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Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project

FORTH REPLACEMENT CROSSING

Document title

**VIBRATION MONITORING REPORT
AUGUST 2013**

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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 August 2013. 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 have risk assessed noise & vibration resulting from all construction activities through the production of Plans for Control of Noise & Vibration (PCNVs). During the preparation of the PCNVs, the assessment/prediction of vibration levels has illustrated that no construction plant, equipment or methodology to be utilised by FCBC during the period in question, was envisaged to induce any levels of vibration at 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

August 2013

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	0	0	0	2
Butlaw Fisheries	1	2	0	0
Clufflat Brae	7	1	1	0
Dundas Home Farm	0	0	0	5
Echline	1	0	0	0
Inchgarvie Lodge	0	0	0	0
Scotstoun	0	0	0	0
Springfield	0	0	0	0
Tigh-Na-Grian	0	2	0	0
Whinnyhill	7	6	0	0

- 2.6.** Peak Particle Velocity (PPV) is used to measure vibration through a solid surface. When a vibration is measured, the point at which the measurement takes place can be considered to have a particle velocity. This particle vibration will take place in three dimensions (x, y and z).
- 2.7.** The Peak Particle Velocity is the highest velocity that is recorded during a particular event, and as such is appropriate for the measurement of activities such as blasting and piling. 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 annual monitor calibration.

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.

**APPENDIX A – MONITORING LOCATIONS & VIBRATION ASSESSMENTS
FROM RELEVANT PCNVs**

Table 2: Monitoring Locations

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During August 2013
M1	Whinny Hill	Network	Band drain works at King Malcolm Drive. Excavation and breaking rock at Castlandhill Road and haulage to Ferrytoll. N.B. No evening, night time or Sunday daytime construction in vicinity.
M3	Tigh-Na-Grian	Crossing	Works within Central Tower cofferdam. North Tower dewatering works. North Tower crane platform piling.
M7	Butlaw Fisheries	Crossing	Works within Central Tower cofferdam. South Tower excavation & airlifting. Pier S1 jet grouting works. Pier S4 airlifting. Pier S5 airlifting & concrete works. Pier S6 backfilling. Society Road embankment works.
M10	Inchgarvie Lodge	Crossing	Launch –fixing steel and erecting formwork. Concrete pours. Backfilling and assembly of stillages. Scaffolding works. Rebar. Formwork and concrete pours at S7/S8. Society road works. South Tower excavation & airlifting. Pier S1 jet grouting works. Pier S4 airlifting. Pier S5 airlifting & concrete works. Pier S6 backfilling Launch – backfilling. Blinding concrete for lay down area. Abutment – curing of main crossing. Bearing plinths. Scaffolding erection for piers. Society road embankment works.
M11	Linn Mill	Network	Launch –fixing steel and erecting formwork. Concrete pours. Backfilling and assembly of stillages. Scaffolding works. Rebar. Formwork and concrete pours at S7/S8. Society road works. N.B. No evening, night time or Sunday daytime construction in vicinity.

M13	Clufflat Brae	Network	<p>Launch –fixing steel and erecting formwork. Concrete pours. Backfilling and assembly of stillages. Scaffolding works. Rebar. Formwork and concrete pours at S7/S8. Society road works.</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M14	Springfield	Network	<p>Launch –fixing steel and erecting formwork. Concrete pours. Backfilling and assembly of stillages. Loading tippers with clay for transport to Dundas. Pier trials area works. Gyratory – structures.</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M15	Echline Field	Network	<p>Launch –fixing steel and erecting formwork. Concrete pours. Backfilling and assembly of stillages. Loading tippers with clay for transport to Dundas. Bulk excavation for mainline. Structures work at gyratory.</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M16	Scotstoun	Network	<p>Bus link works.</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M17	Dundas Home Farm	Network	<p>Utilities works. Environmental bund works. Excavation works for mainline.</p> <p>N.B. No evening, 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 August 2013.



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| DRAGADOS
| Morrison Construction

Table 3: PCNV Predicted PPV & VDV Levels

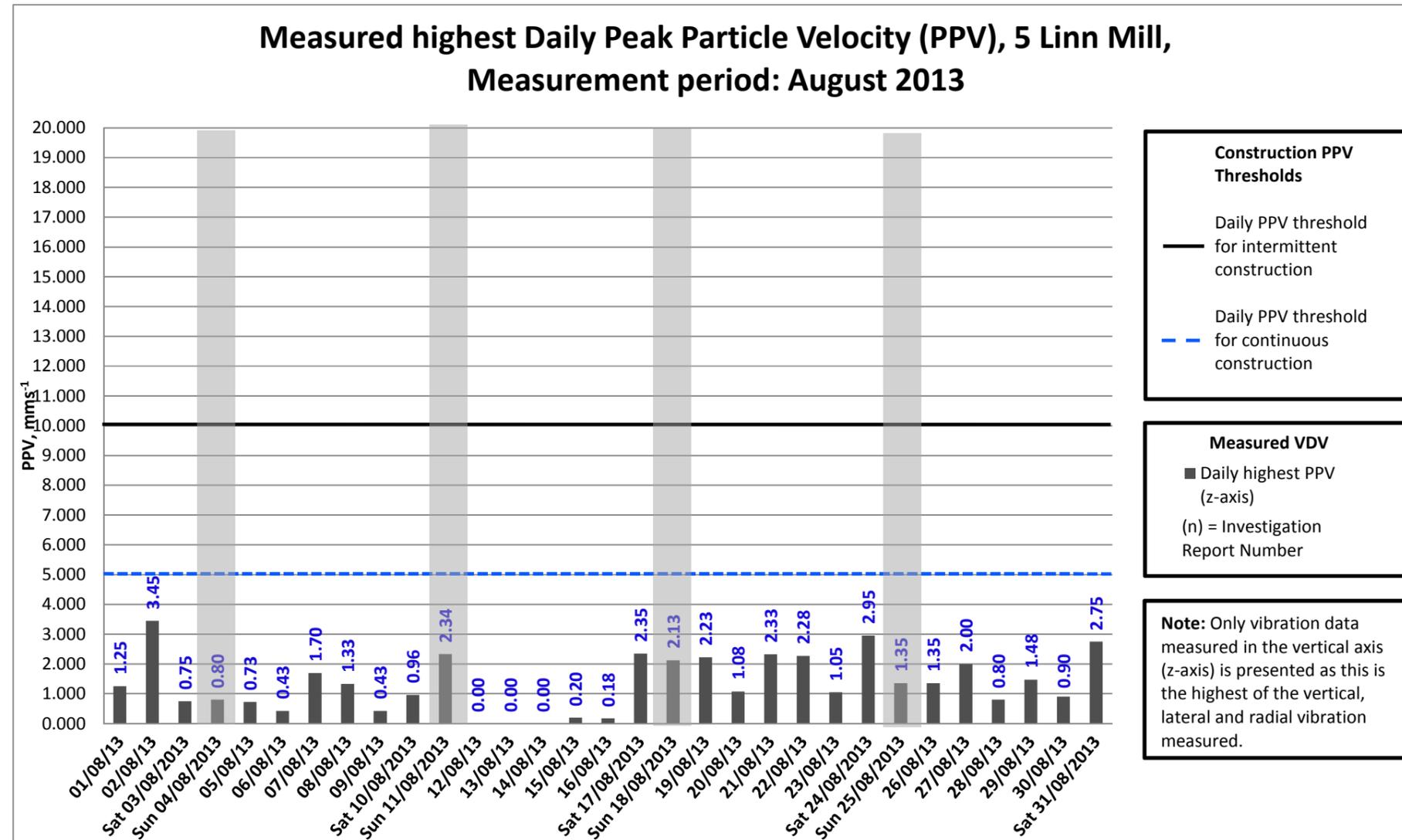
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	130	230	Roller/Whacker	0.44	0.23
Clufflat Brae	40	350	Roller/Whacker	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	250	Roller/Whacker	1.77	0.33
Linn Mill	60	500	Roller/Whacker	1.36	0.33
Scotstoun	40	2000	Roller/Whacker	2.44	0.37
Springfield	50	600	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	270	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

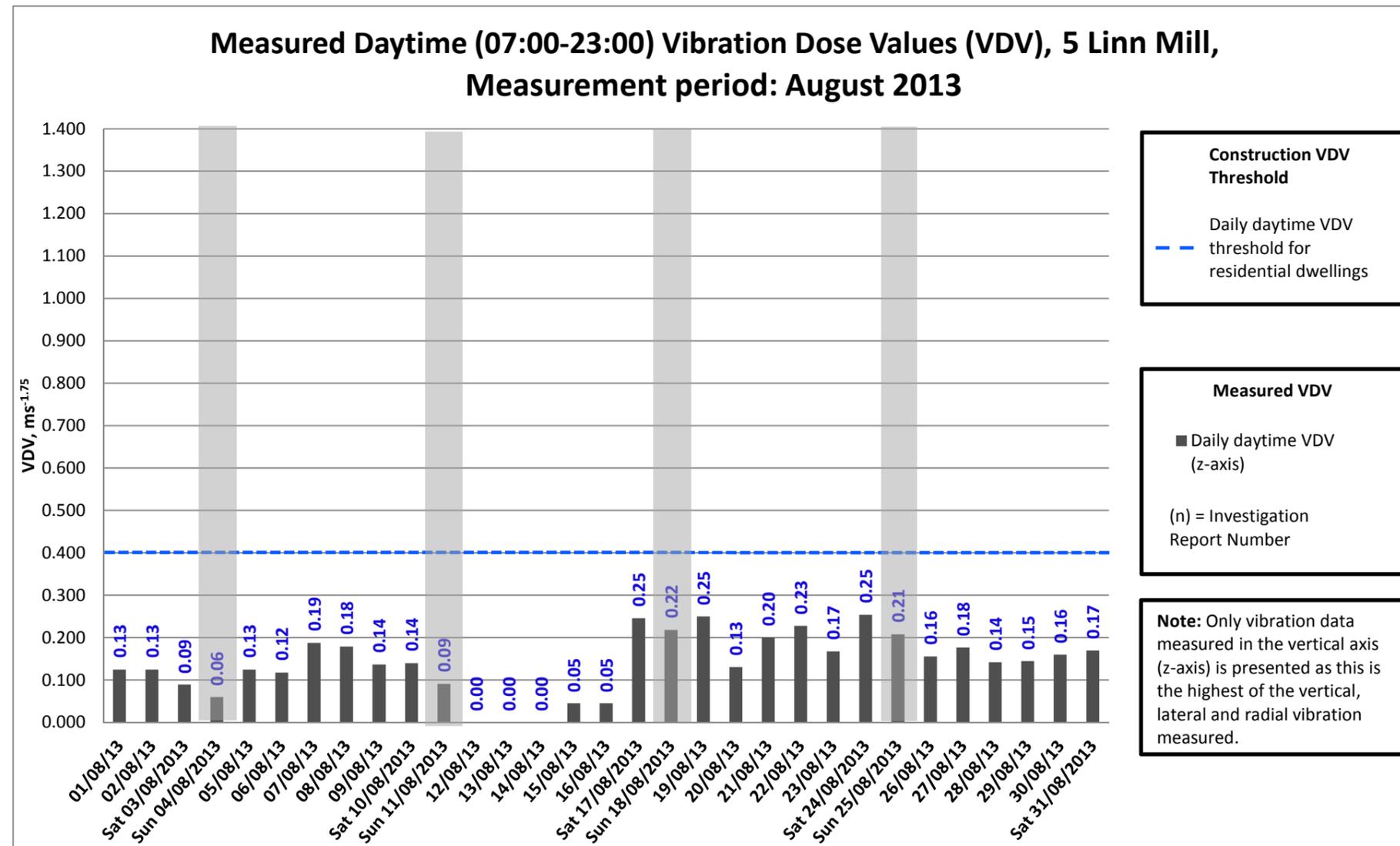
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 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 40m of any occupied sensitive receptors & were not operated within 25m 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



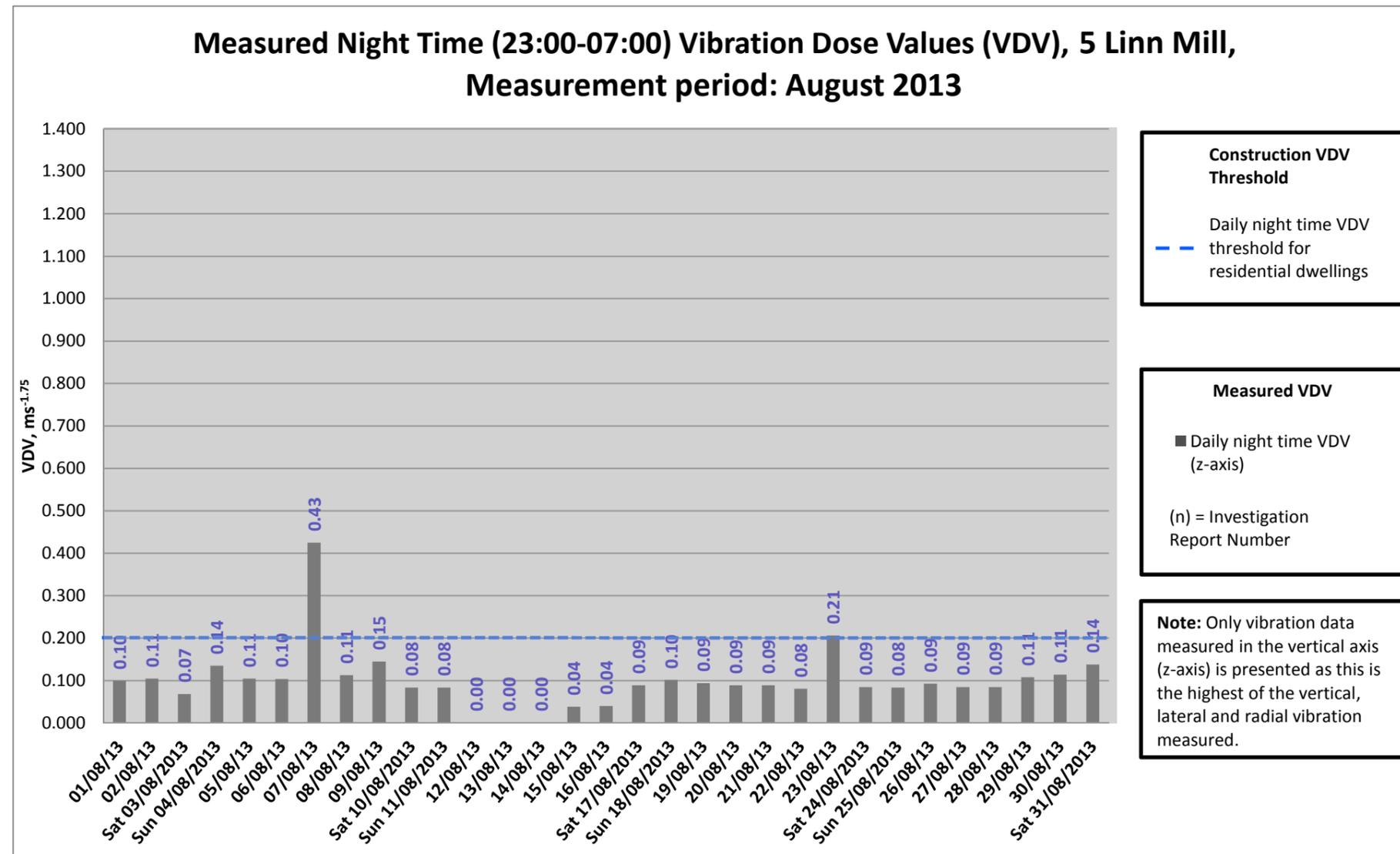
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data missing from 12/08/13, 13/08/2013 and 14/08/13 due to annual machine calibration.



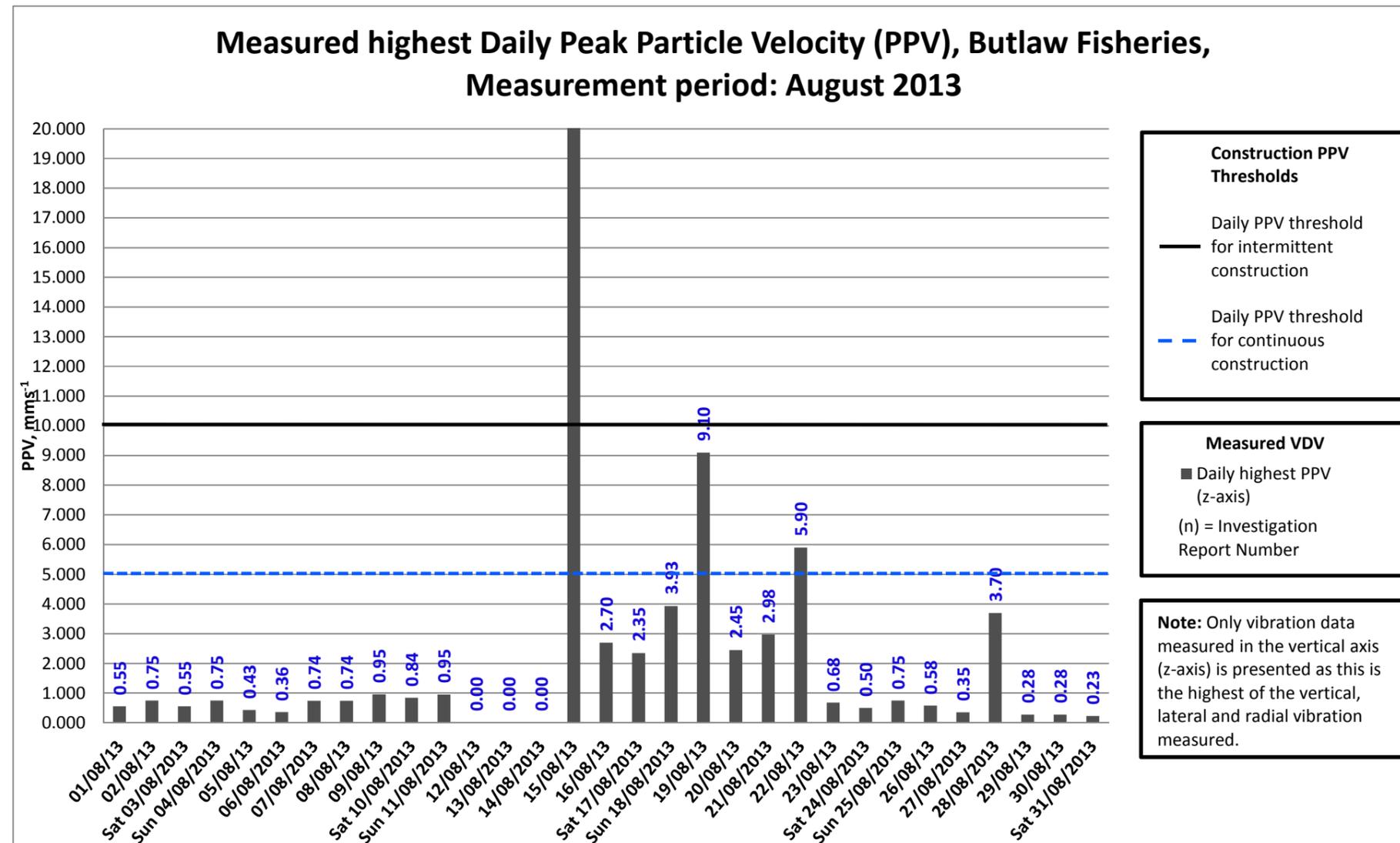
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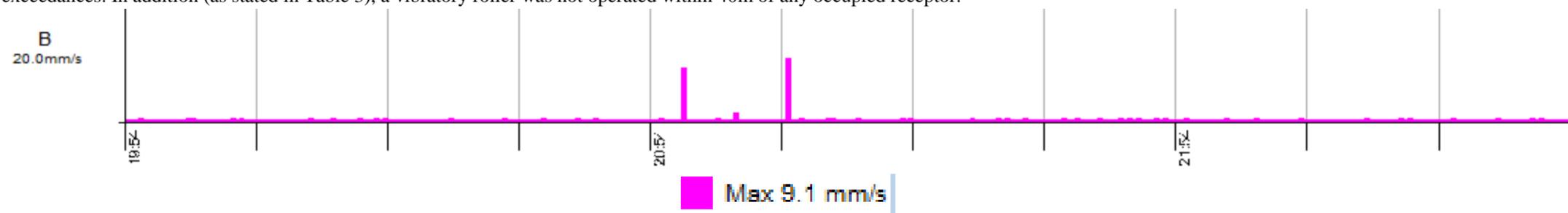
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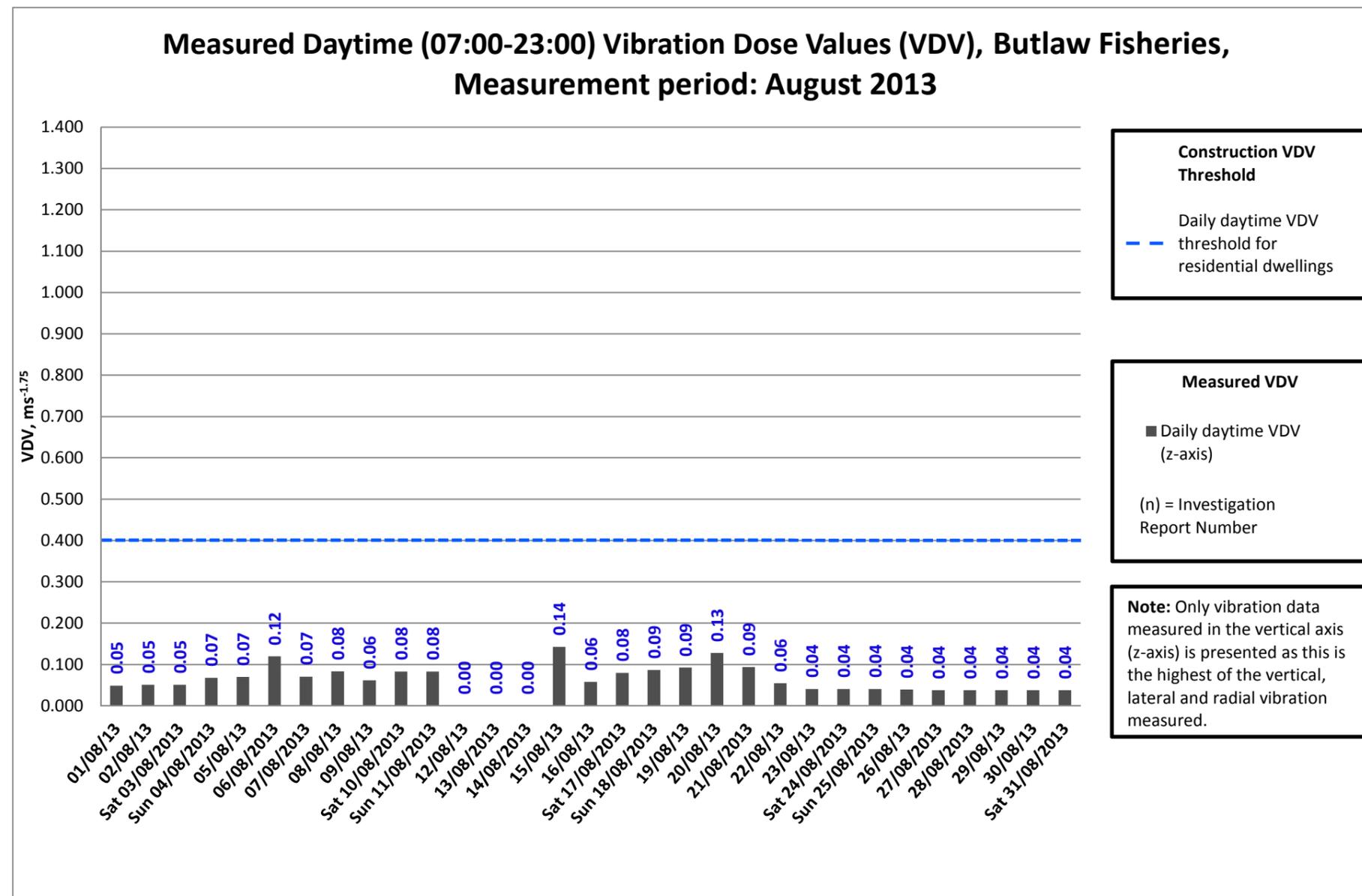
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Linn Mill vibration monitor throughout the month of August 2013. This graph is included for illustrative purposes only.
- Data missing from 12/08/13, 13/08/2013 and 14/08/13 due to annual machine calibration.



Notes:

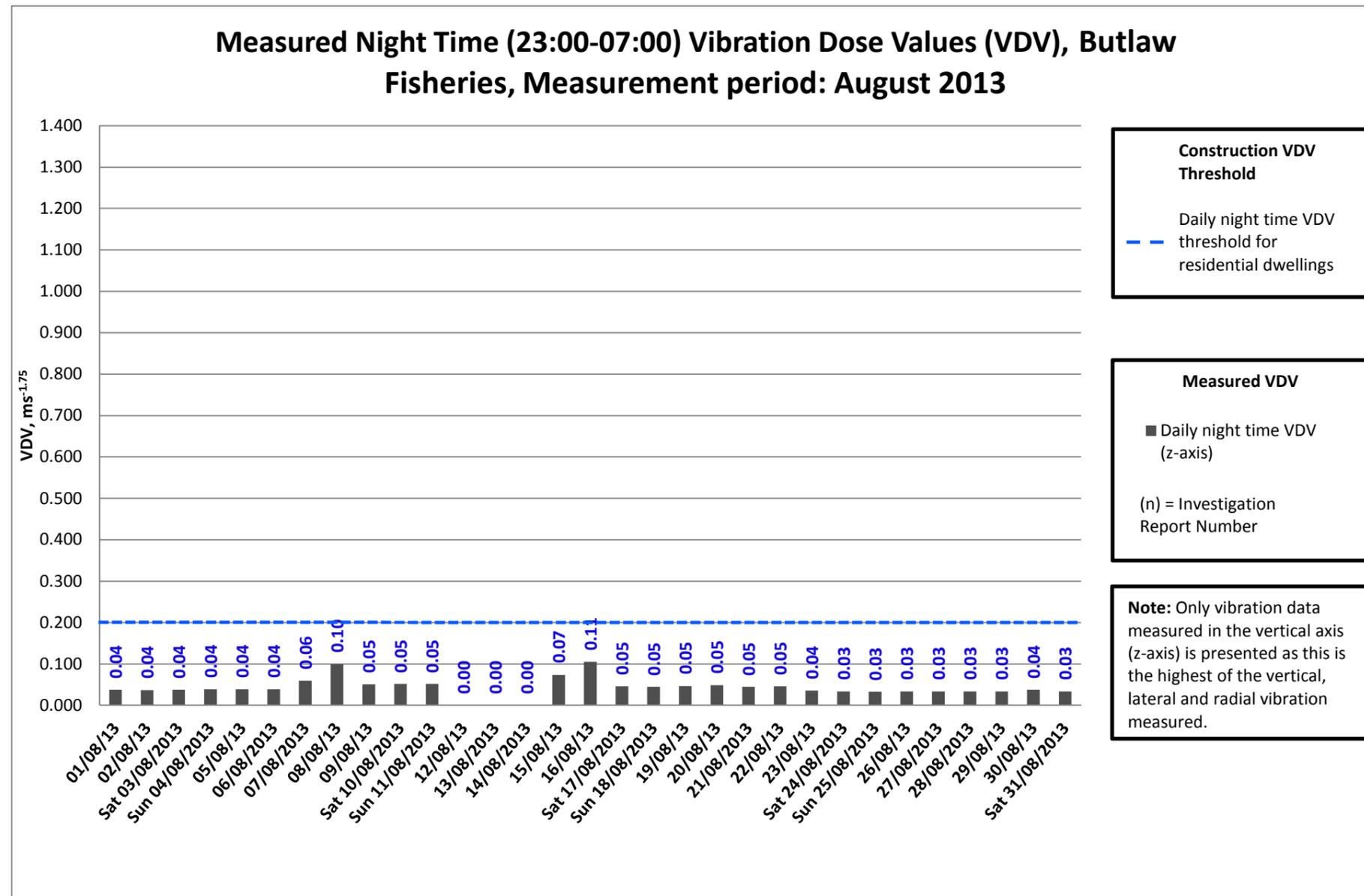
- Data missing from 12/08/13, 13/08/2013 and 14/08/13 due to annual machine calibration.
- The PPV values on 15/08/13, 19/08/13 and 22/08/13 have all been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 19/08/13. It is unlikely that these particular levels were generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, involving vibration inducing equipment were Society Road Embankment, and Pier S6 backfilling works which involved the use of a vibratory roller for certain periods. A vibratory roller exhibits continuous levels of vibrations over the period of use not intermittent, isolated levels as displayed in the above exceedances. In addition (as stated in Table 3), a vibratory roller was not operated within 40m of any occupied receptor.





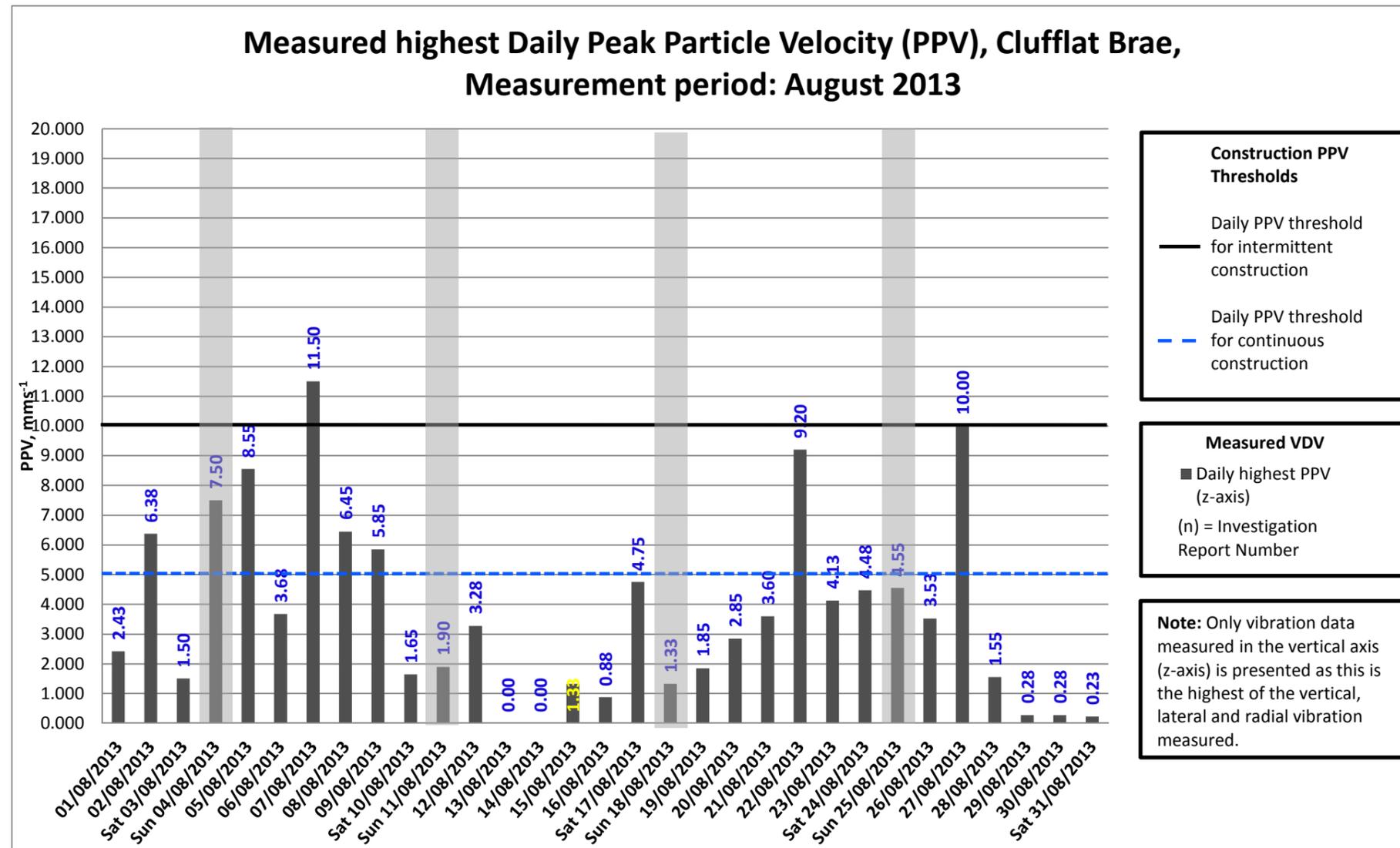
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- Data missing from 12/08/13, 13/08/2013 and 14/08/13 due to annual machine calibration



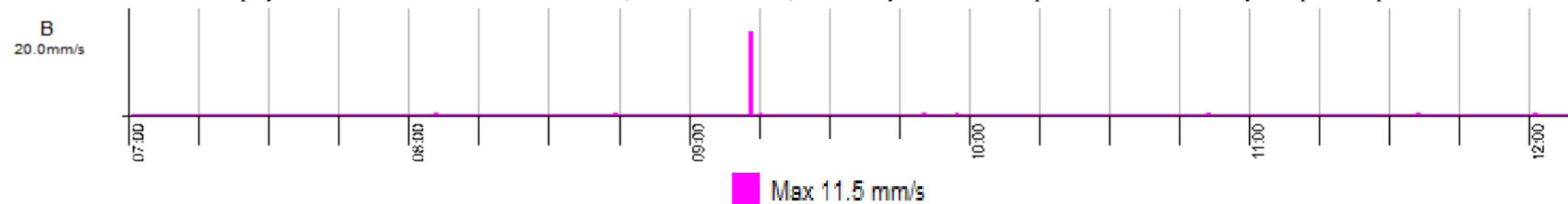
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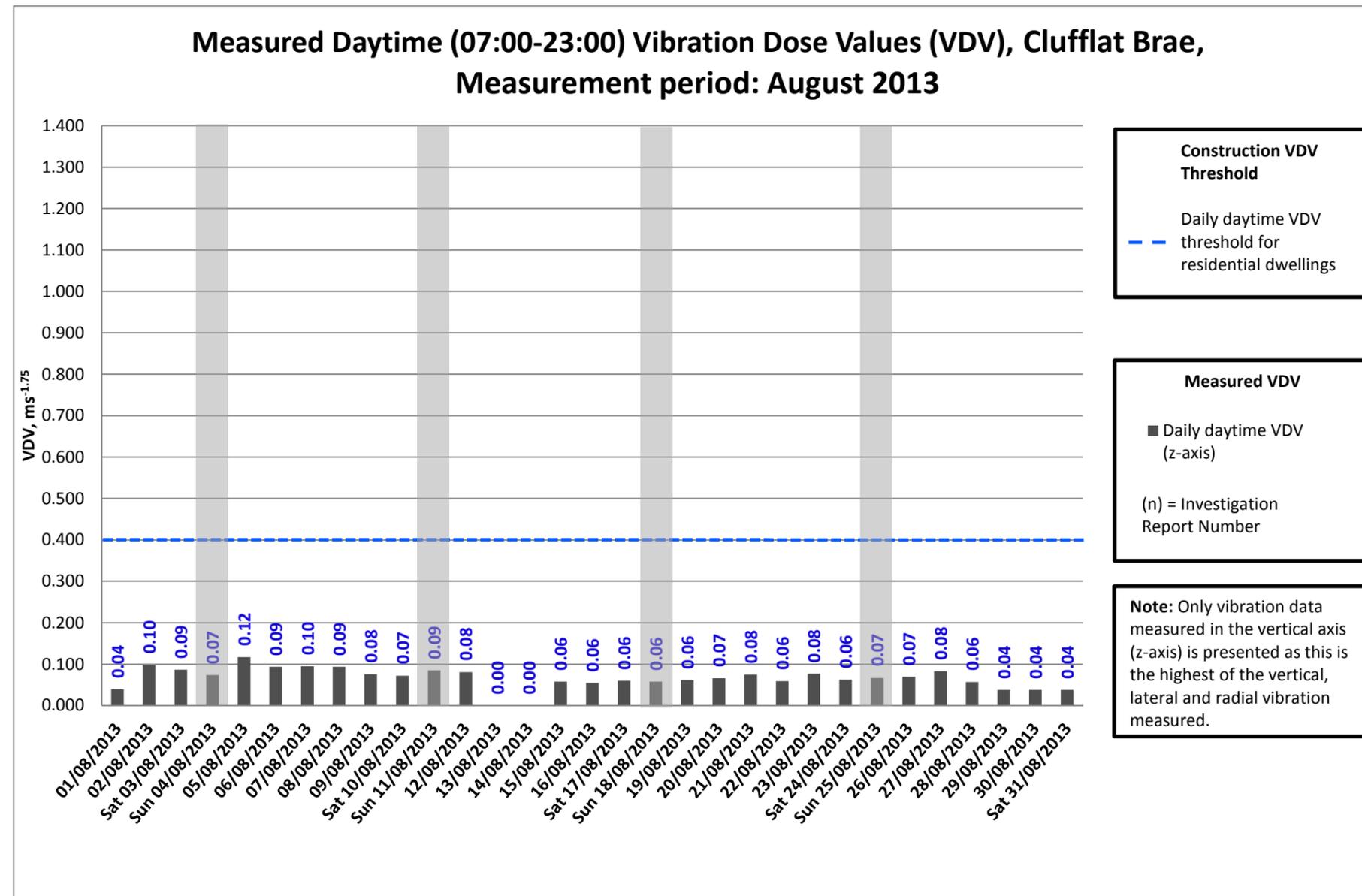
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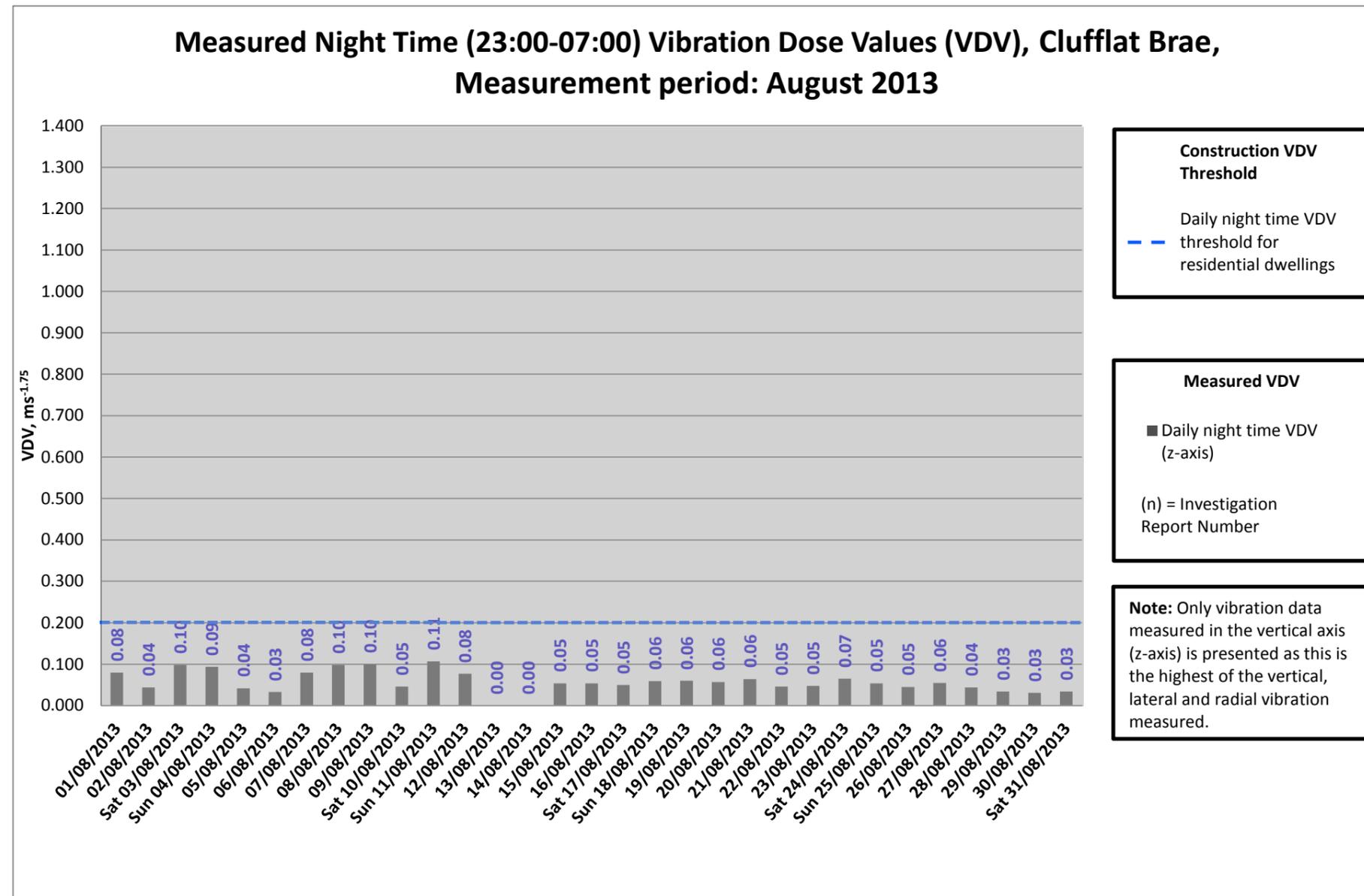
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data missing from 13/08/13 and 14/08/2013 due to annual machine calibration.
- The PPV values on 02/08/13, 05/08/13, 07/08/13, 08/08/13, 09/08/13, 22/08/13 and 27/08/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 07/08/13). Furthermore, it is extremely unlikely that these particular levels were generated as a result of FCBC construction, as the only works to be conducted in the vicinity of the monitor on any of these dates in question, involving vibration inducing plant, were backfilling and assembly of stillages, which involved the use of a vibratory roller for certain periods. A vibratory roller exhibits continuous levels vibration over the period of use, not intermittent, isolated levels as displayed in the above exceedances. In addition (as stated in Table 3), a vibratory roller was not operated within 40m of any occupied receptor.



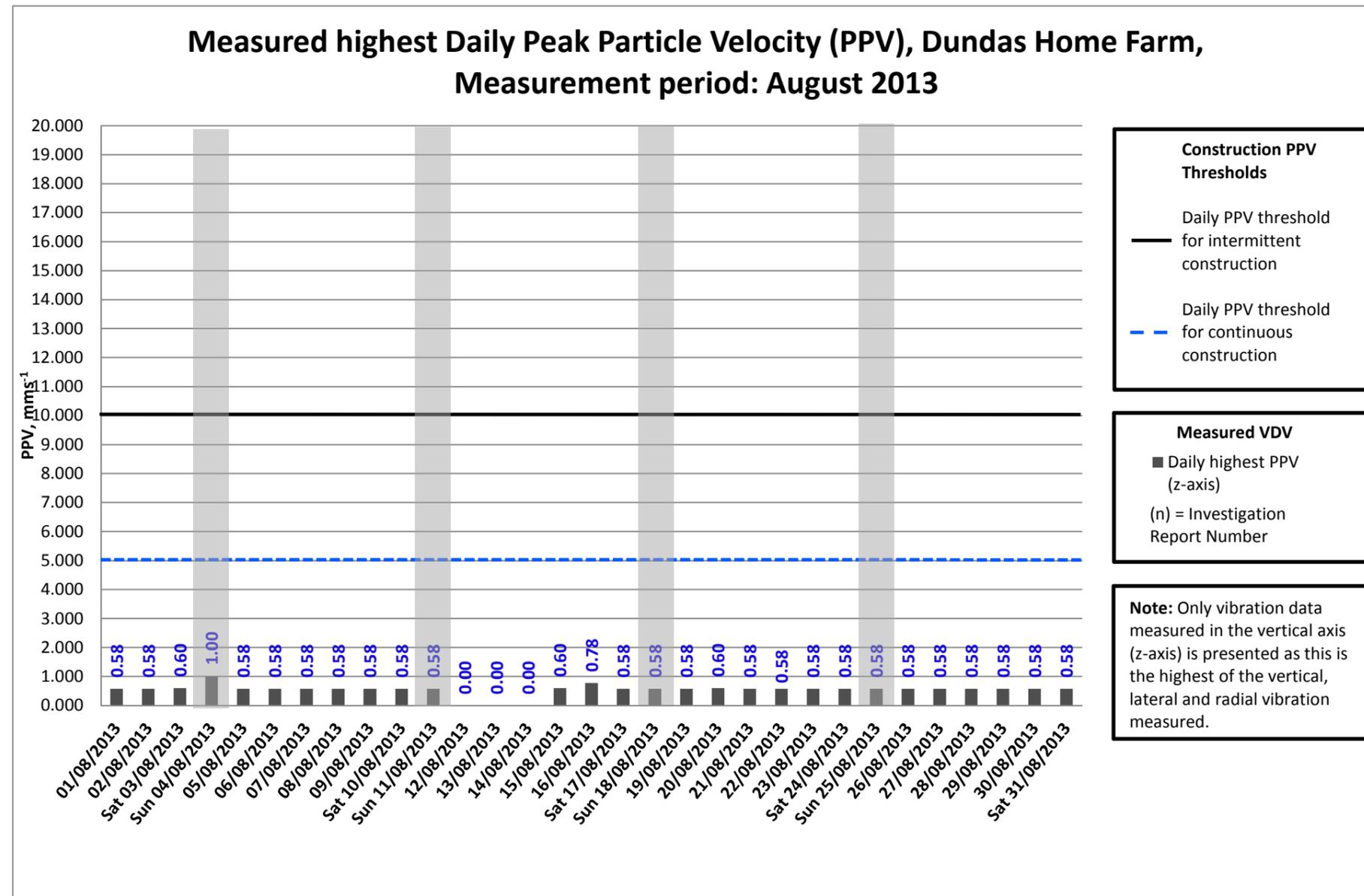


Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data missing from 13/08/13 and 14/08/13 due to annual machine calibration.

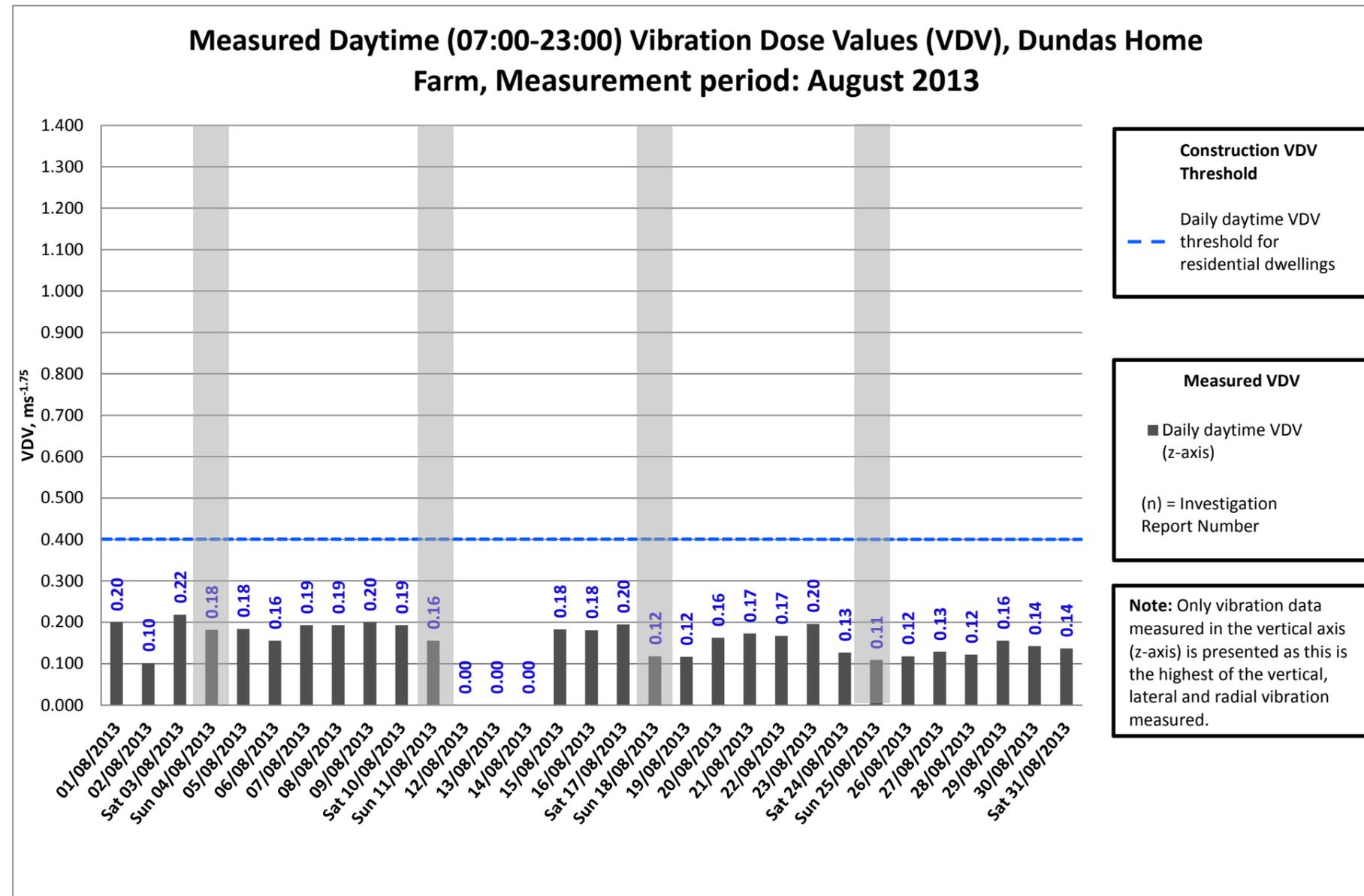


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Clufflat Brae vibration monitor throughout the month of August 2013. This graph is included for illustrative purposes only.
 - Data missing from 13/08/13 and 14/08/13 due to annual machine calibration.



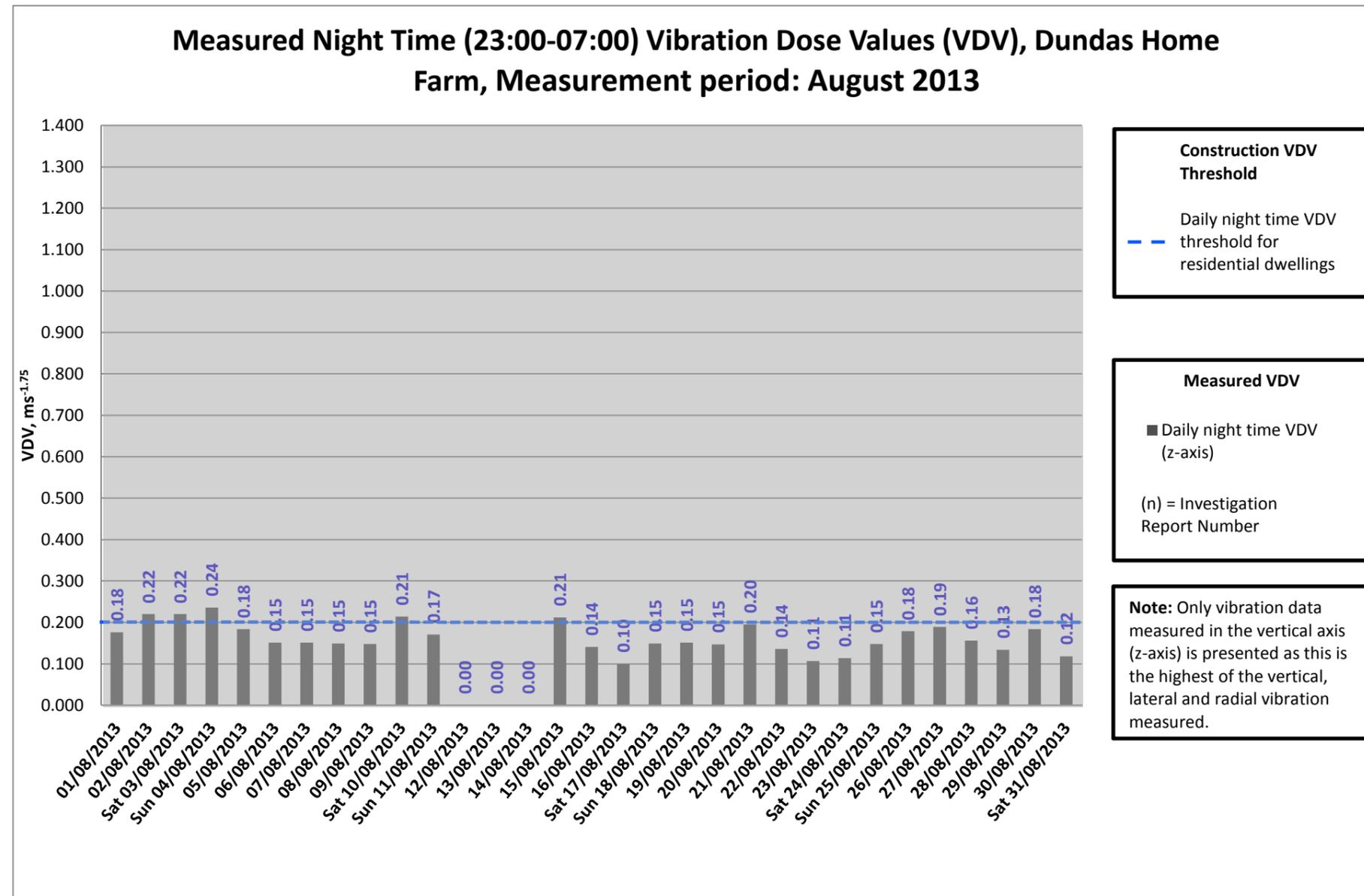
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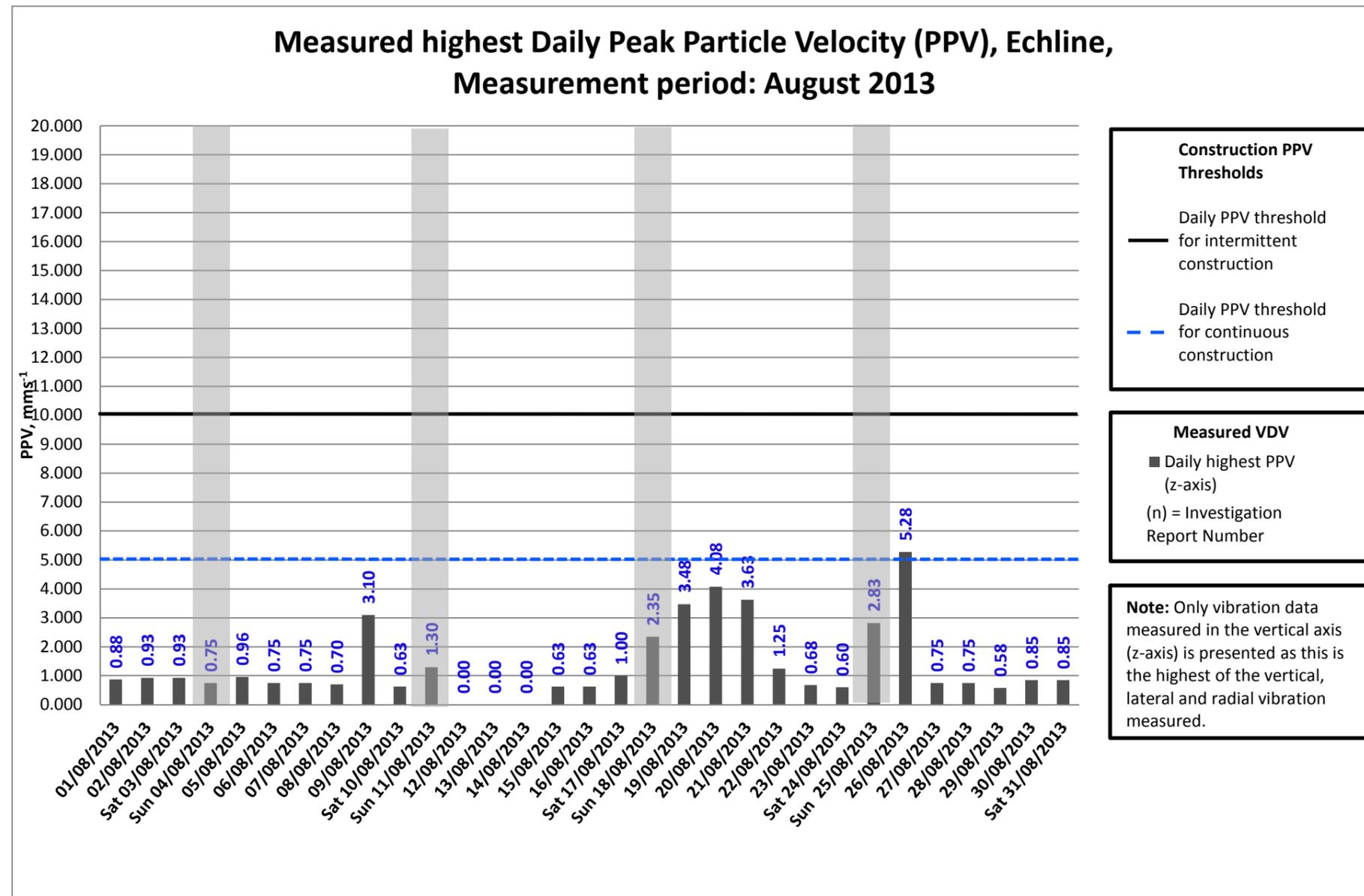
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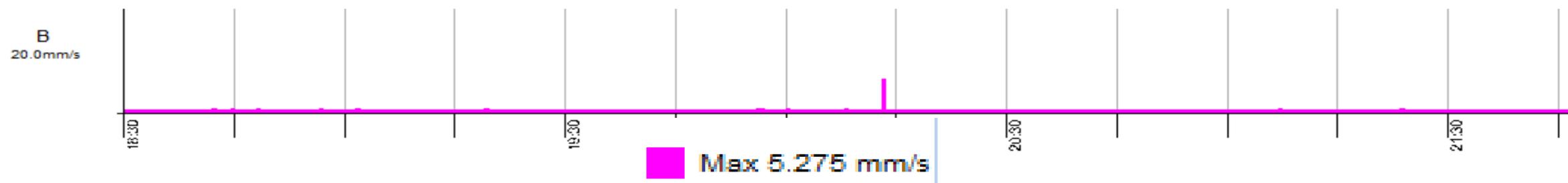
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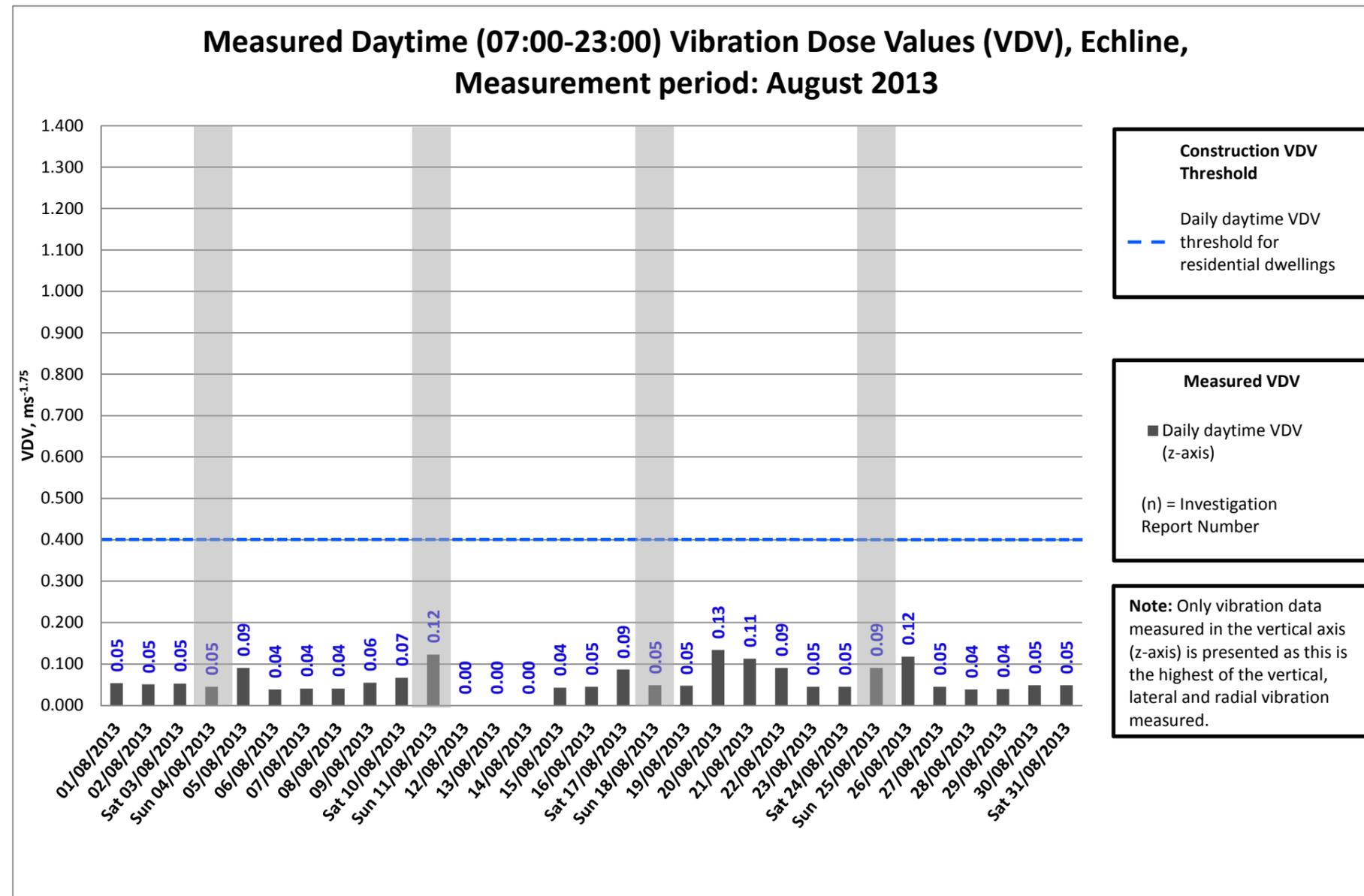
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas vibration monitor throughout the month of August 2013. This graph is included for illustrative purposes only.
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Notes

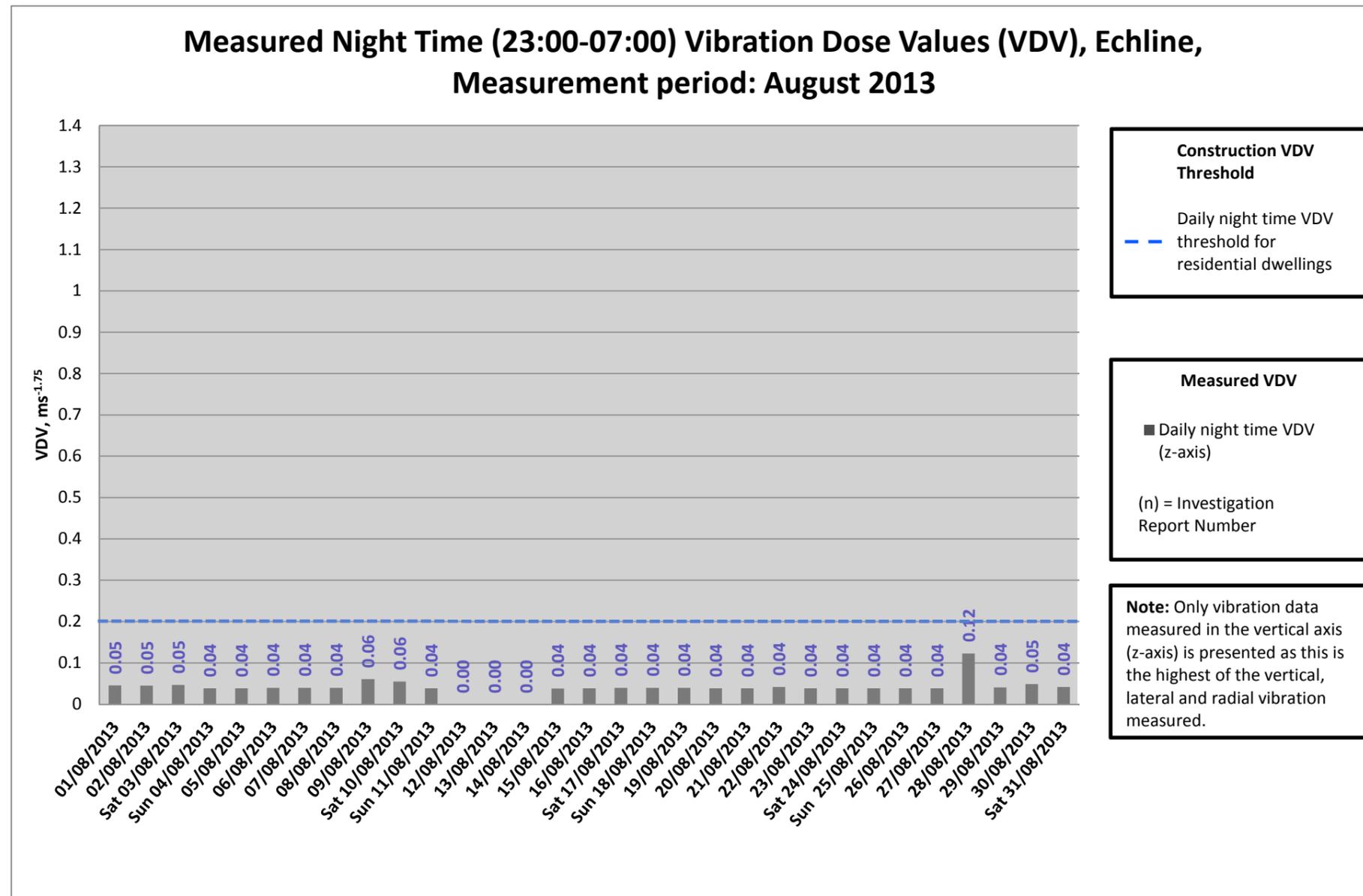
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data missing from 12/08/13, 13/08/13 and 14/08/13 due to annual machine calibration.
- The PPV value on the 26/08/13 has been investigated, and has been seen to be individual, isolated event (see Vibrock PPV graph below from 26/08/13). Furthermore, it is extremely unlikely that these particular levels were generated as a result of FCBC construction, as the only works to be conducted in the vicinity of the monitor on any of these dates in question, involving vibration inducing plant, were backfilling and assembly of stillages, which involved the use of a vibratory roller for certain periods. A vibratory roller exhibits continuous levels vibration over the period of use, not intermittent, isolated levels as displayed in the above exceedances. In addition (as stated in Table 3), a vibratory roller was not operated within 40m of any occupied receptor.





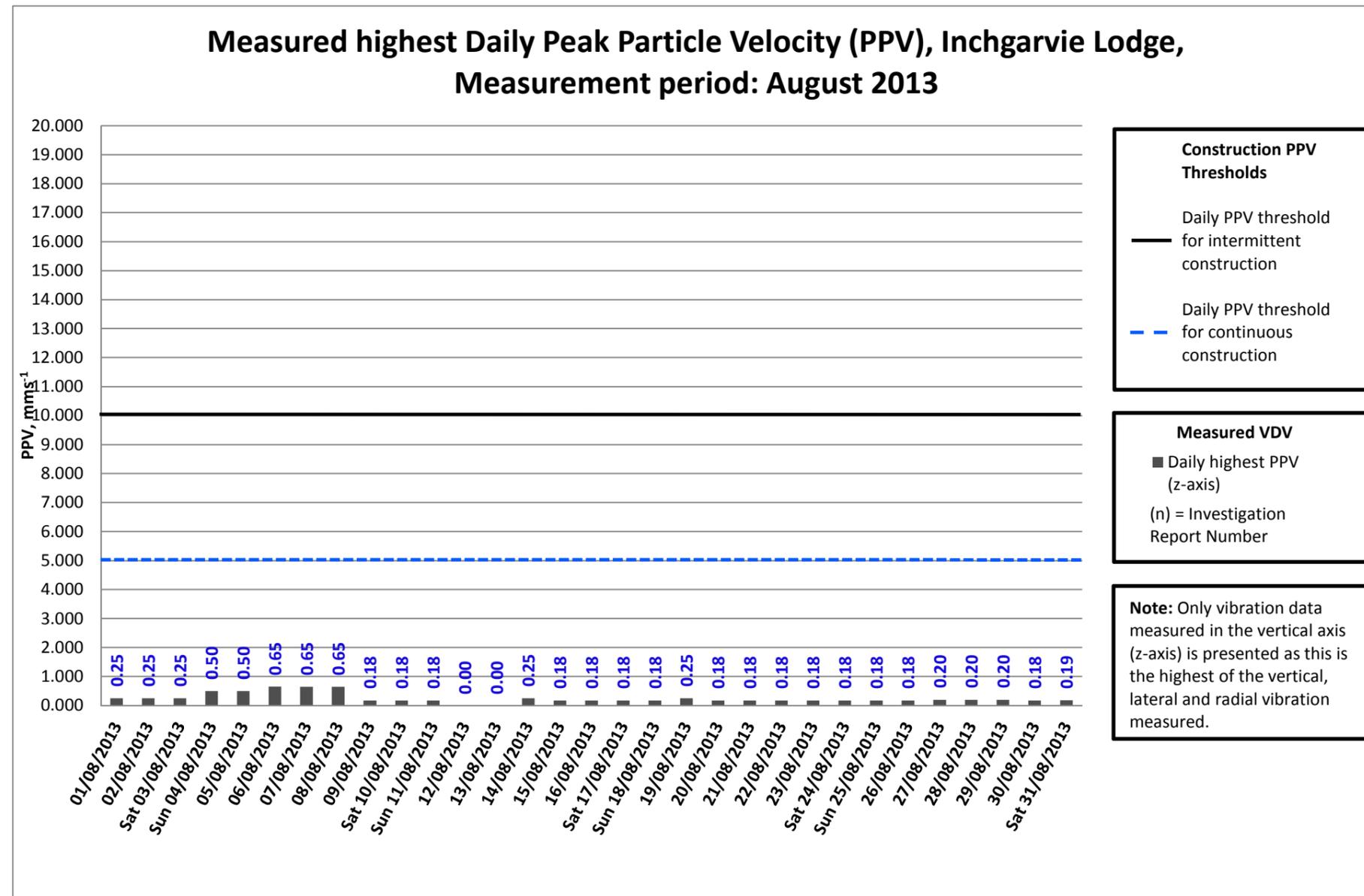
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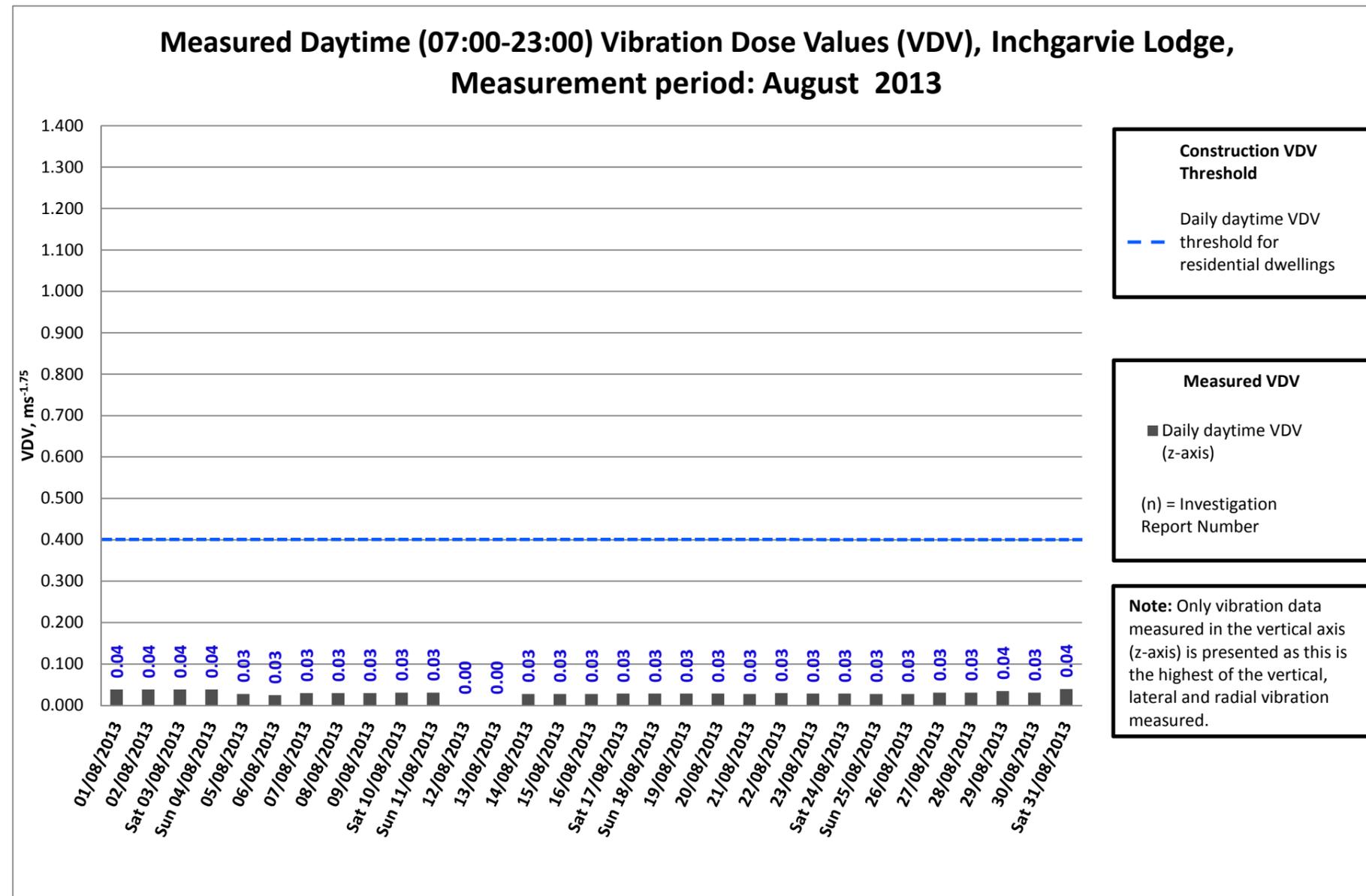
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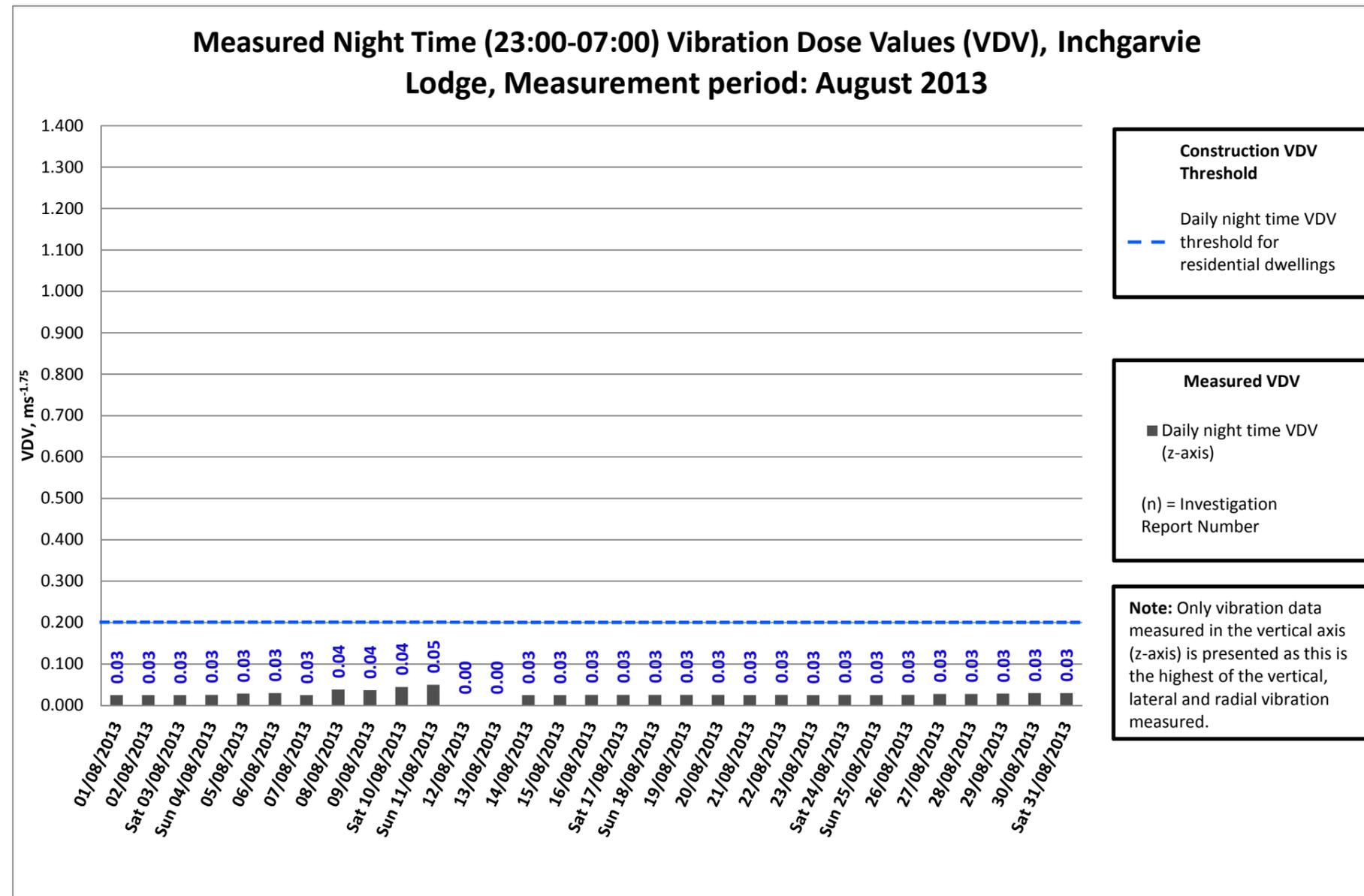
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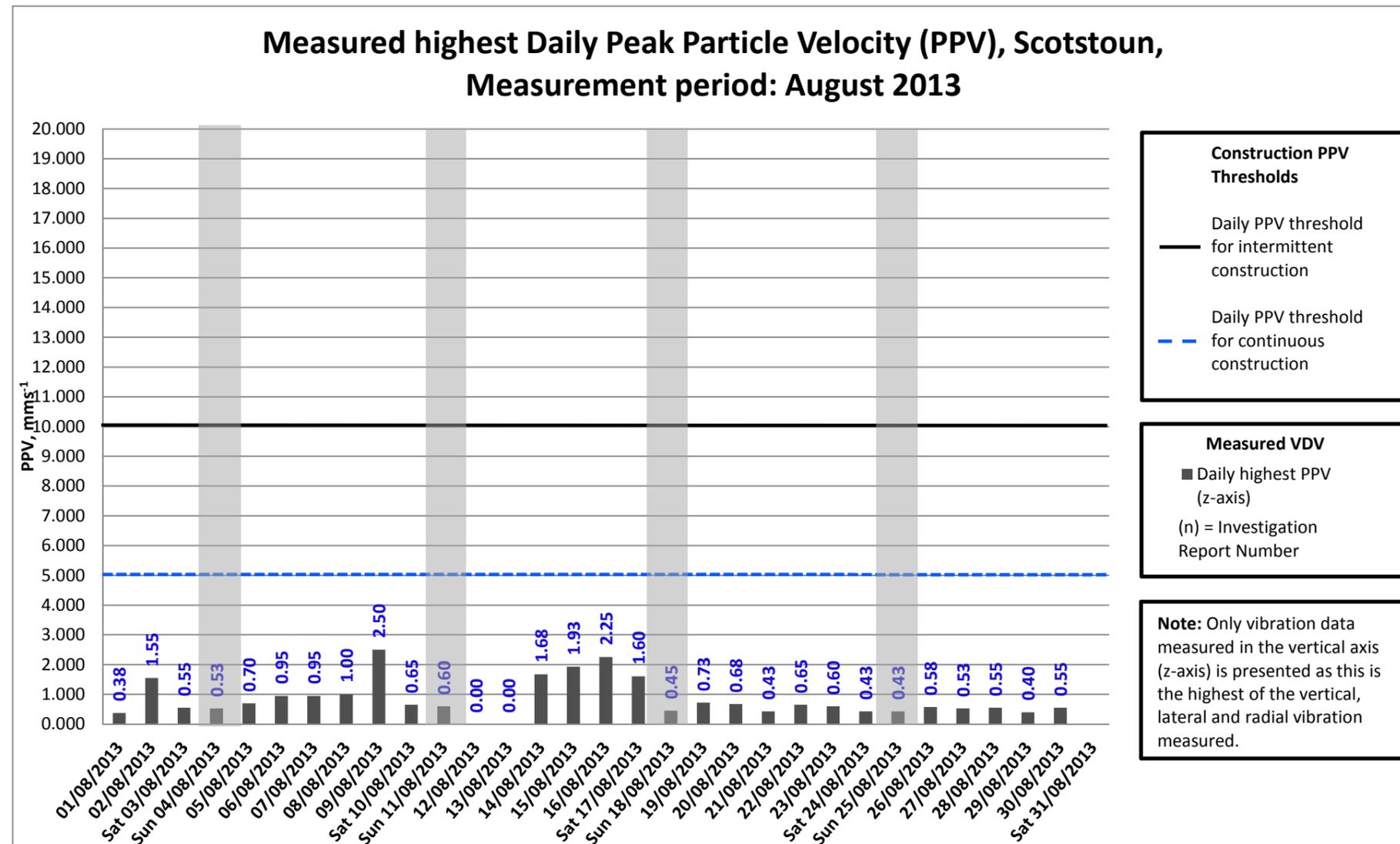
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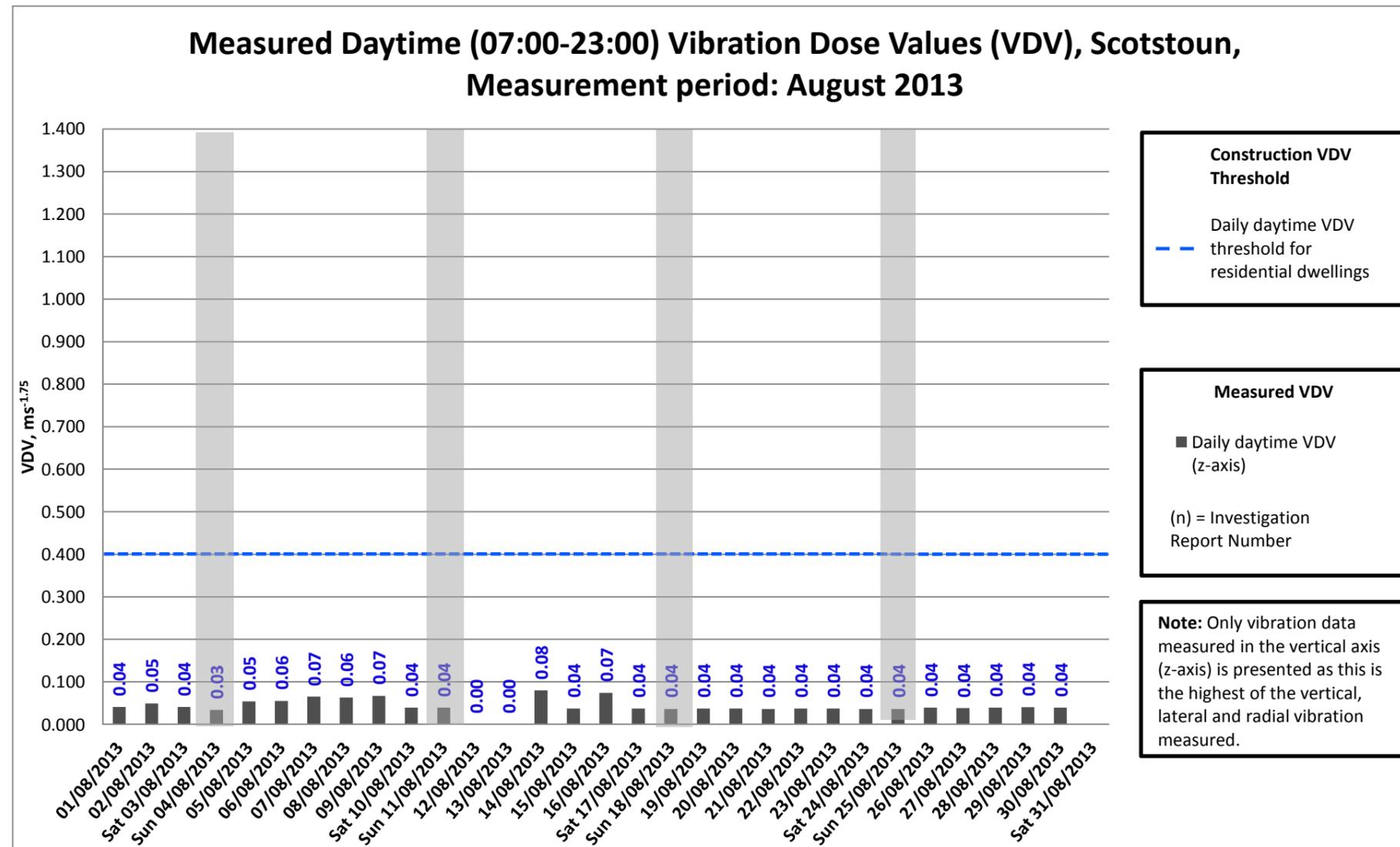
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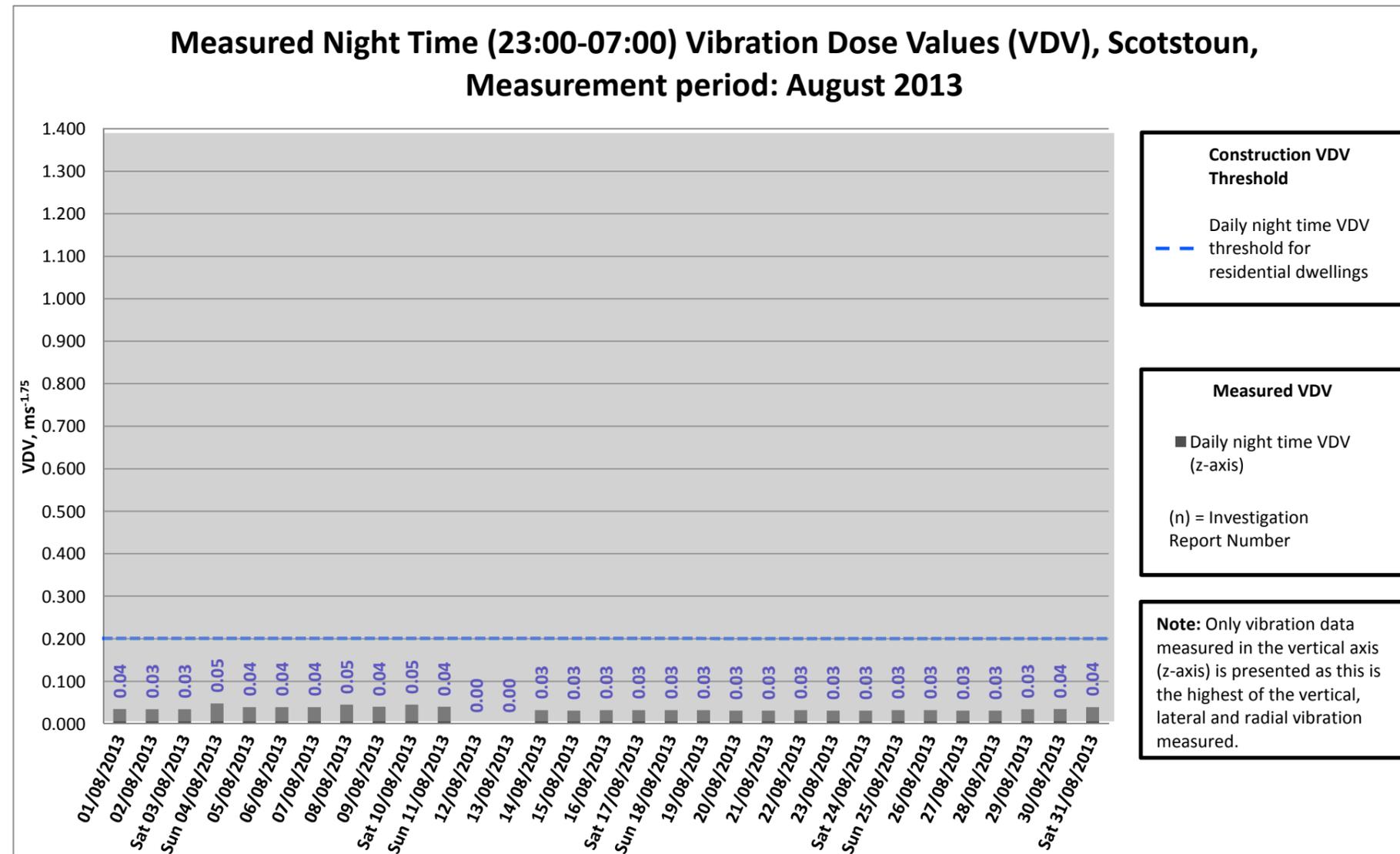
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- Data missing from thee 12/08/13 and 13/08/13 due to annual machine calibration.



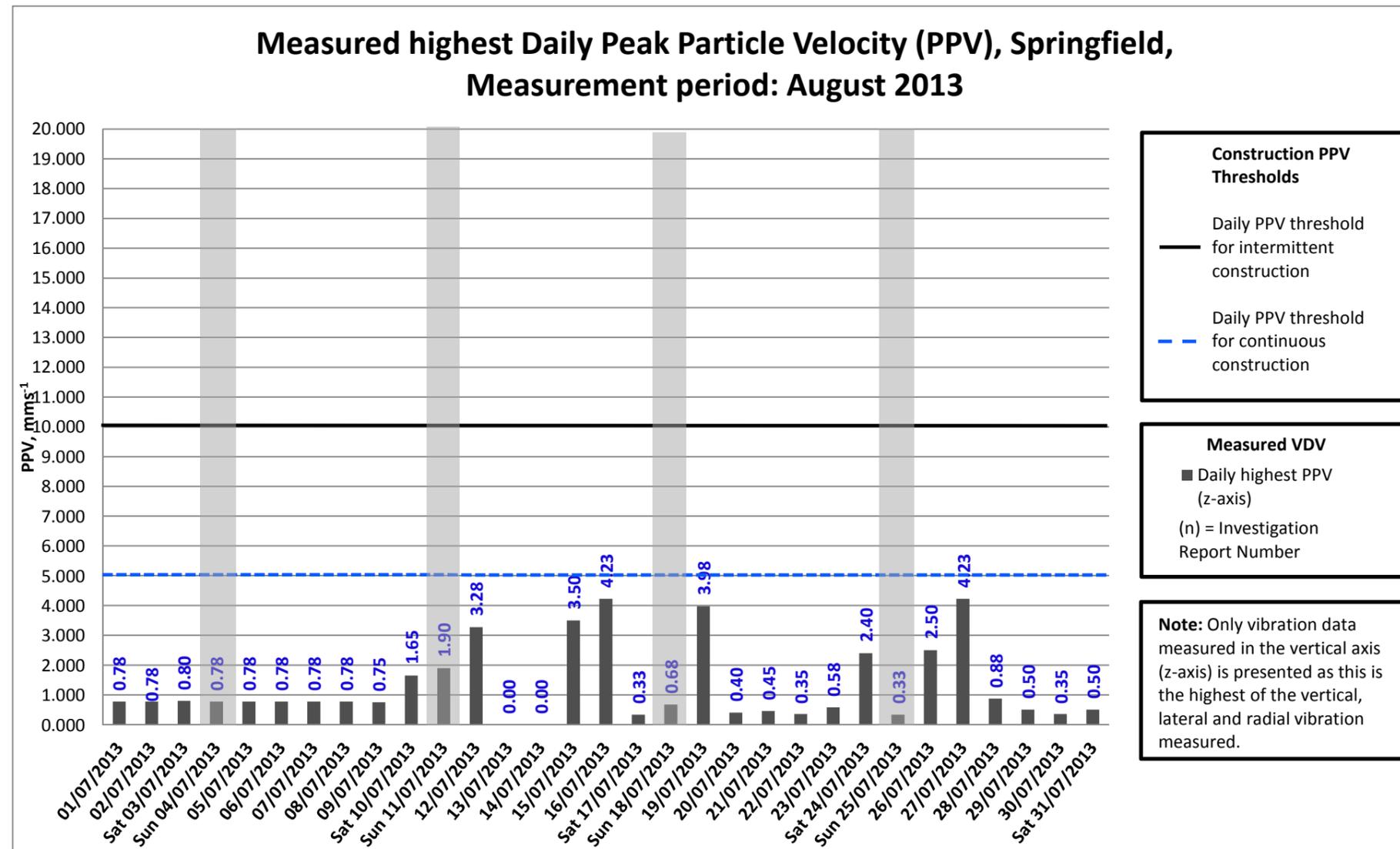
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- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
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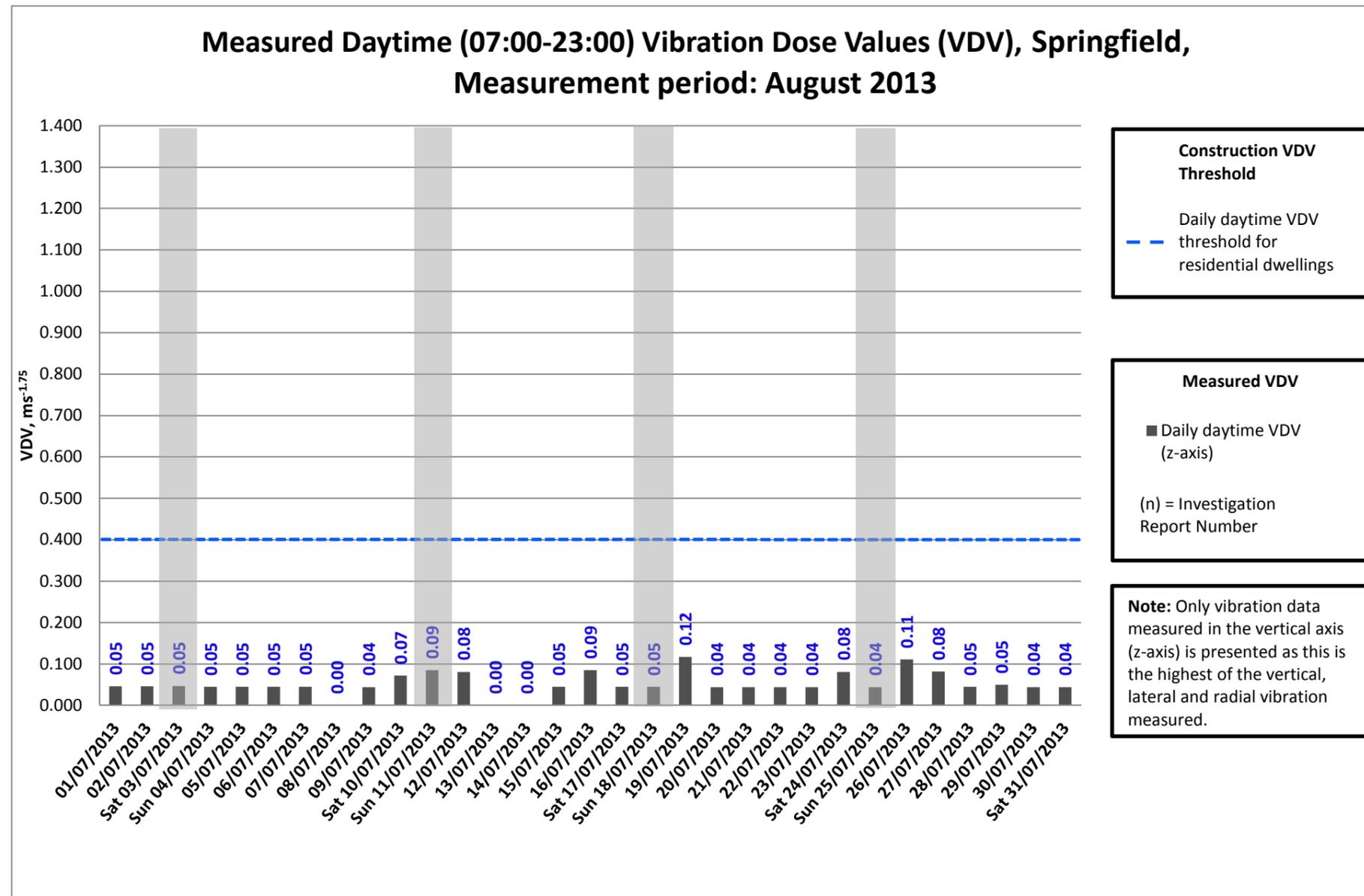
Notes:

- 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 August 2013. This graph is included for illustrative purposes only.
- Data is missing from 12/08/13 and 13/08/13 due to annual machine calibration.



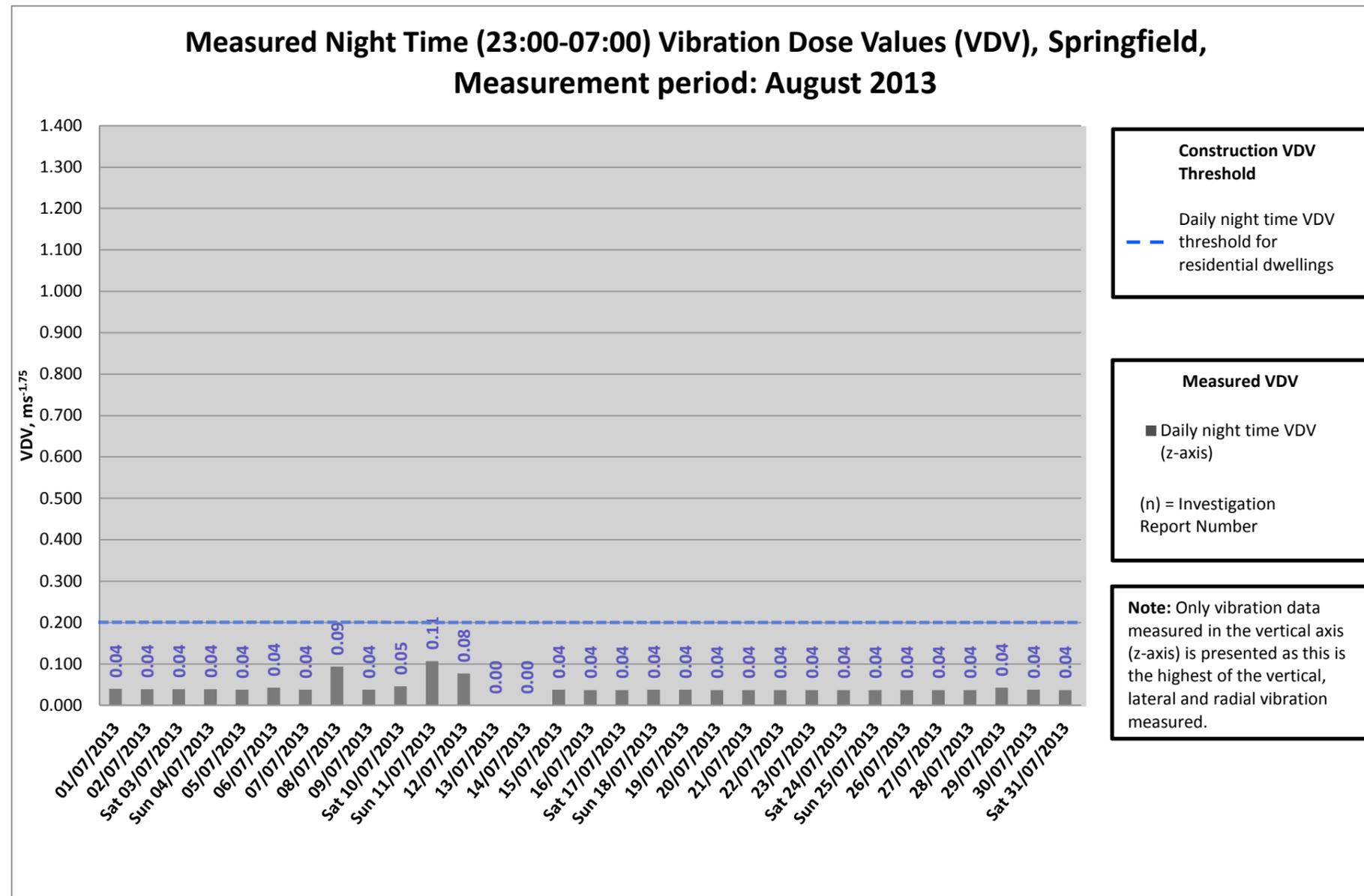
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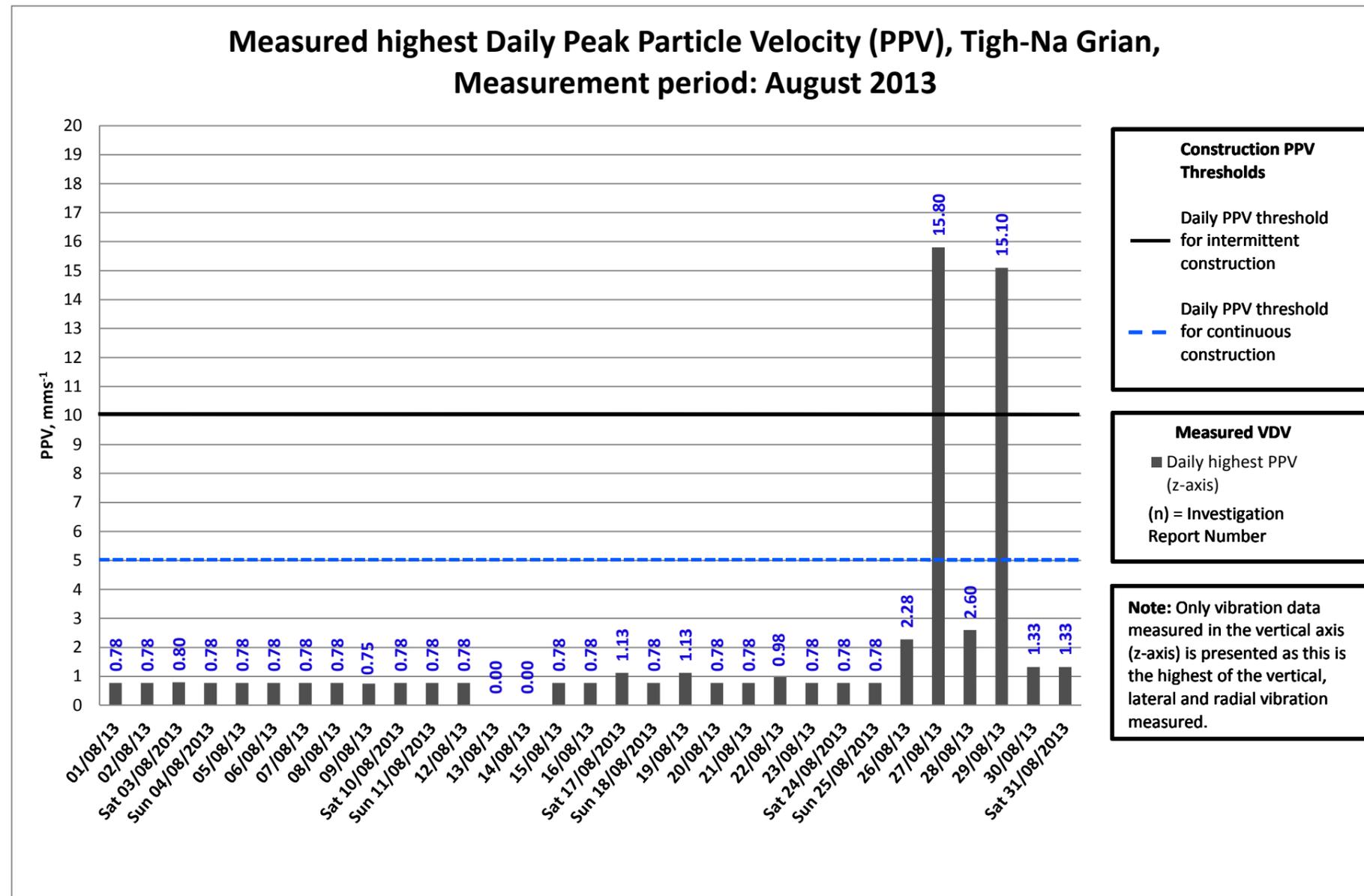


Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sunday.
- Data missing from 13/08/13 and 14/08/13 due to annual machine calibration.

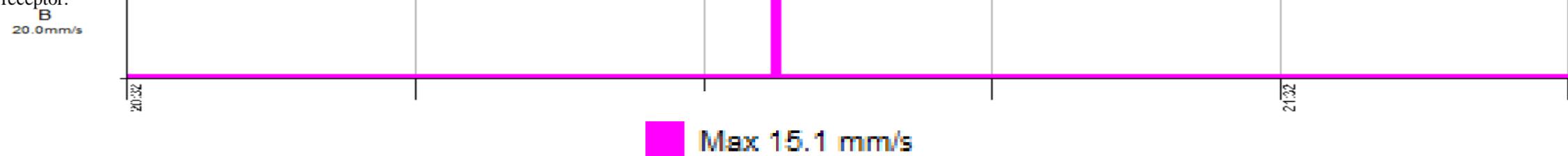


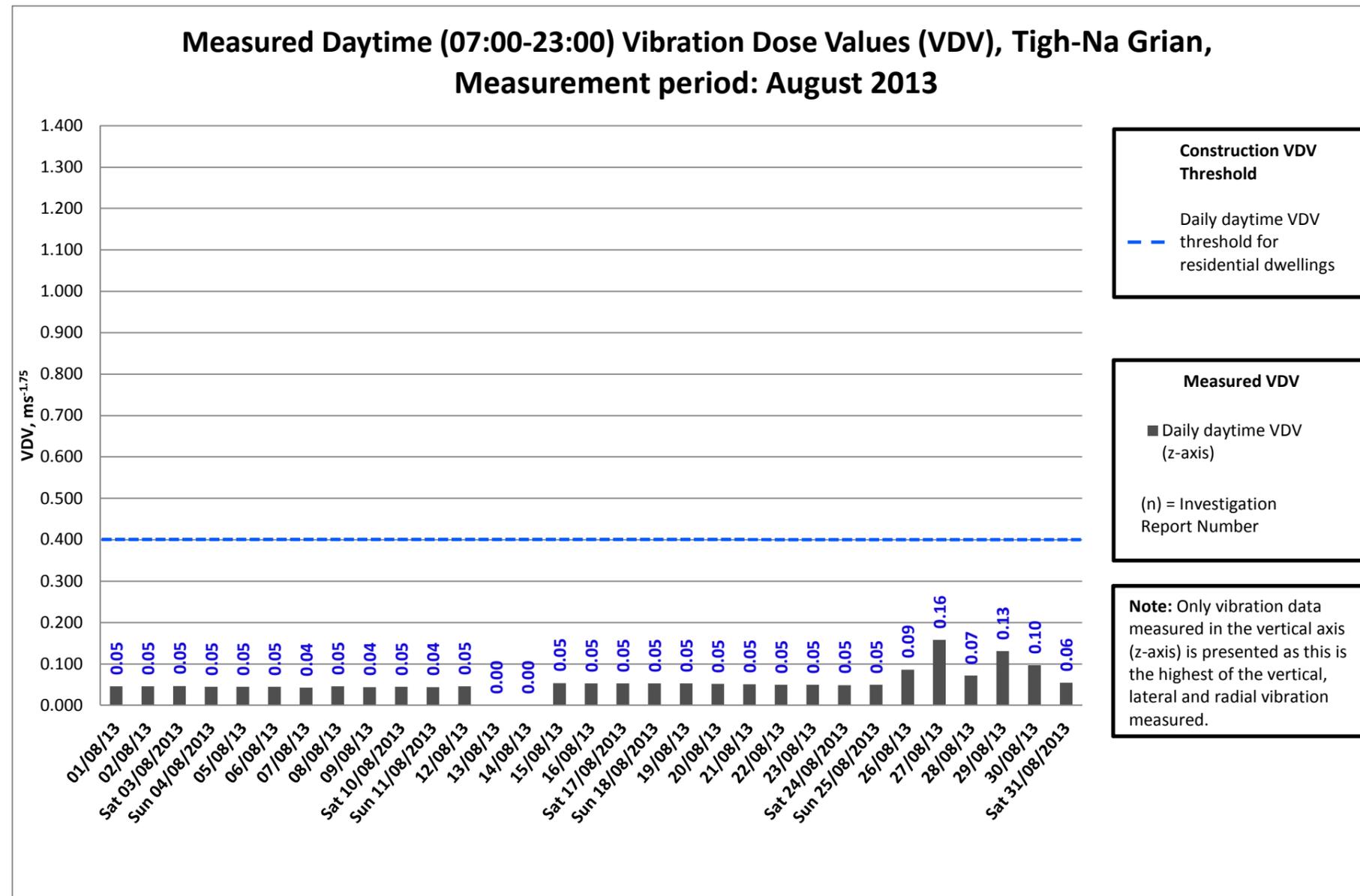
- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of August 2013. This graph is included for illustrative purposes only.
 - Data missing from 13/08/13 and 14/08/13 due to annual machine calibration.



Notes:

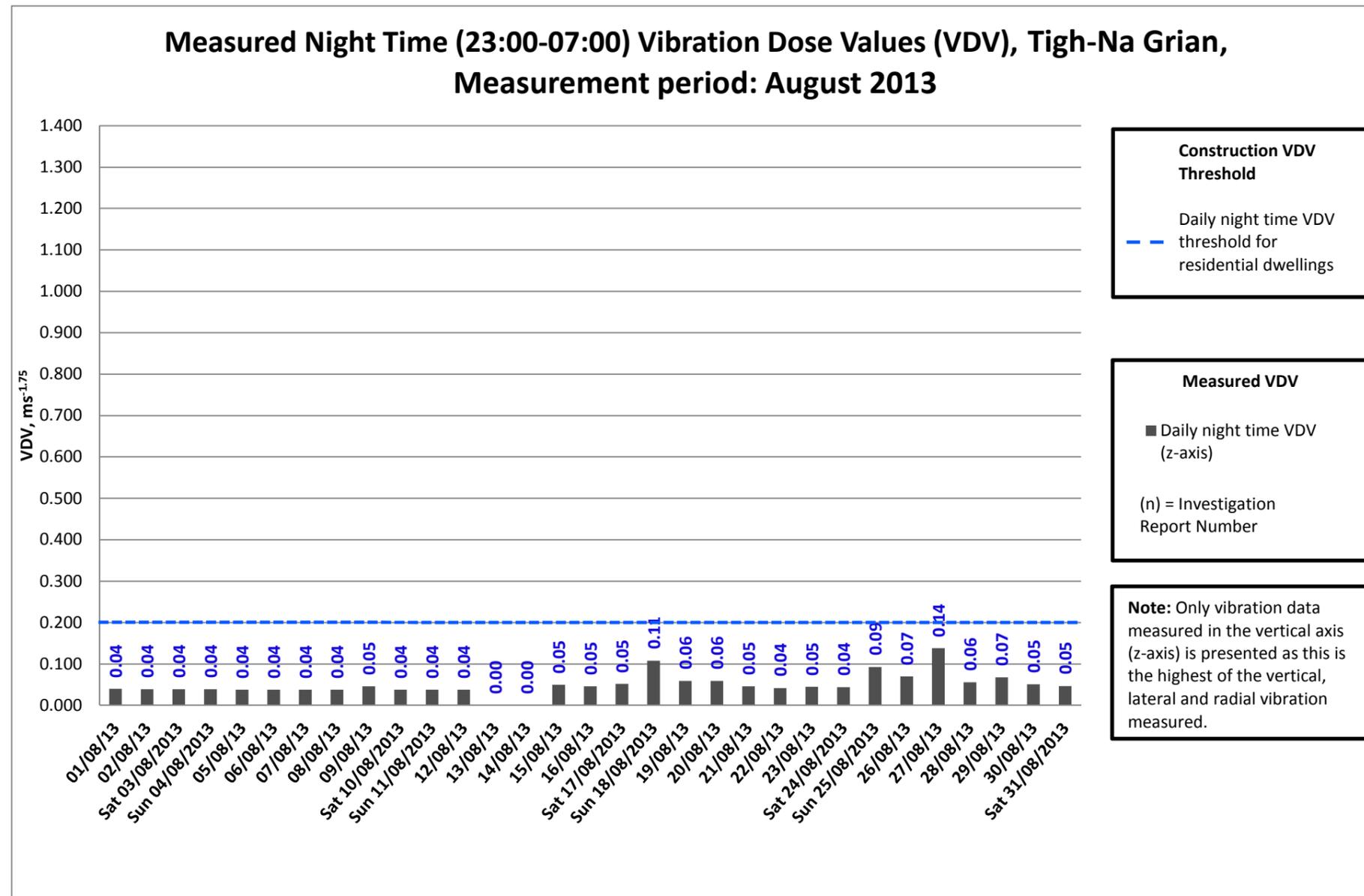
- Data missing from 13/08/13 and 14/08/13 due to annual machine calibration.
- The PPV values on the 27/08/13 and 29/08/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 27/08/13). Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only the works to be conducted throughout the month of August in vicinity of the monitor, were piling works at the North Tower, which is over 250m from the receptor.





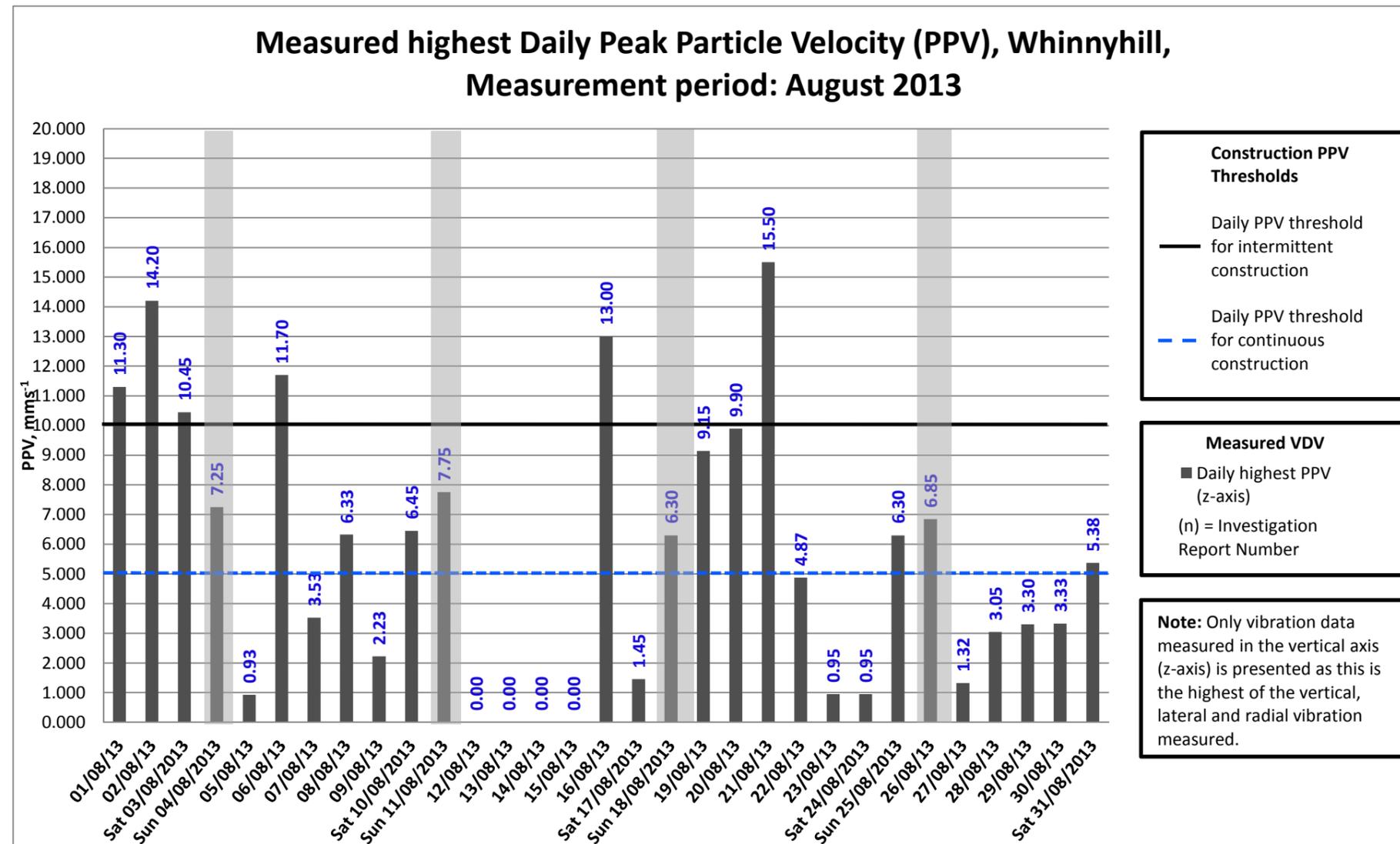
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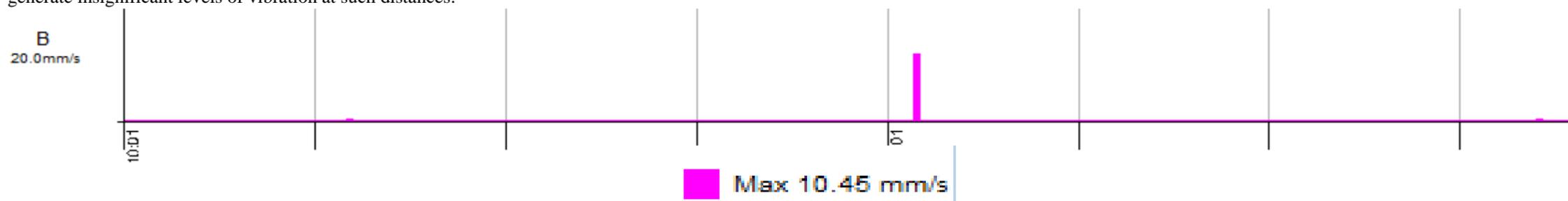
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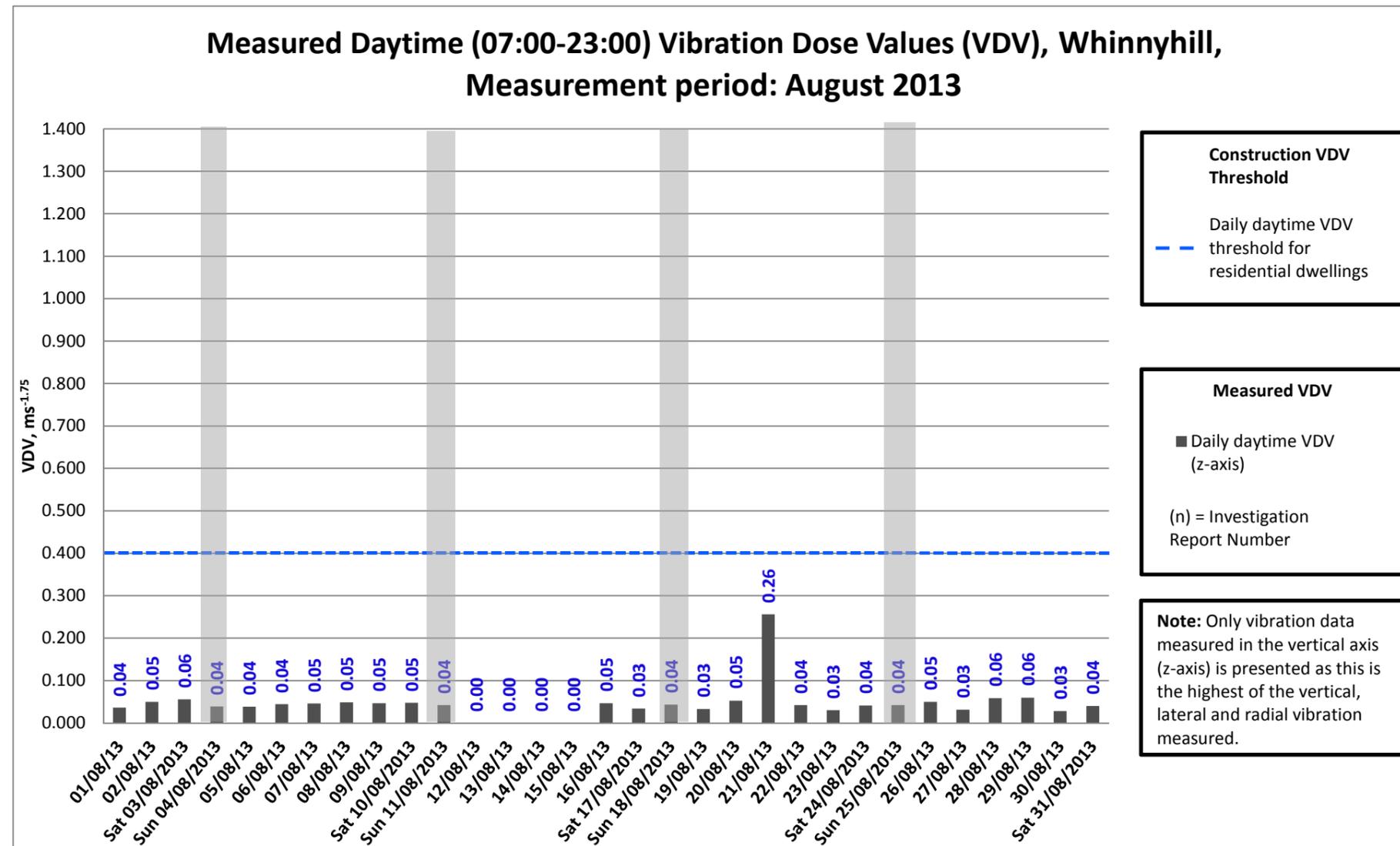
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Notes:

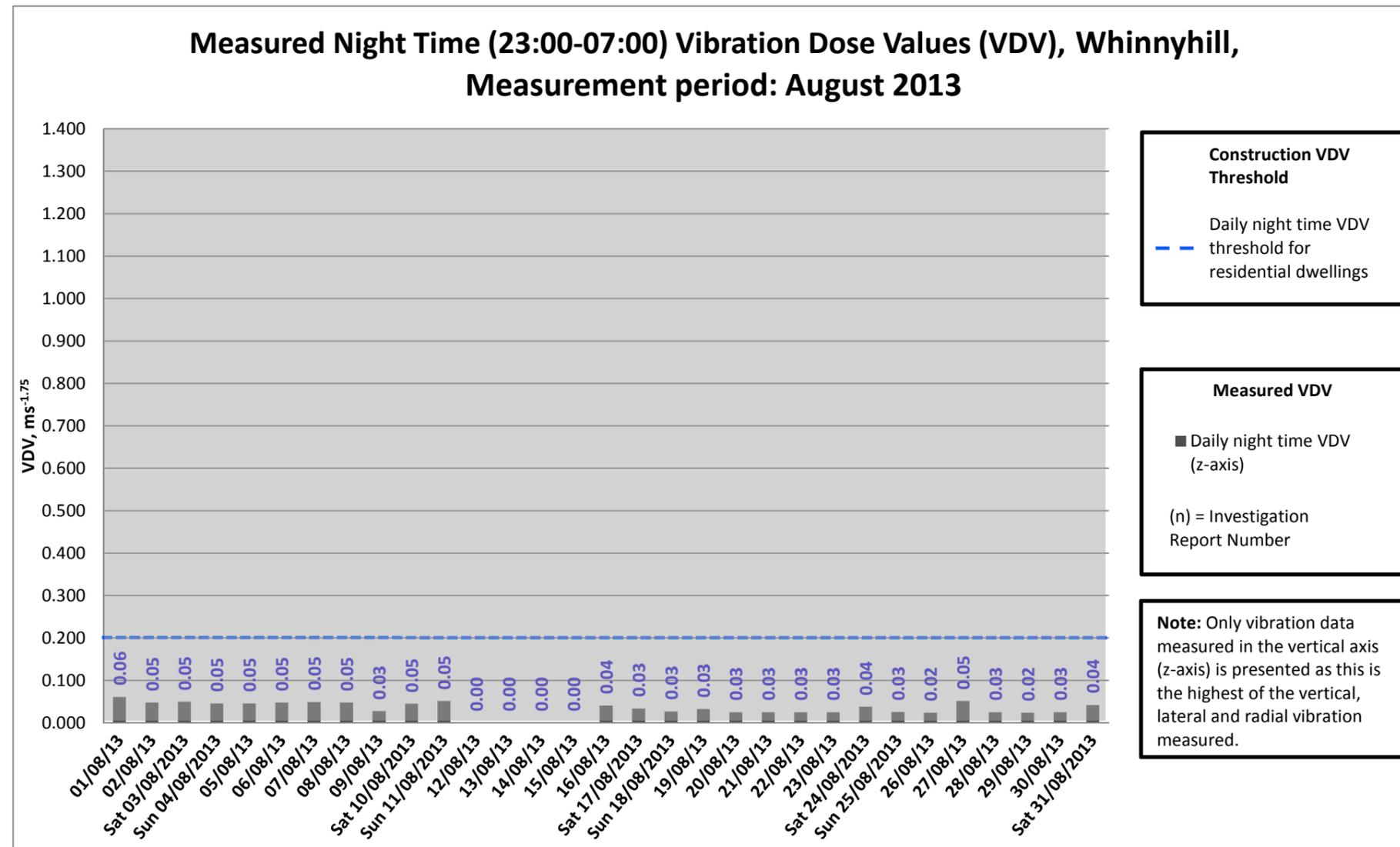
- Data missing from 12/08/13, 13/08/13, 14/08/13 and 15/08/13 due to annual machine calibration.
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 01/08/13, 02/08/13, 03/08/13, 04/08/13, 06/08/13, 08/08/13, 10/08/13, 11/08/13, 16/08/13, 18/08/13, 19/08/13, 20/08/13, 21/08/13, 25/08/13 and 26/08/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 02/08/13), the majority of which are within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only work to be conducted throughout the month of August in the vicinity of the monitor, was the band drains at King Malcolm Drive and the breaking and excavation of rock at Castlandhill Road, which are a minimum distance of 270m from the monitor, and did not involve the use of any vibration inducing plant or equipment other than a rock breakers, which (as detailed in the footnote to Table 3), generate insignificant levels of vibration at such distances.





Notes:

- Data missing from 12/08/13, 13/08/13, 14/08/13 and 15/08/13 due to annual machine calibration.
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.



Notes:

- Data missing from 12/08/13, 13/08/13, 14/08/13 and 15/08/13 due to annual machine calibration.
- 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 August 2013. This graph is included for illustrative purposes only.