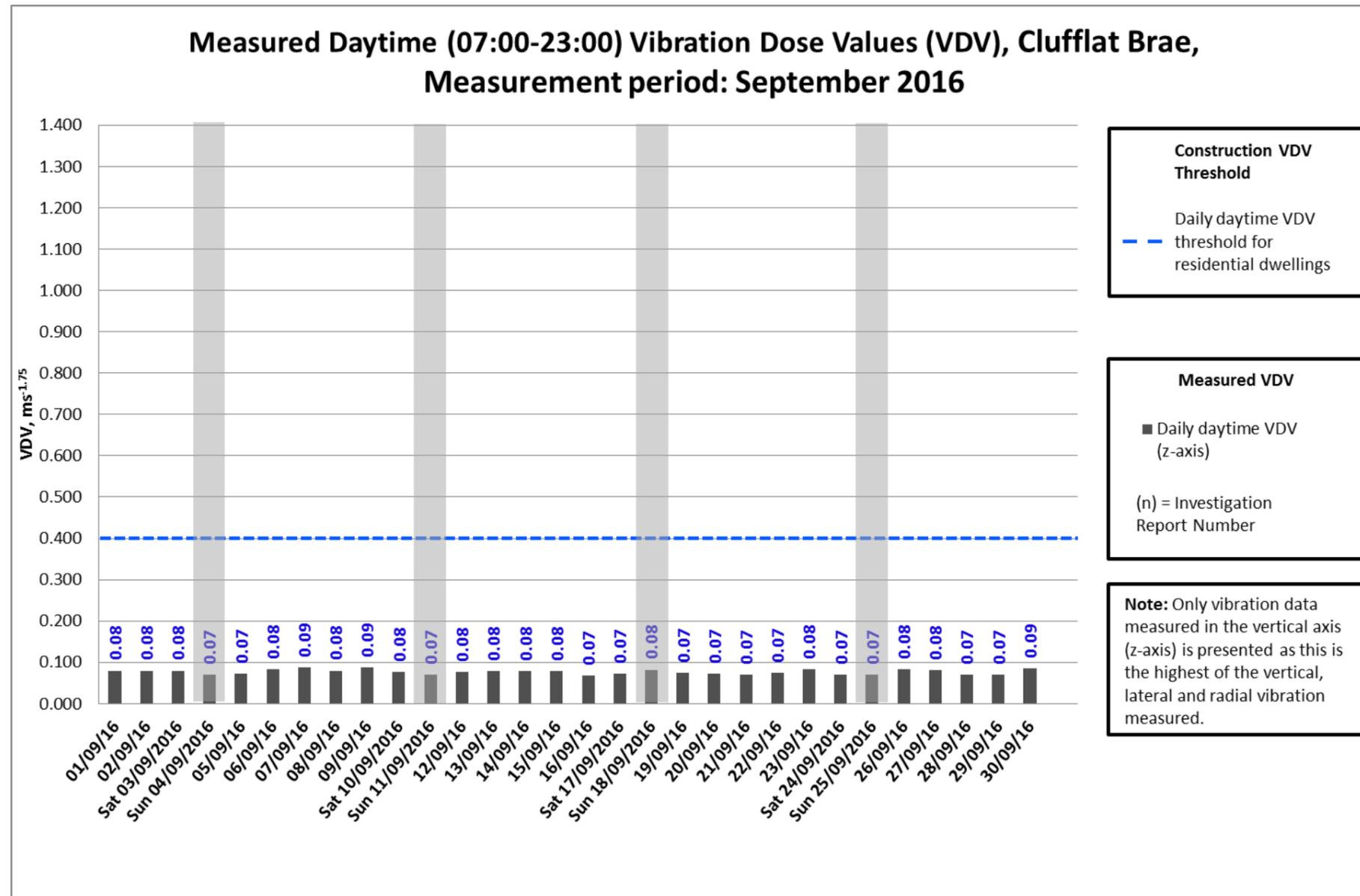
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.



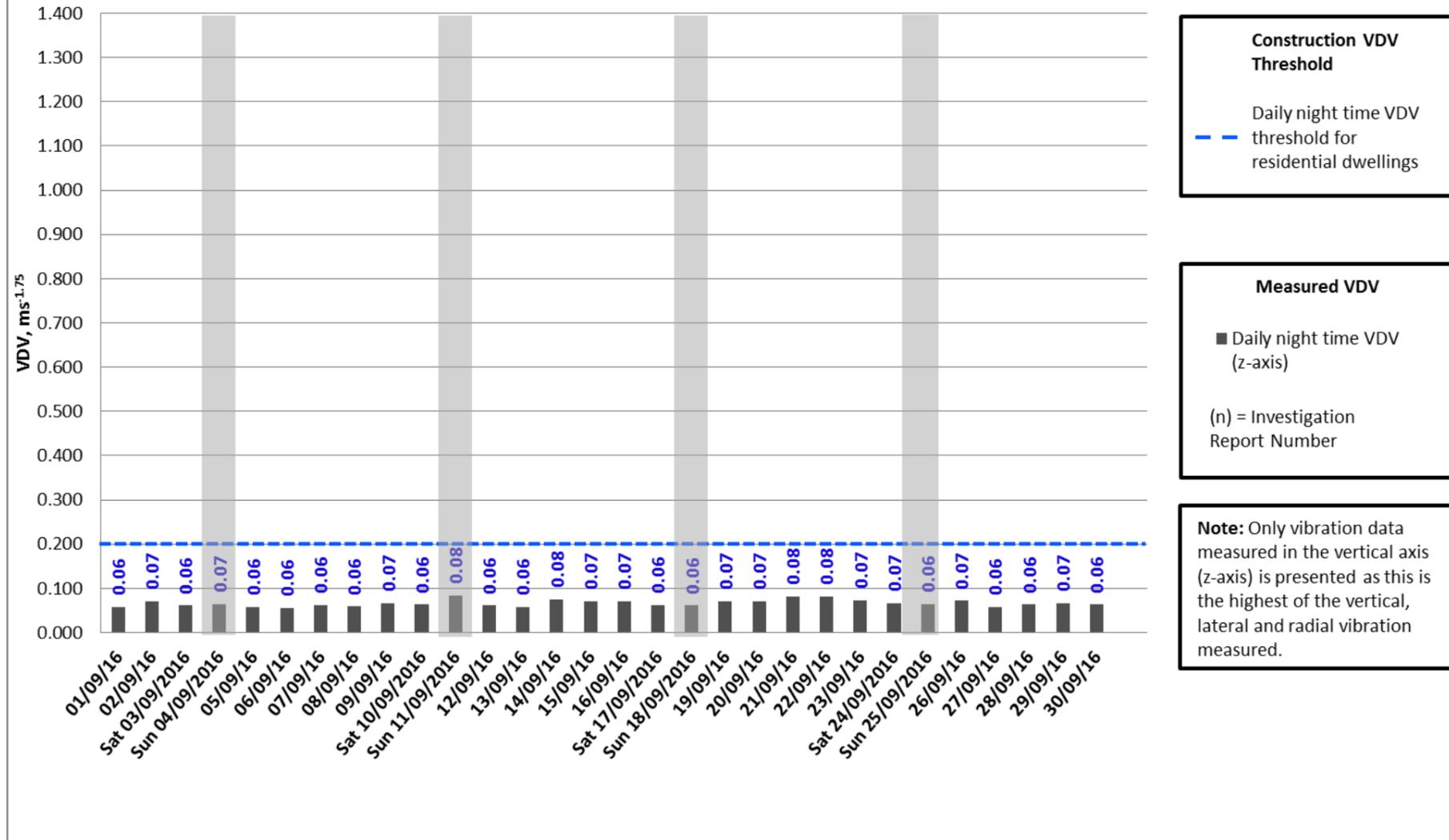
Exceedances on the 3rd, 5th, 6th, 7th, 8th, 10th, 12th, 13th, 15th, 17th, 23rd, 25th, 28th and 29th of September have been investigated and found to be caused by individual isolated events (graph above from the 12/09/2016). With the monitor being located in a public amenity area there is a likelihood that the exceedances seen above might have been caused by pedestrians using this area. However it is worth noting that during this period, there have been excavation works ongoing at the Suds pond east of the south abutment, approximately 30m away. Due to this and the fact that there isn't any supporting evidence to state otherwise, these exceedances might also have been caused by the Suds works.



Exceedances on the 9th, 11th, 14th, 18th, 19th, 20th, 21st, 22nd, 26th and 27th of September 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 events (graph above from the 11/09/2016).



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Clufflat Brae, Measurement period: September 2016



Construction VDV Threshold

Daily night time VDV threshold for residential dwellings

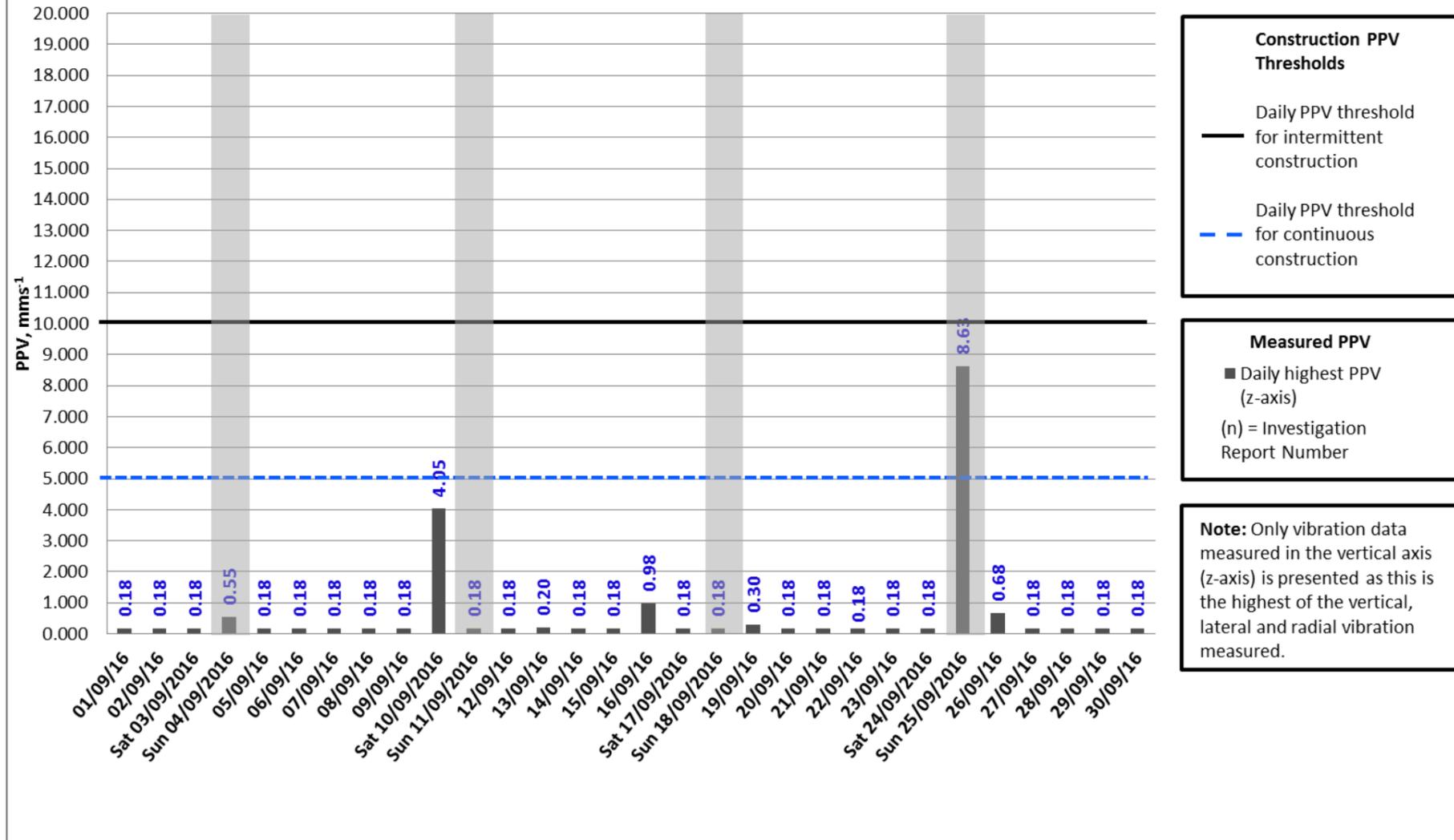
Measured VDV

■ 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.

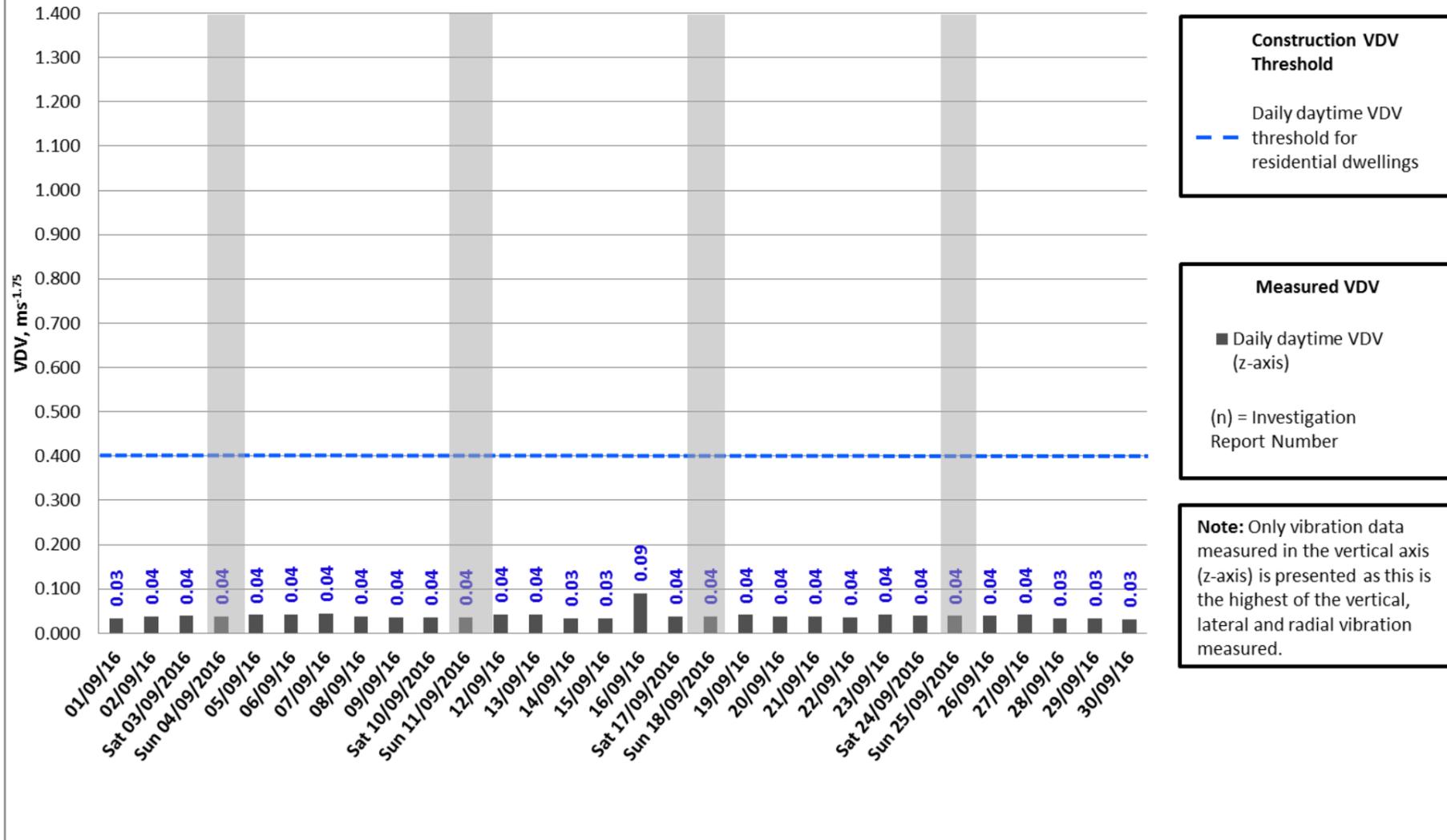
Measured highest Daily Peak Particle Velocity (PPV), Dundas Home Farm, Measurement period: September 2016





Exceedance on the 25th September has been investigated and found to be caused by an isolated event that is unlikely to have been a construction related activity.

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



Construction VDV Threshold

Daily daytime VDV threshold for residential dwellings

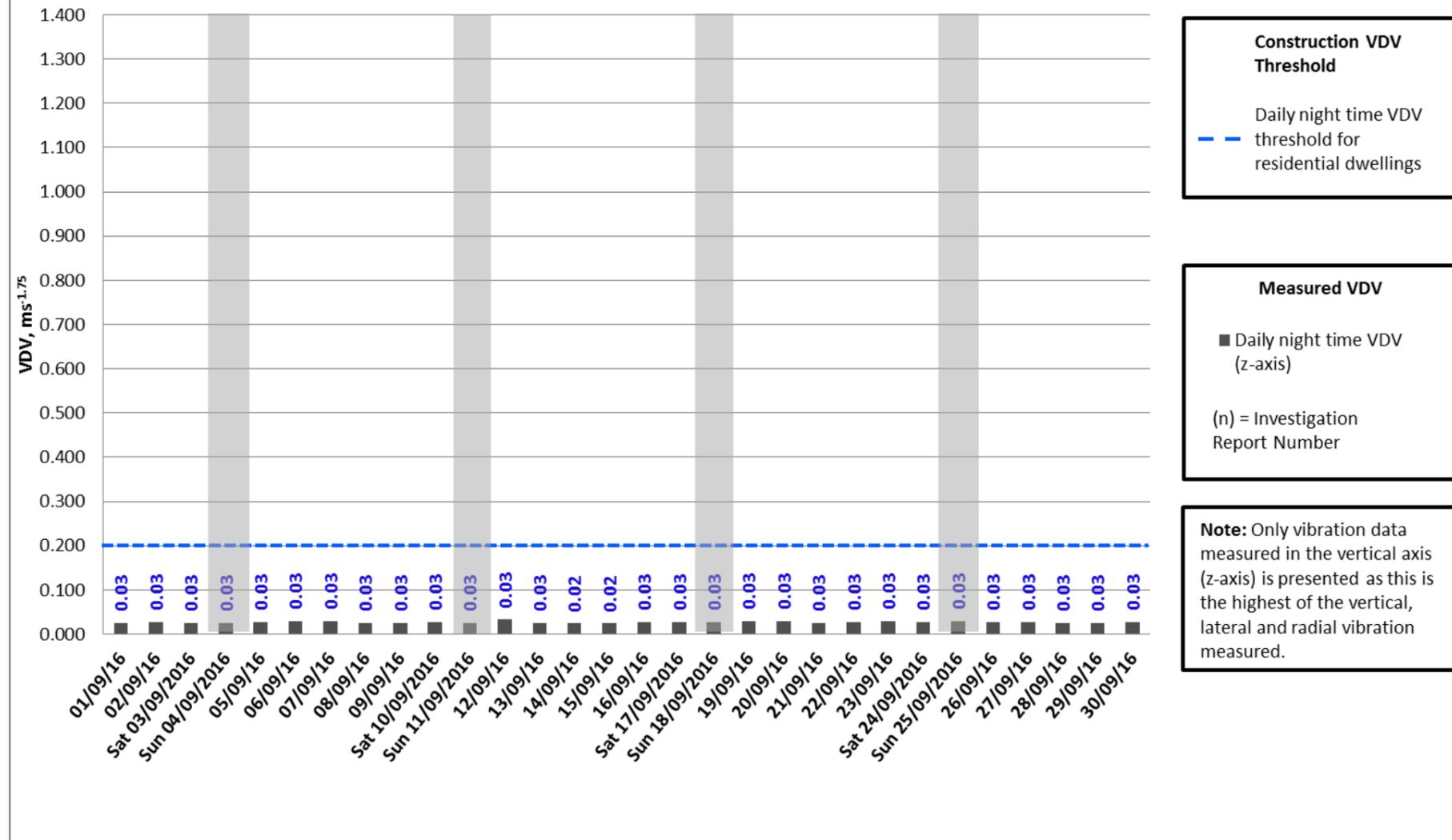
Measured VDV

■ 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: September 2016



Construction VDV Threshold

Daily night time VDV threshold for residential dwellings

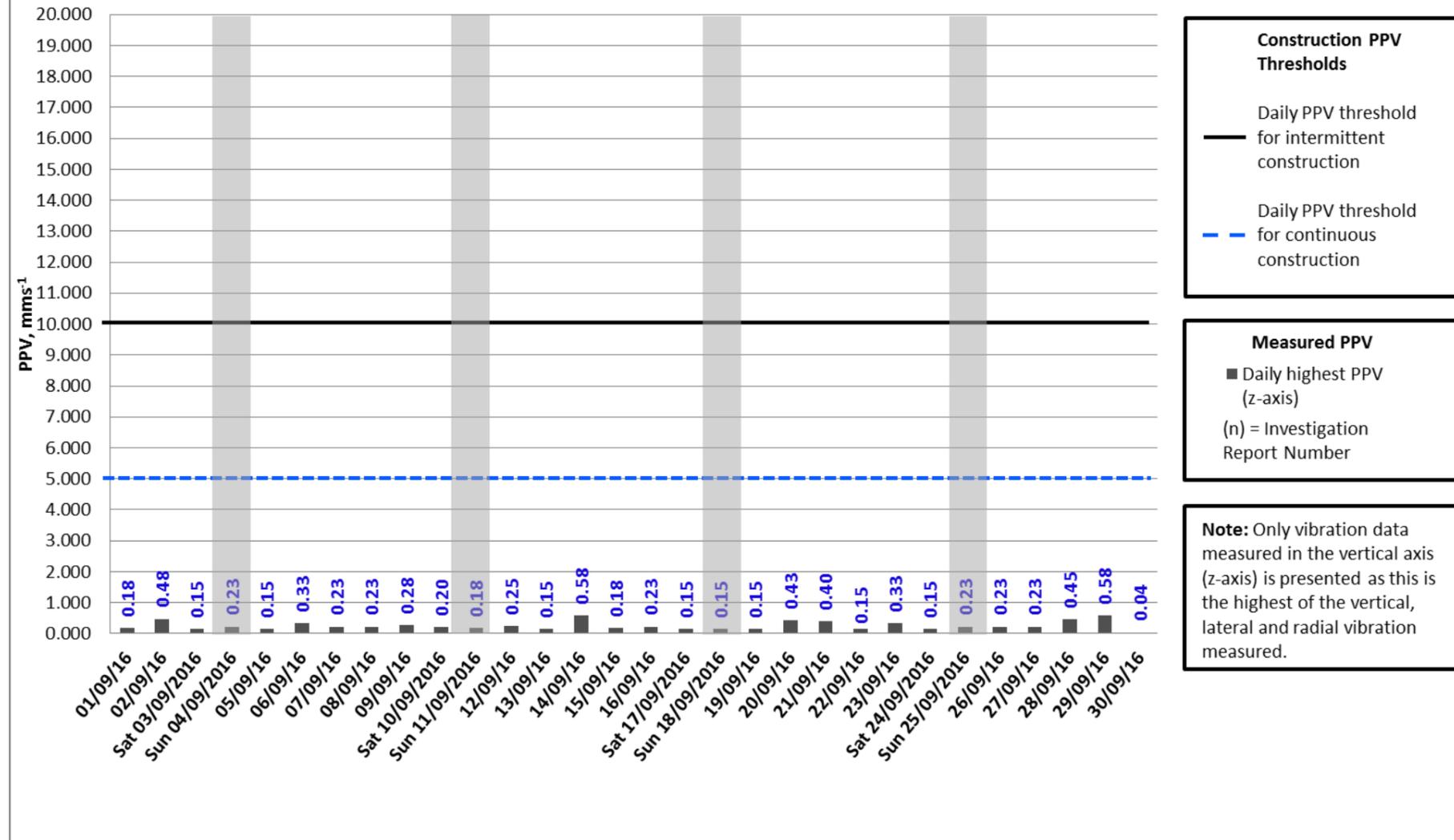
Measured VDV

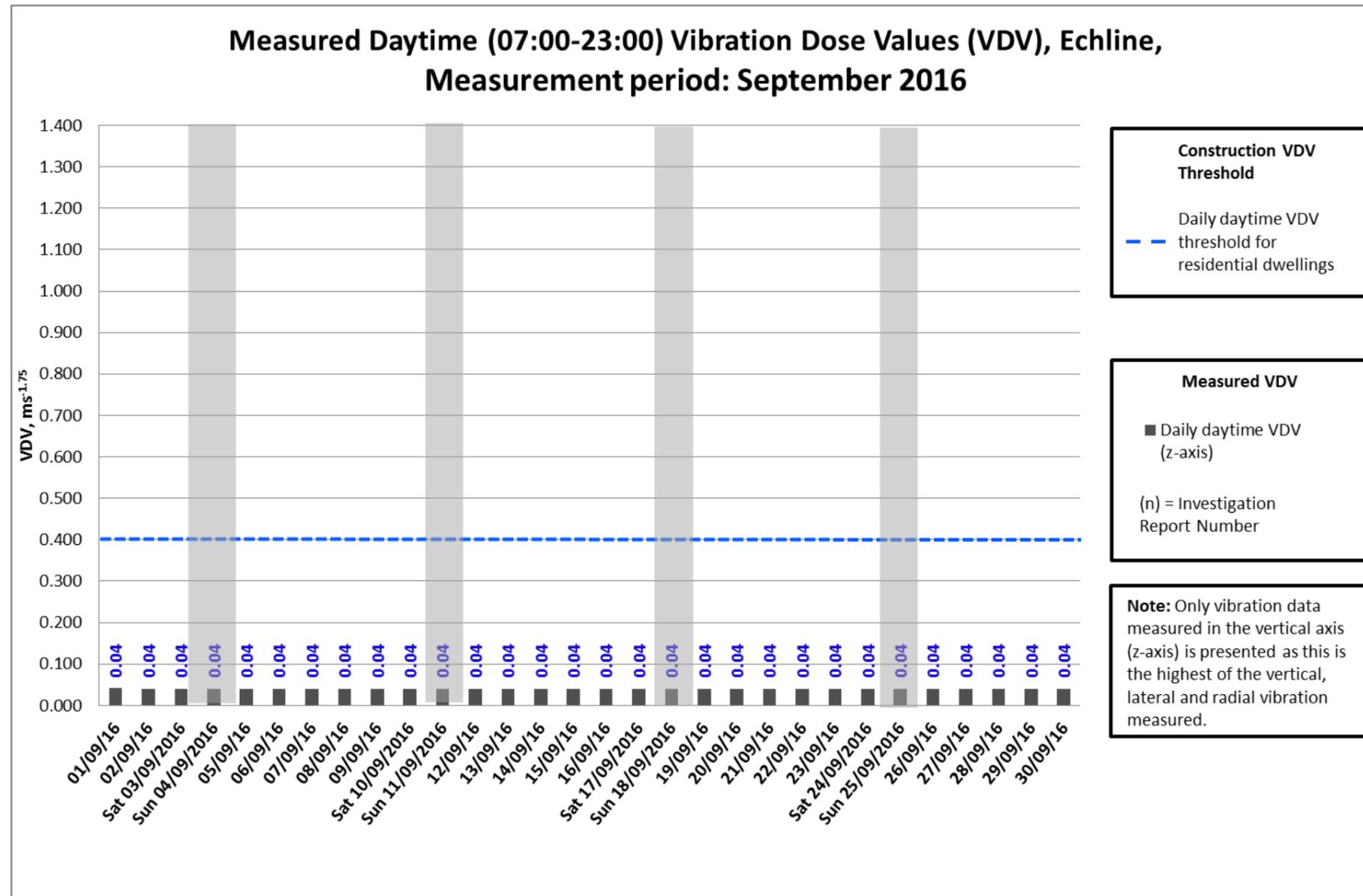
■ Daily night time VDV (z-axis)

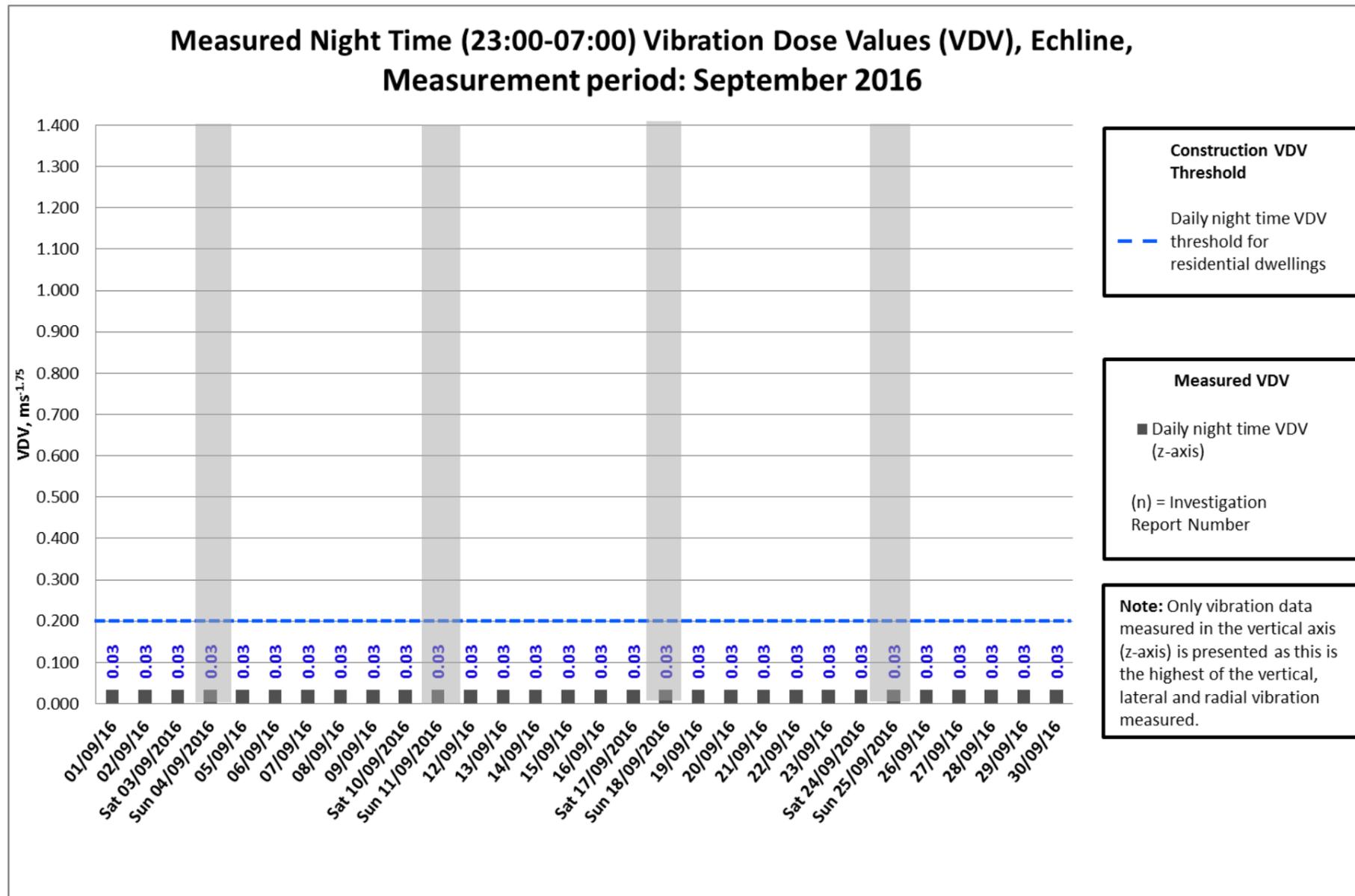
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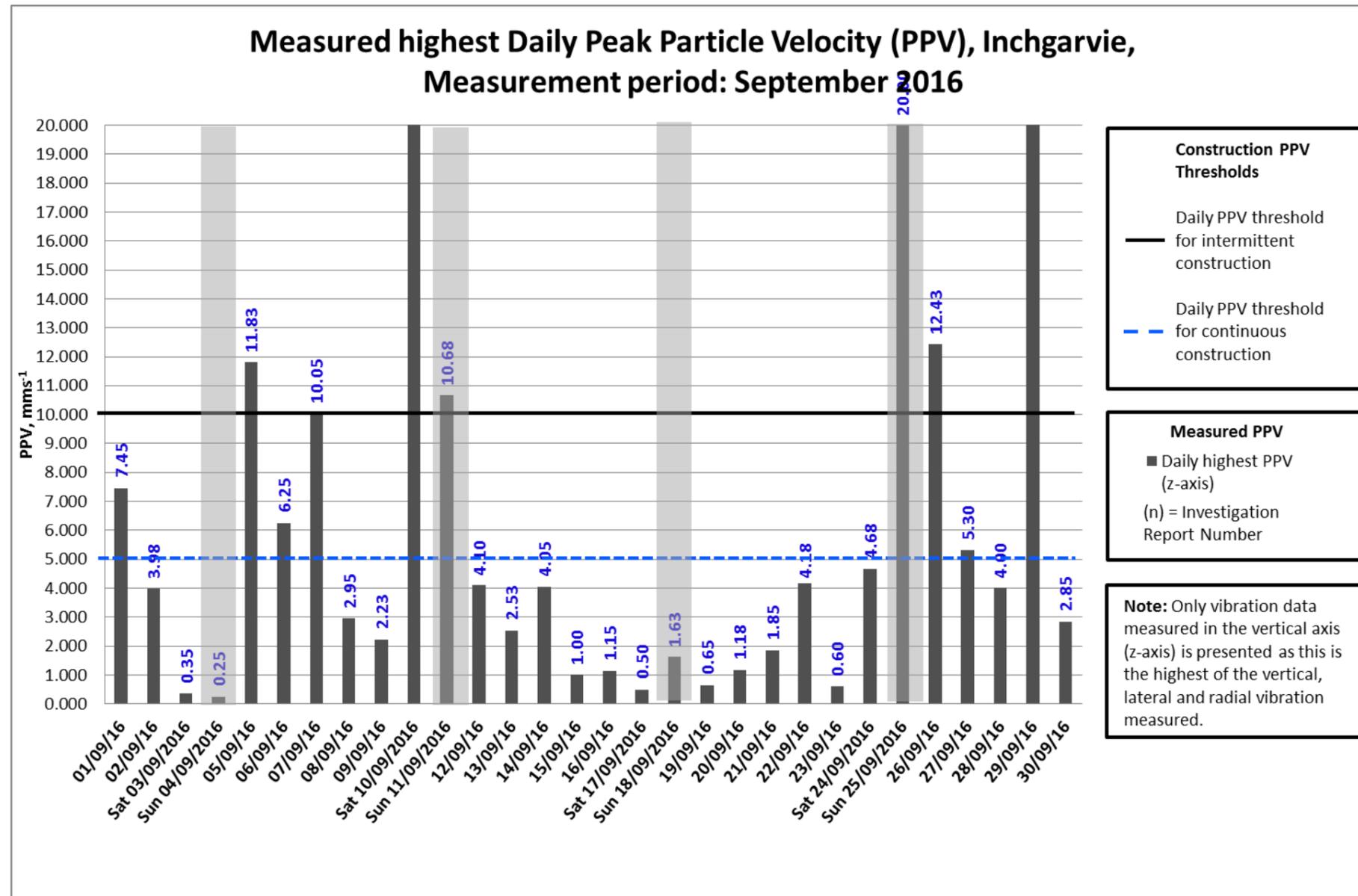
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

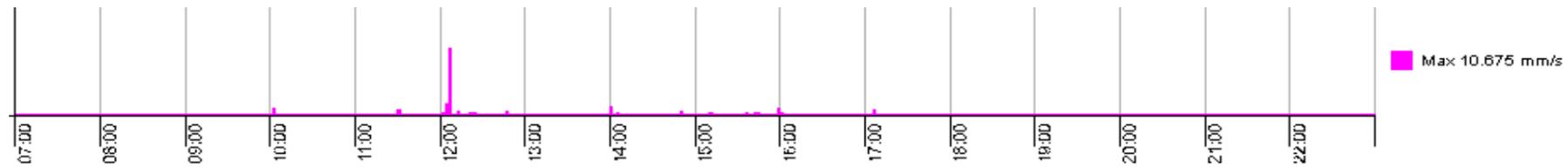
Measured highest Daily Peak Particle Velocity (PPV), Echline, Measurement period: September 2016



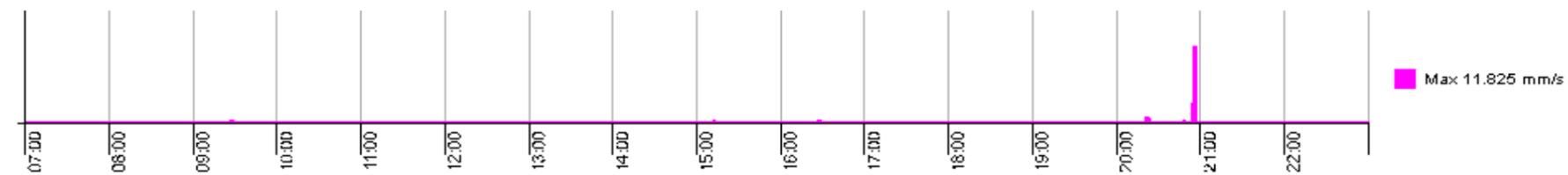




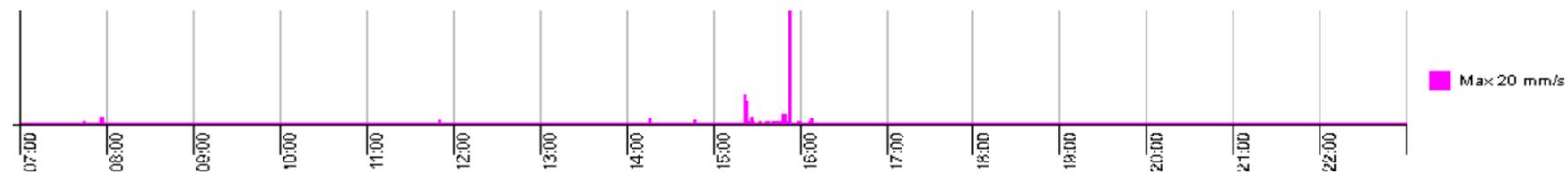




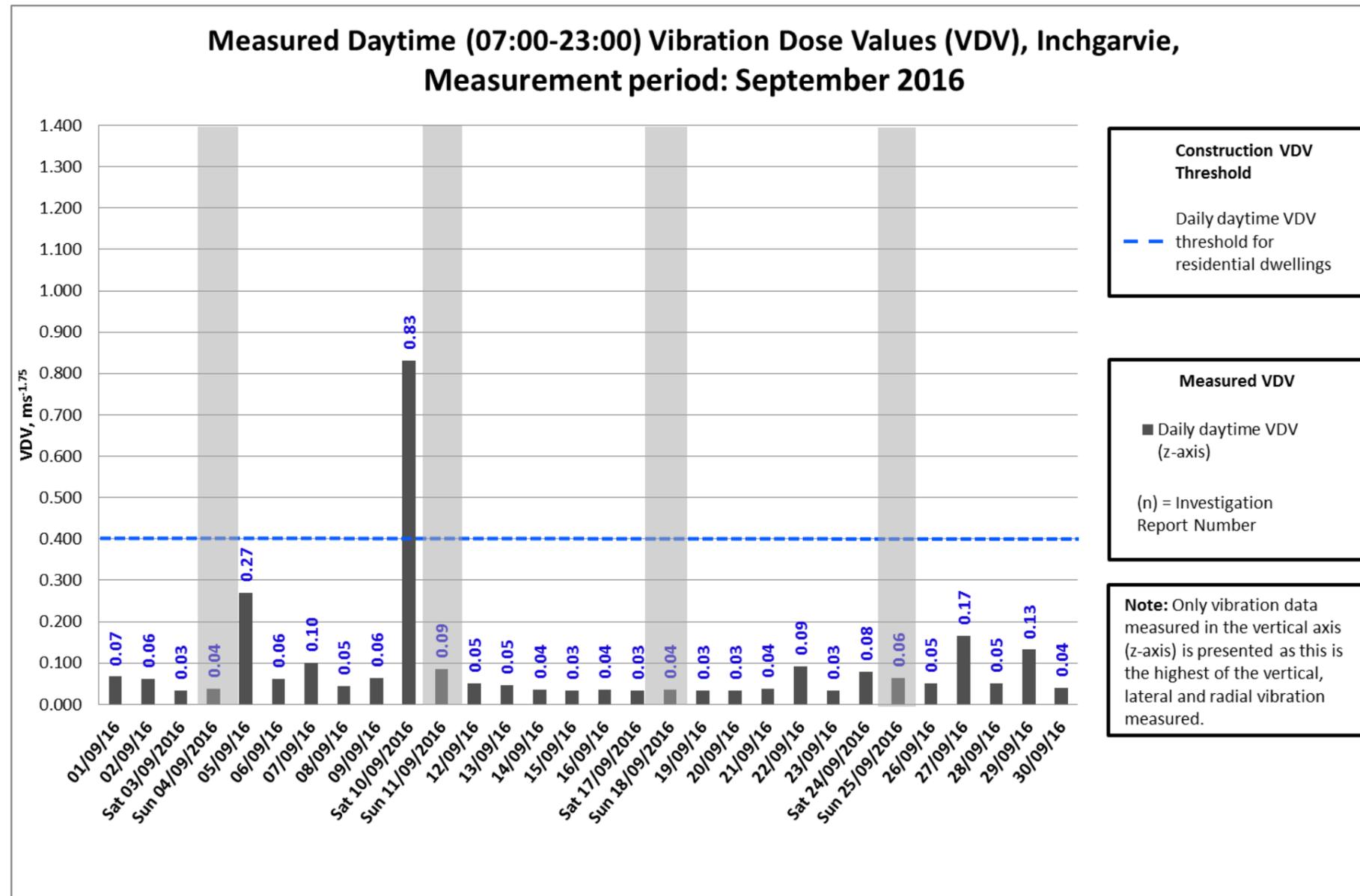
Exceedances on the 11th and 26th September have been investigated and found to be caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 11/09/2016). During this period, the resident at the property where the monitor is situated, had ongoing private construction works. It is likely that the exceedances shown in the graph above were caused by the private works at the property, rather than construction activities connected with the new bridge crossing and supporting infrastructure. However, it is worth noting during this period that there has been excavation works ongoing at the SUDS pond east of the south abutment, approximately 40m away. Due to the proximity of the excavation works, and the fact there isn't any supporting evidence to state otherwise, these exceedances might also have been caused by the Suds works.

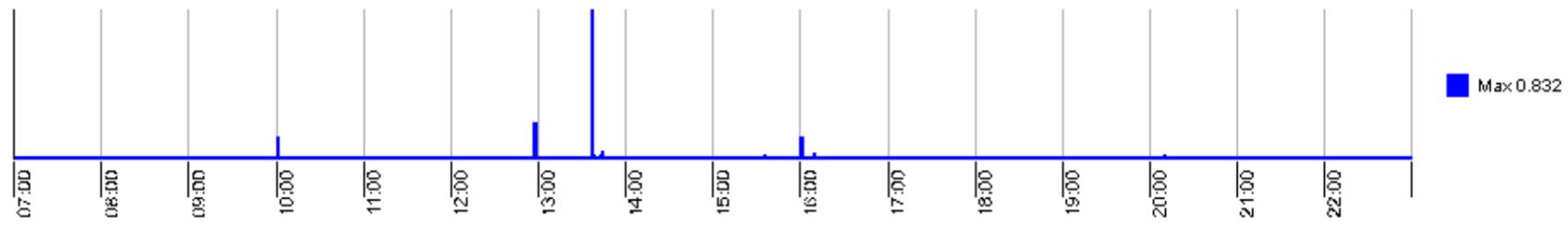


Exceedances on the 1st, 5th, 6th and 7th September have been investigated and found to have been caused out with construction working hours and therefore it is unlikely that construction related activities were the cause of these events (graph above from the 05/09/2016).



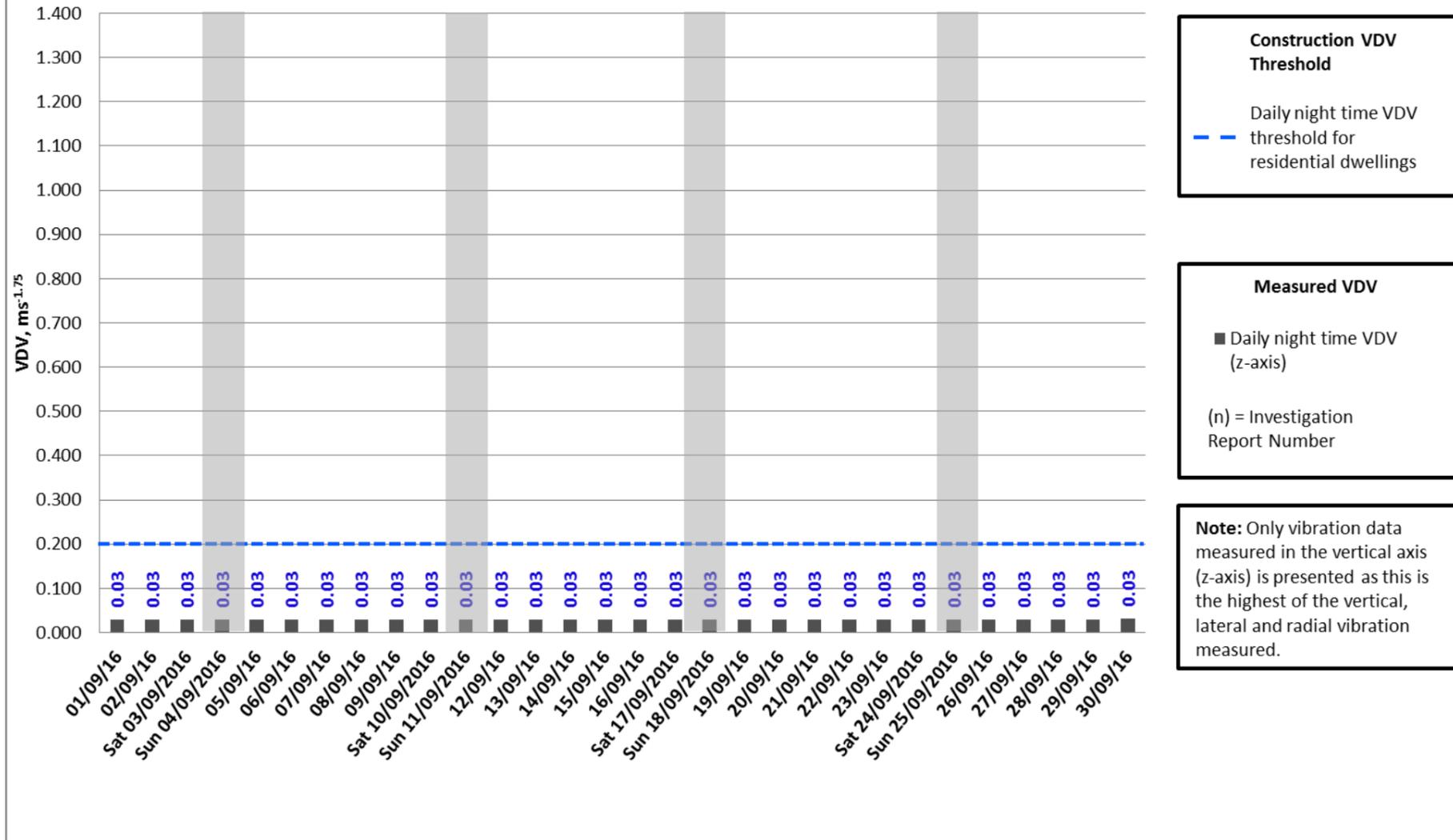
Exceedances on the 10th, 25th and 29th September have been investigated and found to have been caused by the resident having private building work done on their property (graph above from 25/09/2016).





Exceedance on the 10th of September has been investigated and found to have been caused by the resident having private building work done on their property.

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



Construction VDV Threshold

Daily night time VDV threshold for residential dwellings

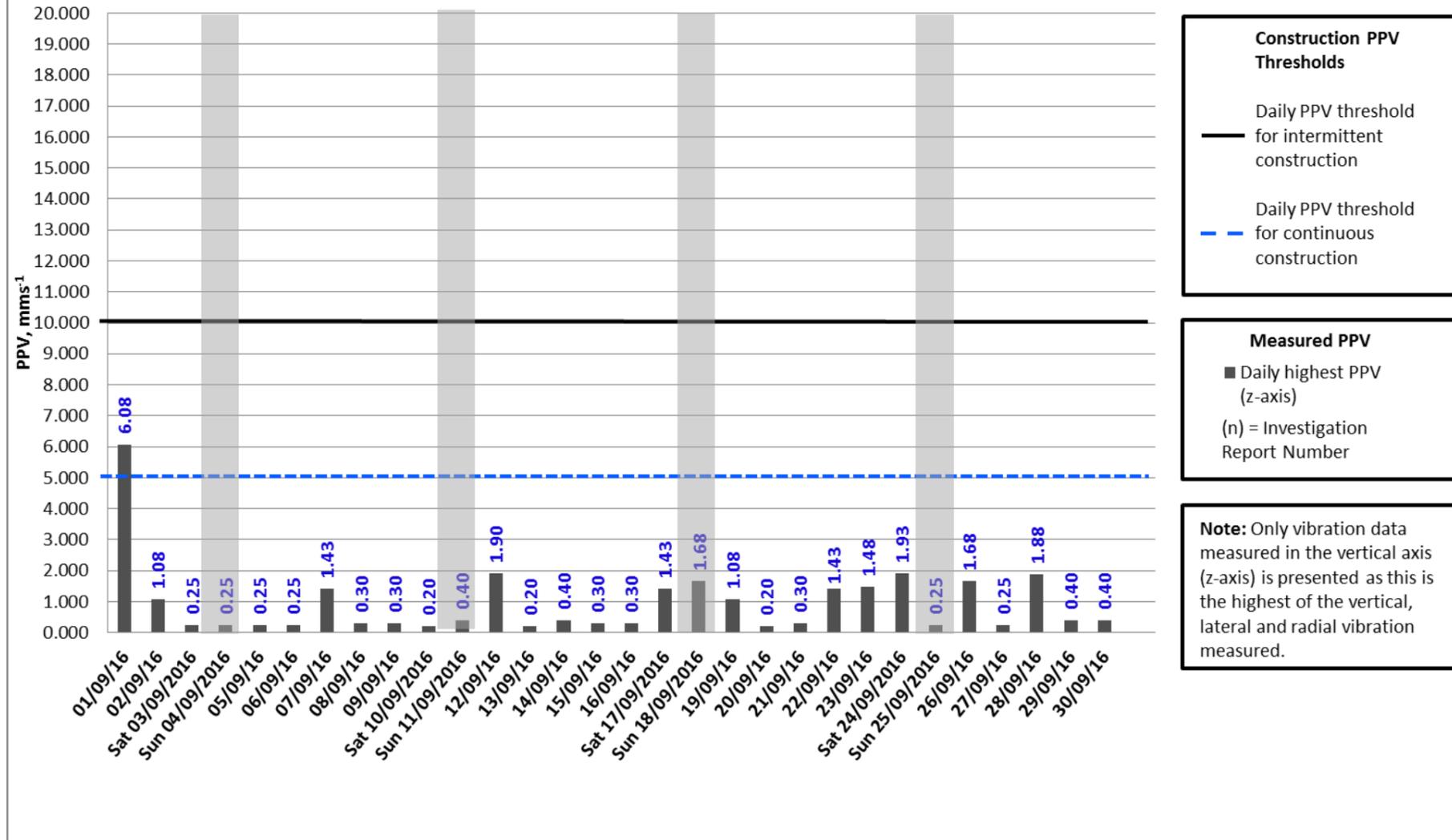
Measured VDV

■ 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 highest Daily Peak Particle Velocity (PPV), Linn Mill, Measurement period: September 2016



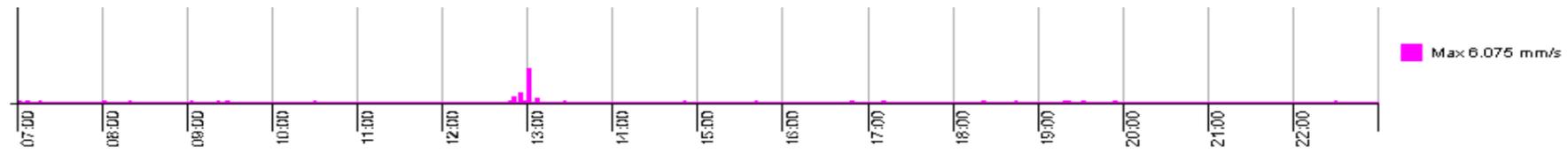
Construction PPV Thresholds

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

Measured PPV

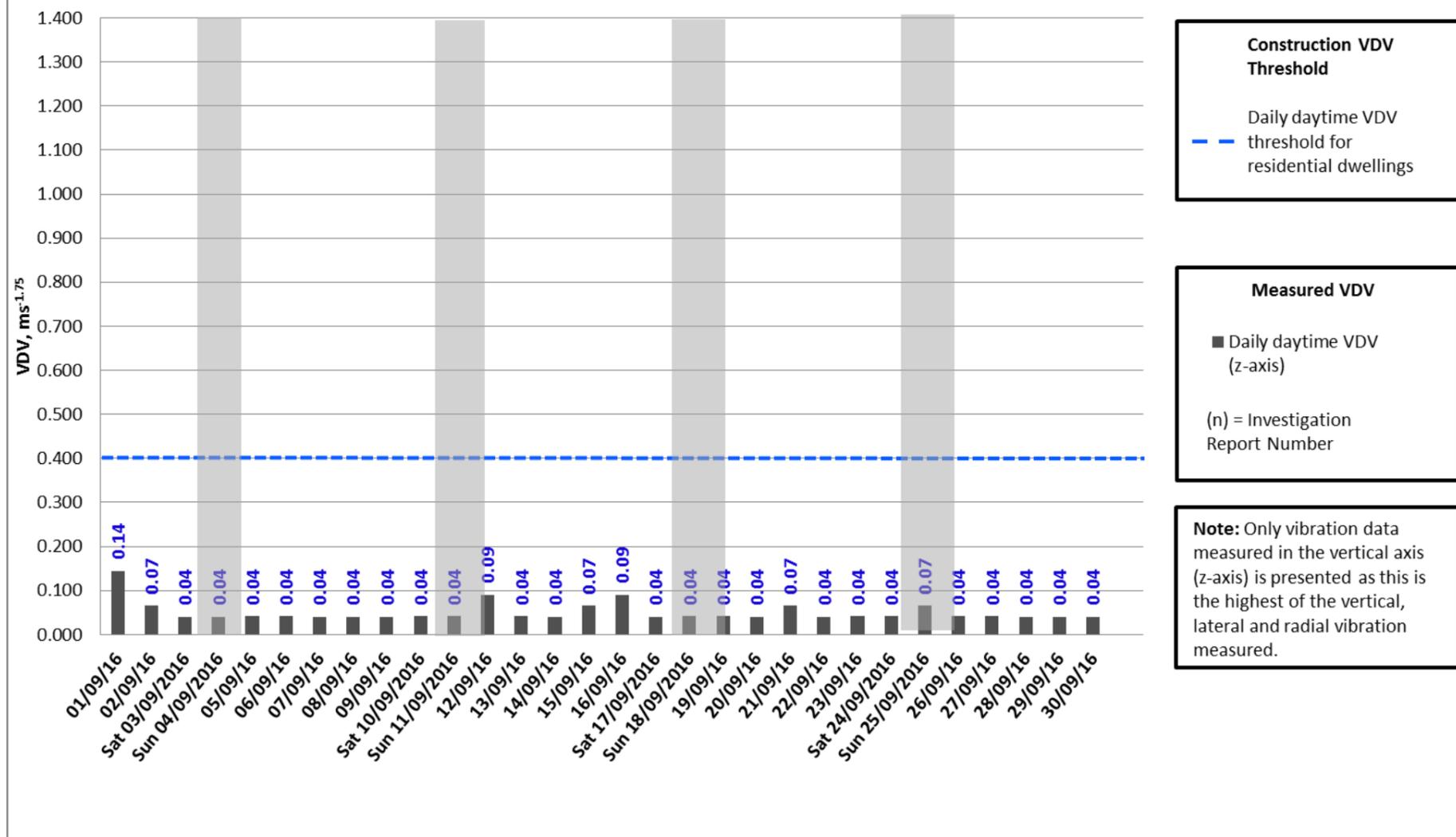
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

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.



Exceedance on the 1st September has been investigated and found to have been caused by an individual isolated event that is unlikely to have been due to construction related activity.

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



Construction VDV Threshold

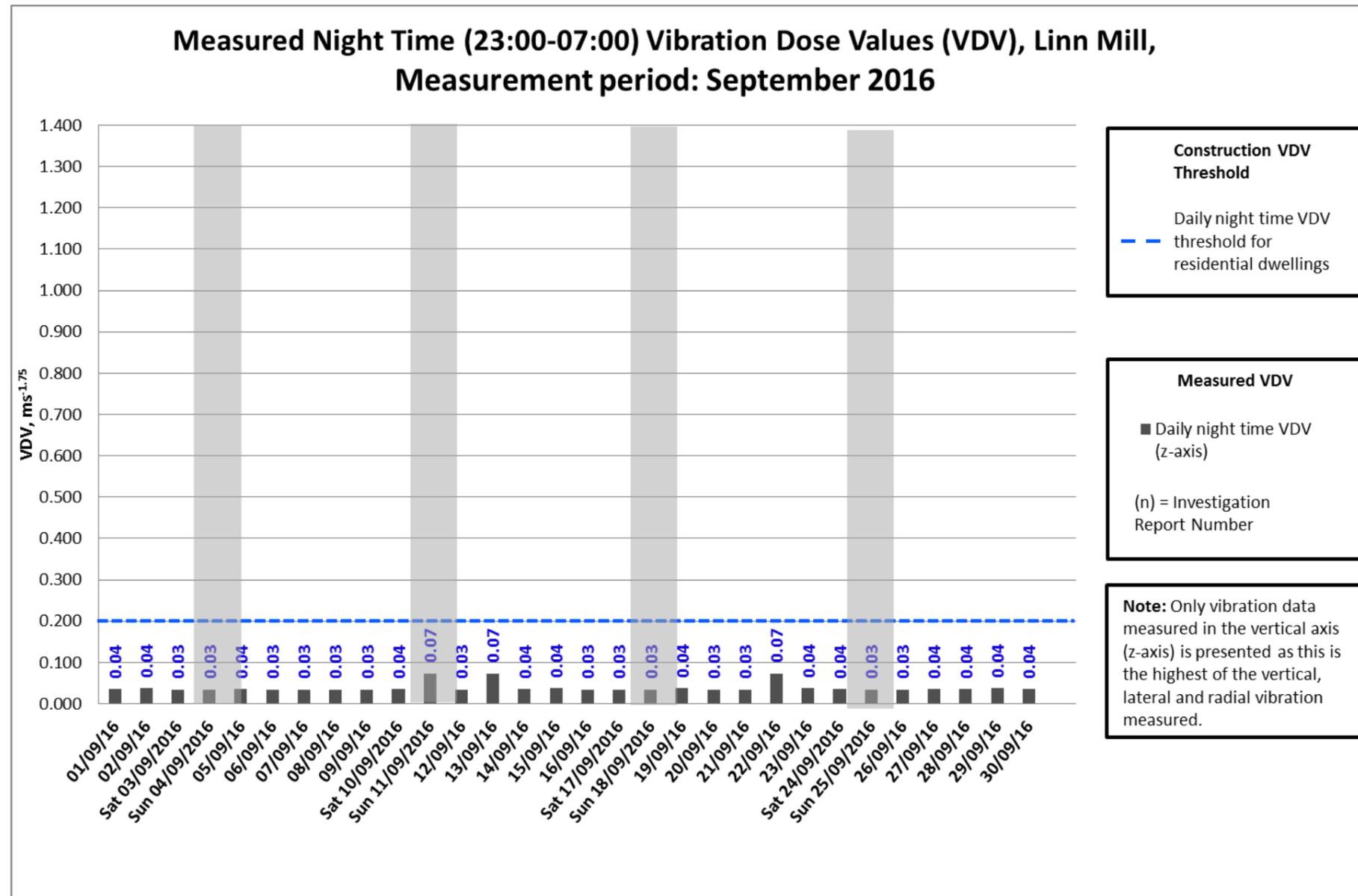
Daily daytime VDV threshold for residential dwellings

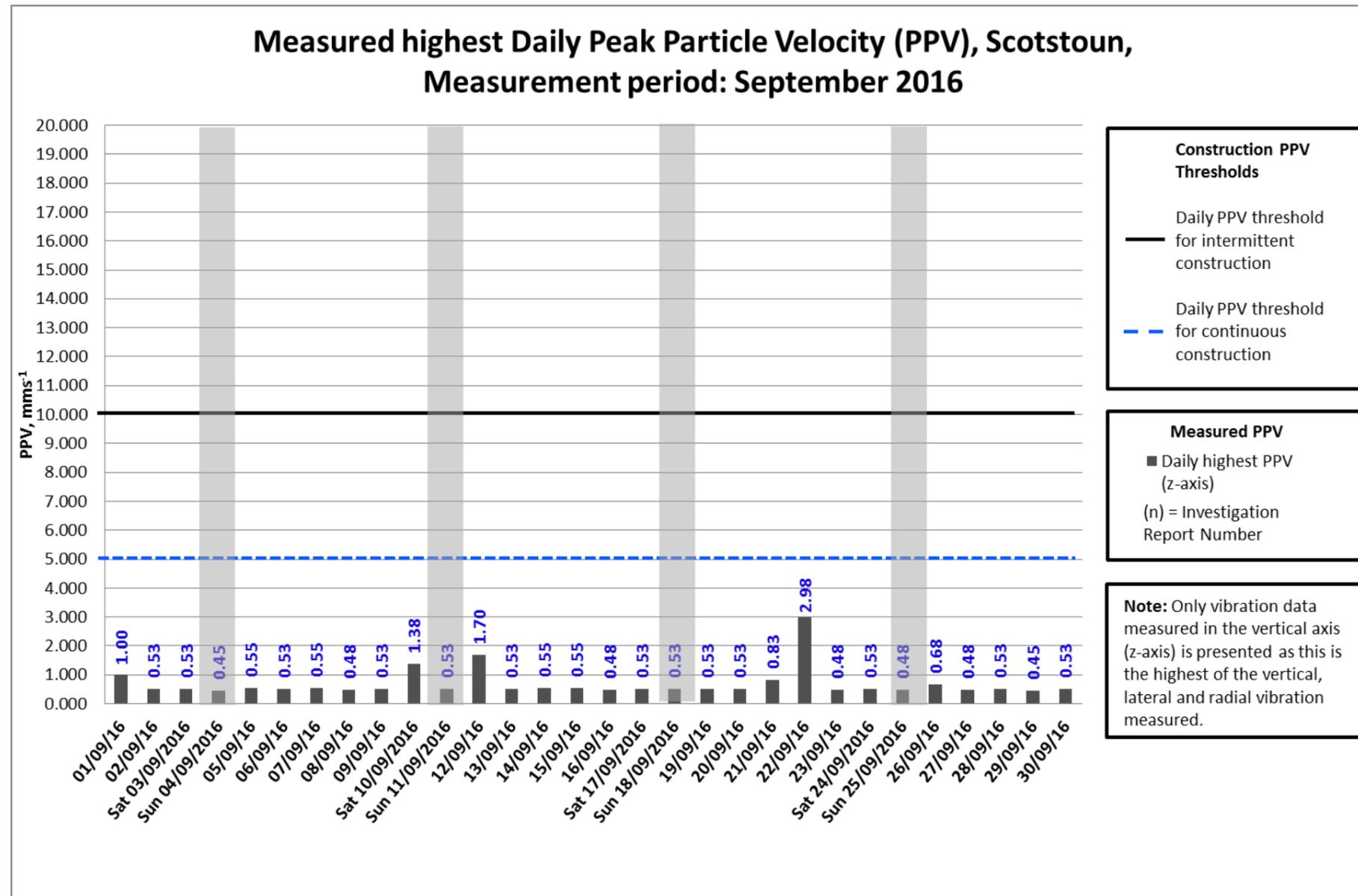
Measured VDV

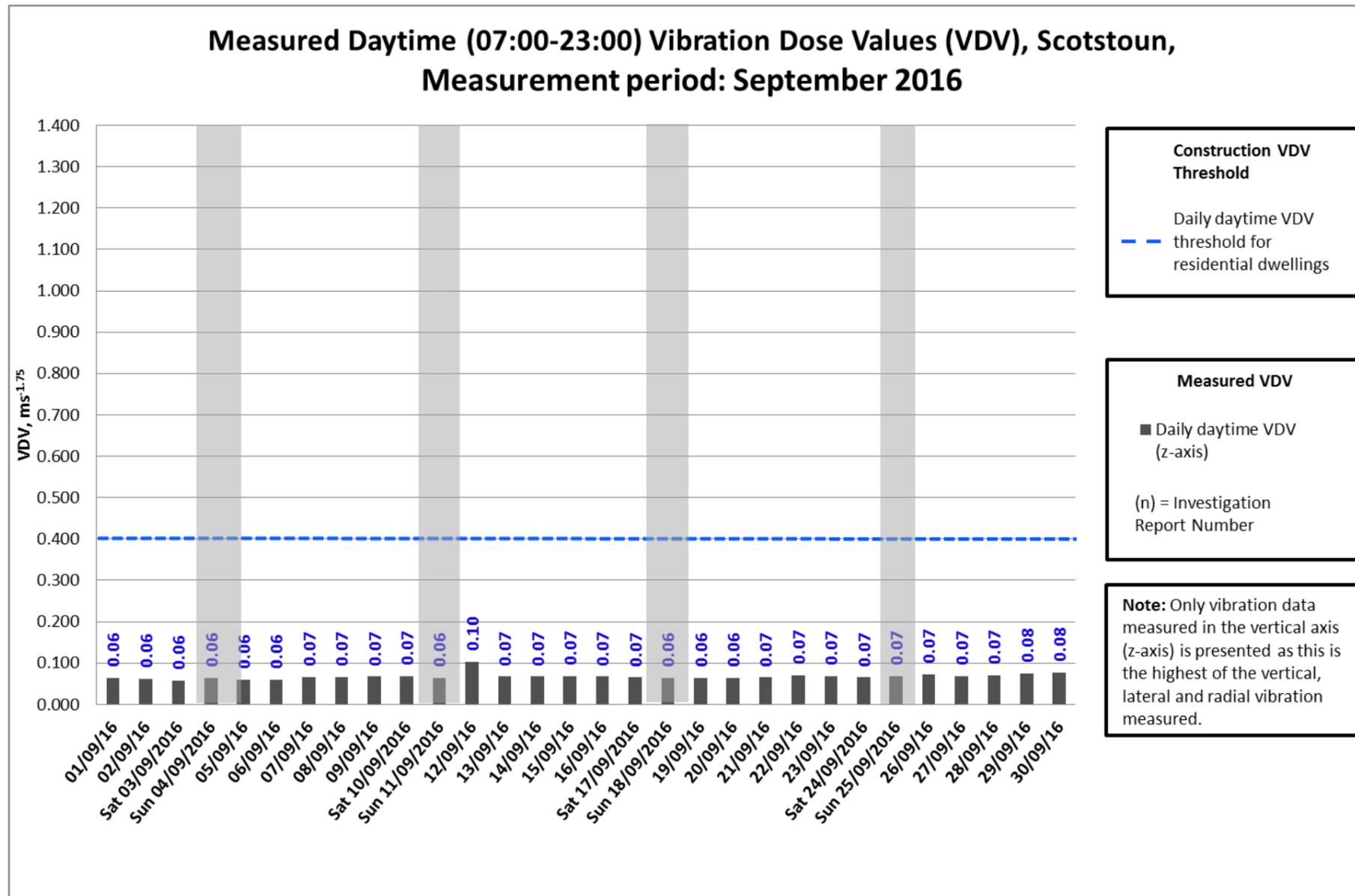
■ Daily daytime VDV (z-axis)

(n) = Investigation Report Number

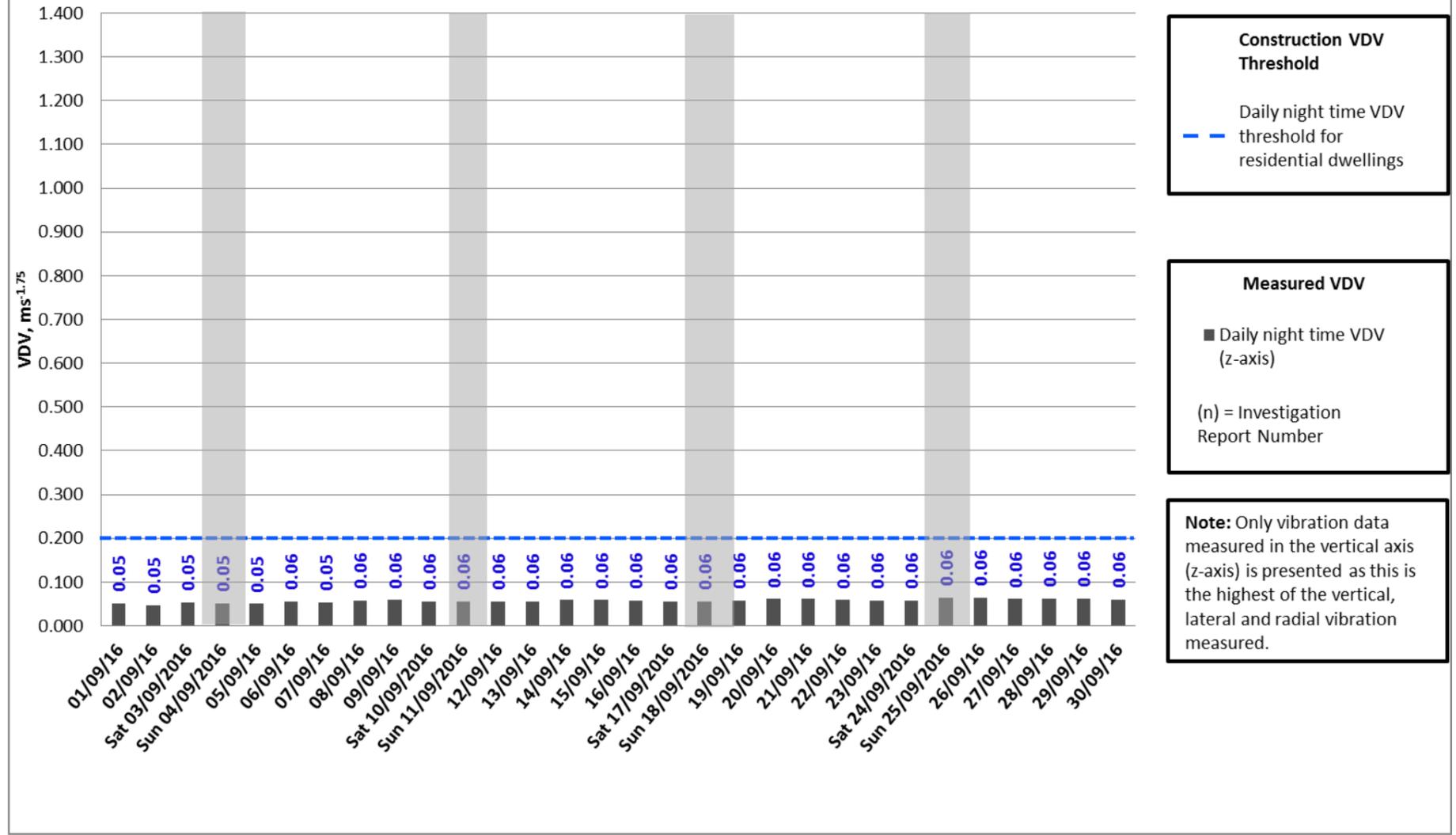
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.







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



Construction VDV Threshold

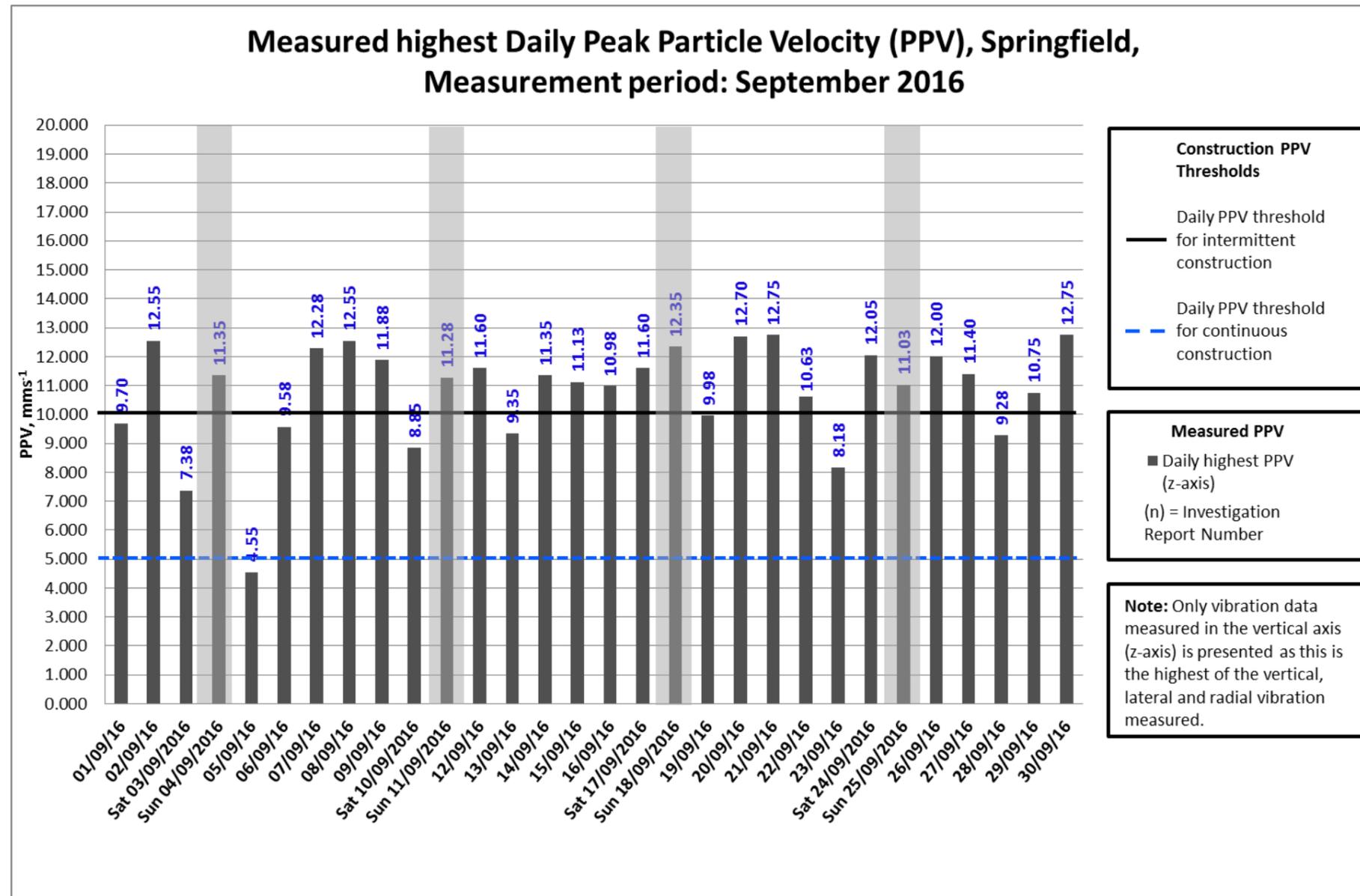
Daily night time VDV threshold for residential dwellings

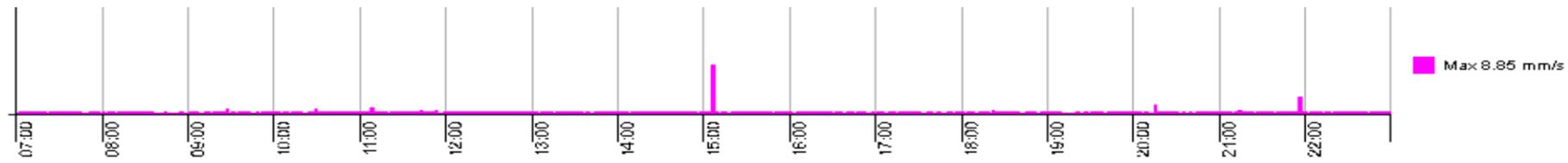
Measured VDV

■ Daily night time VDV (z-axis)

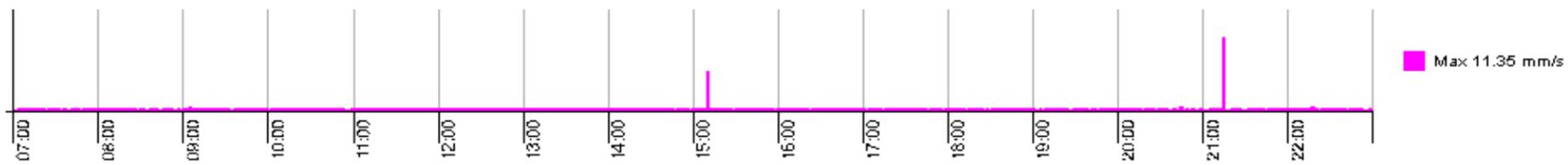
(n) = Investigation Report Number

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.

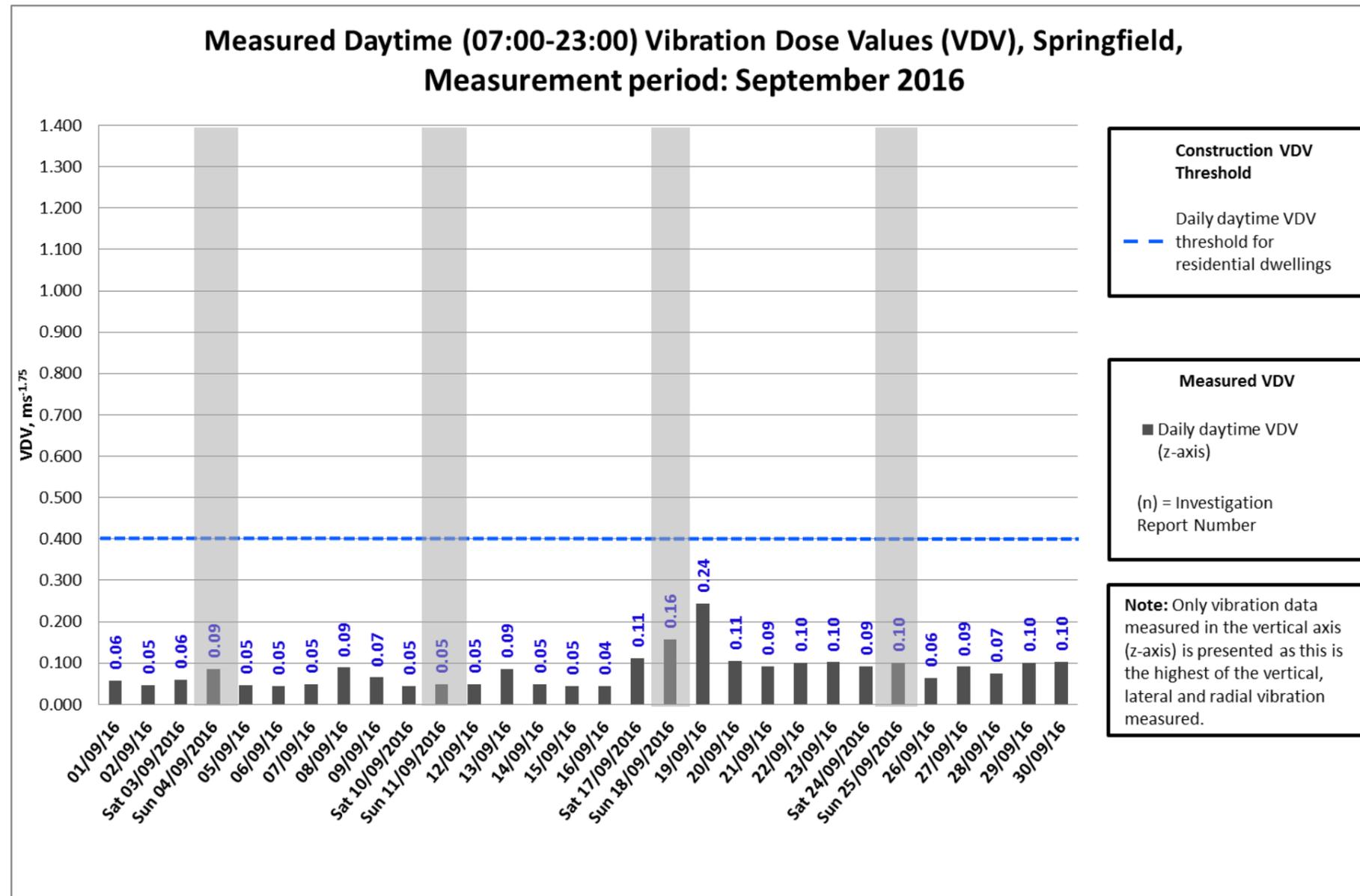


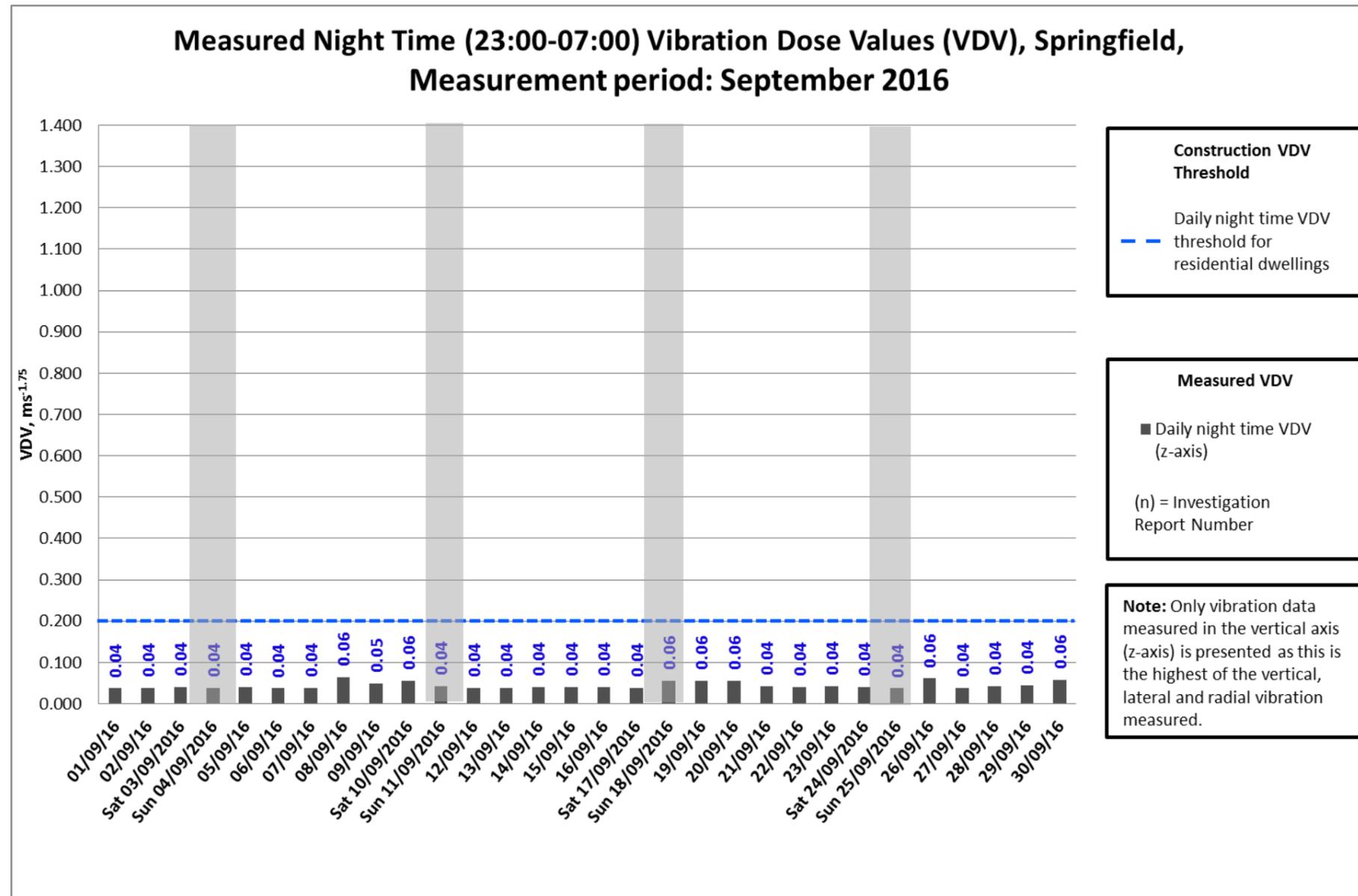


Exceedances on the 4th, 7th, 8th, 9th, 10th, 12th, 13th, 17th, 18th, 19th, 22nd, 24th, 25th, 26th, 27th, 28th, 29th and 30th of September have been investigated and found to have been caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 10/09/16). The vibration monitor is located in the residents back garden, so resident's activity may have caused these exceedances. The closest works were located approximately 260m away which consists mainly of road surfacing. Due to the distance to the nearest works it is unlikely the exceedances stated above were caused by the Forth Crossing works.

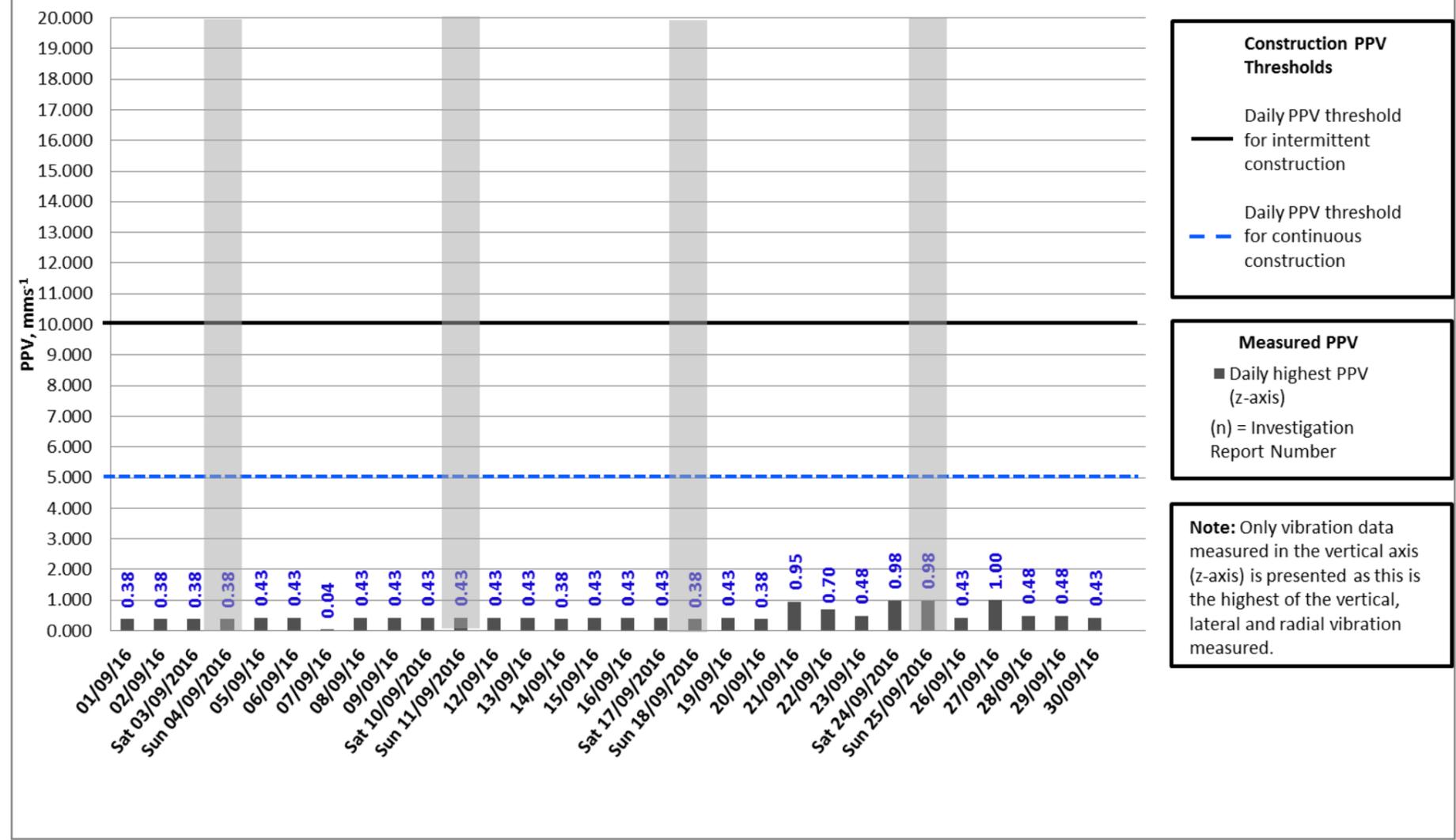


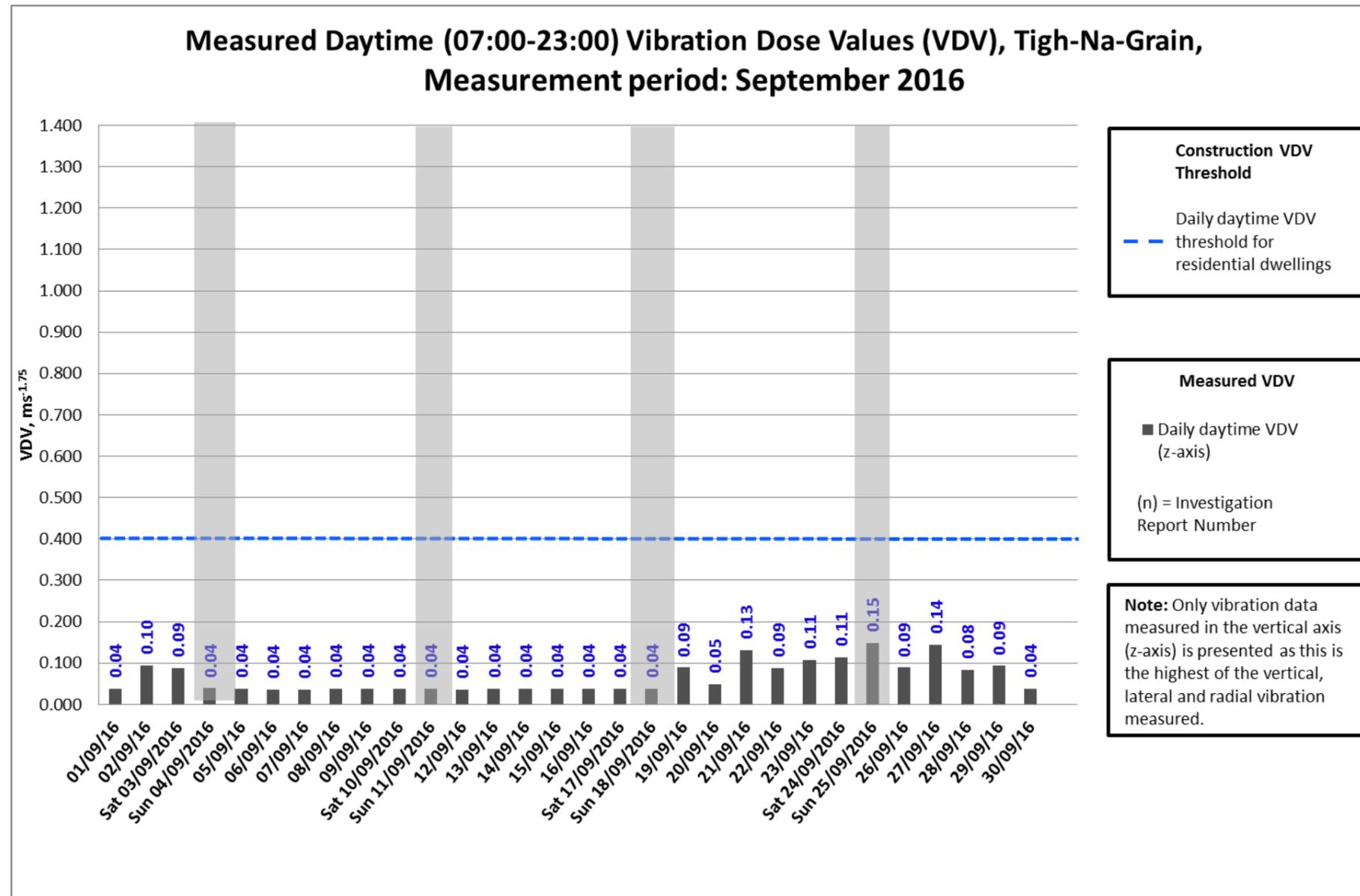
Exceedances on the 1st, 2nd, 3rd, 6th, 11th, 14th, 15th, 16th, 20th, 21st and 23rd of September have been investigated and found to be caused out with construction working hours and therefore it is unlikely that construction related activities were the cause for these exceedances (graph above from the 14/09/2016).

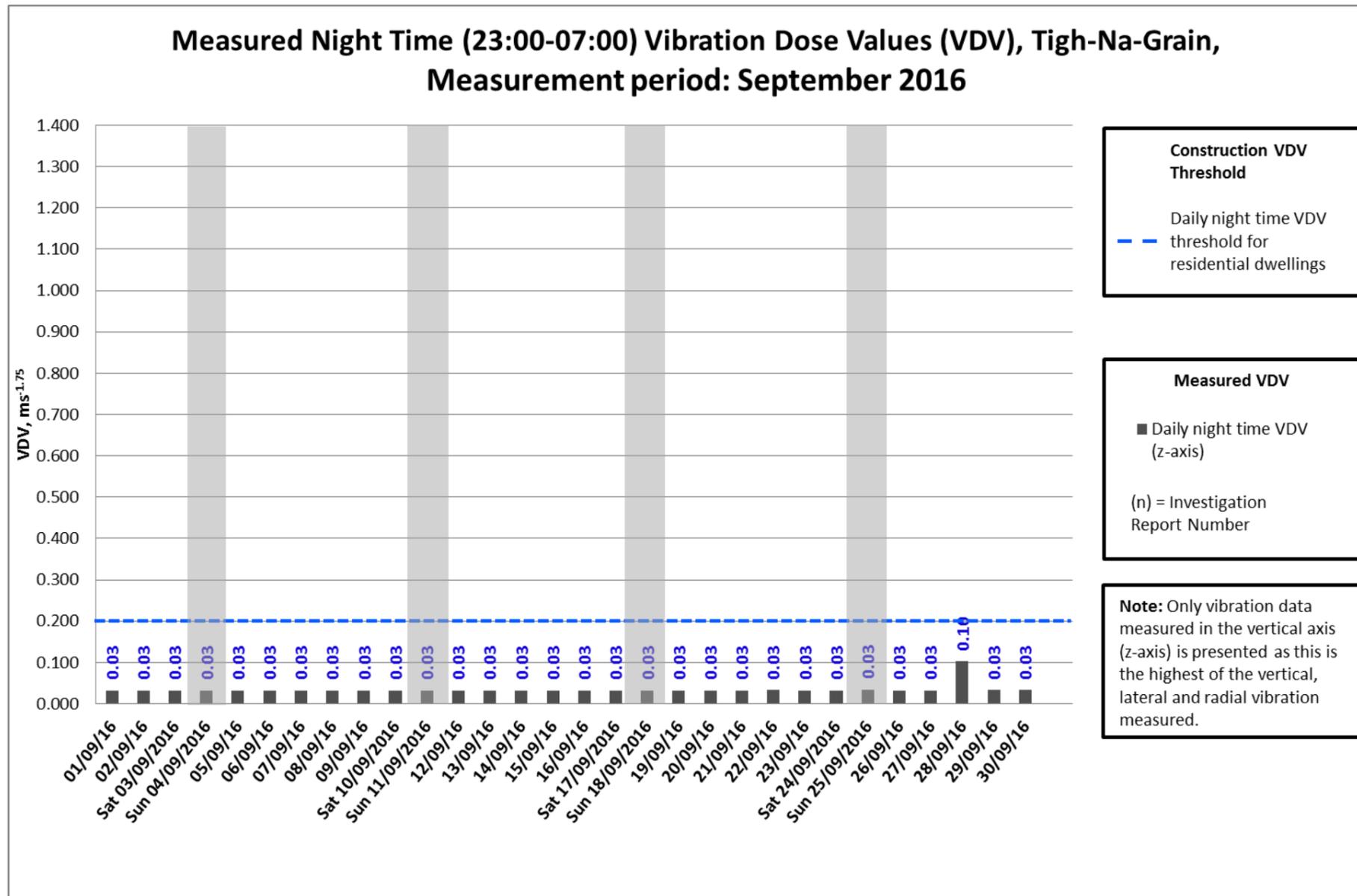




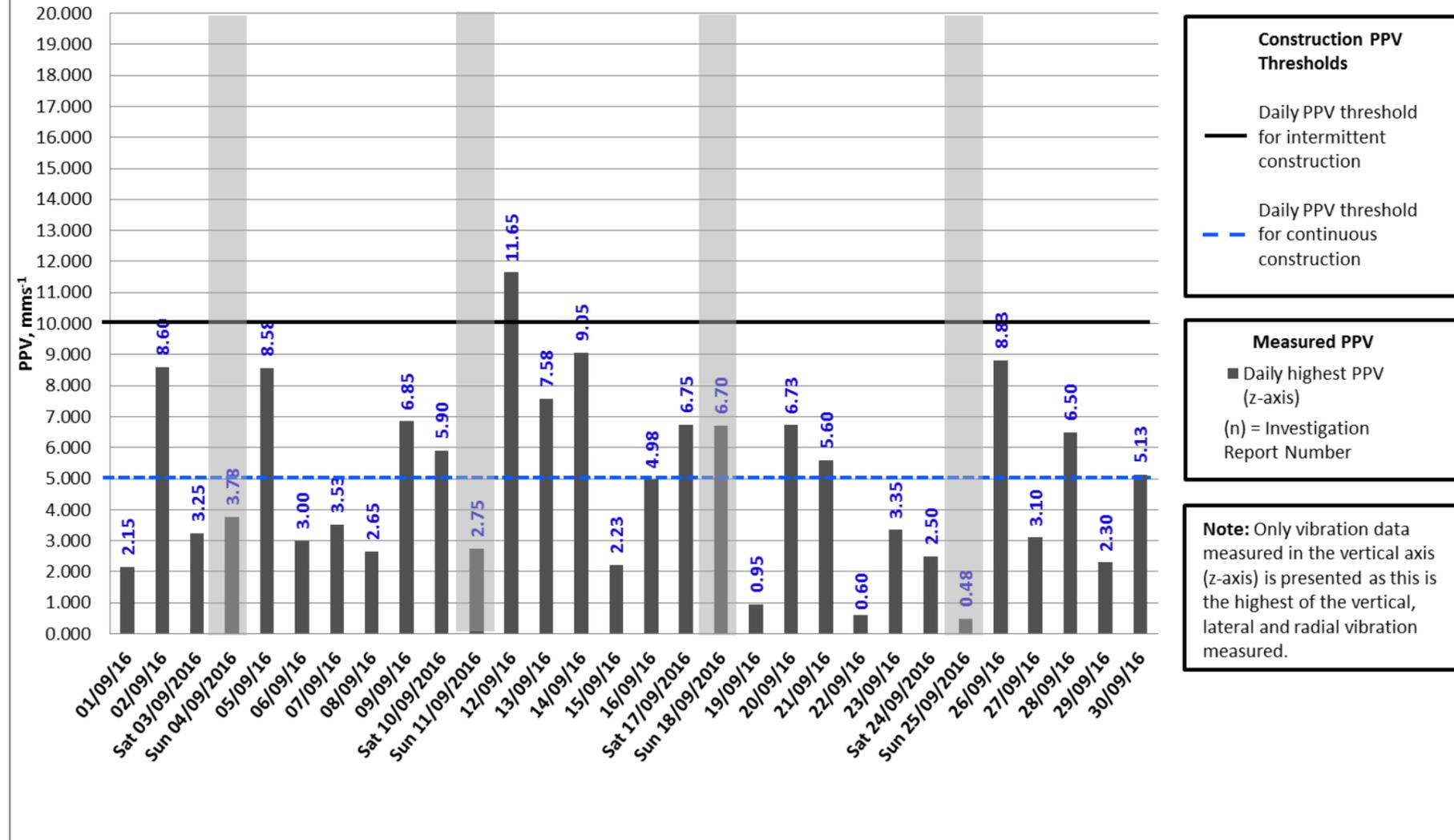
Measured highest Daily Peak Particle Velocity (PPV), Tigh-Na-Grain, Measurement period: September 2016







Measured highest Daily Peak Particle Velocity (PPV), Whinnyhill, Measurement period: September 2016



Construction PPV Thresholds

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

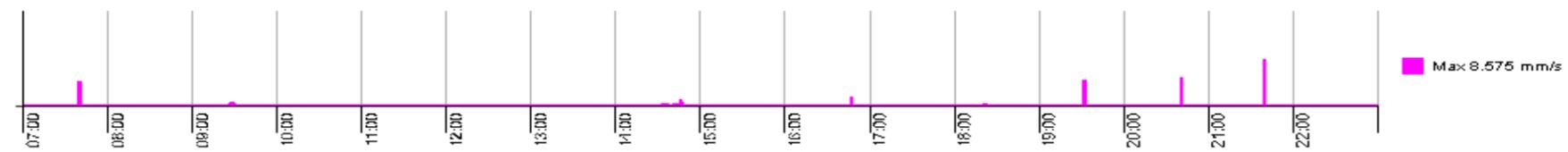
Measured PPV

- 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 2nd, 9th, 10th, 12th, 13th, 14th, 16th, 17th, 19th, 20th, 21st, 26th and 28th of September have been investigated and found to have been caused by individual isolated events that are unlikely to have been construction related activities (graph above from the 12/09/16).



Exceedances on the 5th and 30th of September have been investigated and found to have been caused out with construction working hours and therefore it is unlikely that construction related activities were the cause for these exceedances (graph above from the 05/09/2016).

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

