




Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

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 February 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

March 2013

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})
Butlaw Fisheries	0	0	0	0
Clufflat Brae	3	1	0	0
Dundas Home Farm	0	0	0	0
Echline	5	0	0	0
Inchgarvie Lodge	0	0	0	0
Linn Mill	4	8	0	0
Scotstoun	0	0	0	0
Springfield	0	0	0	0
Tigh-Na-Grian	0	13	0	2
Whinnyhill	5	7	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 VDV 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 January 2013
M1	Whinny Hill	Network	<p>Breaking of rock Loading of rock Drilling and Blast 15 (conducted 01/03/13)</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M3	Tigh-Na-Grian	Crossing	<p>Placement of Central Tower cofferdam North Tower caisson excavation North Tower jet grouting</p>
M7	Butlaw Fisheries	Crossing	<p>Placement & dewatering of Central Tower cofferdam South Tower jet grouting Pier S1 caisson excavation Pier S4 excavation & concrete works Pier S5 excavation & concrete works Excavation & Breaking works at pier S6 Drilling for de-stressing wells at pier S6 Backfilling at pier S7</p>
M10	Inchgarvie Lodge	Crossing	<p>South Tower jet grouting Pier S1 caisson excavation Pier S4 excavation & concrete works Pier S5 excavation & concrete works Excavation & Breaking works at pier S6 Drilling for de-stressing wells at pier S6 Backfilling at pier S7 Excavation and temporary drainage works at launch Stabilising batters at launch Works at South Abutment, including erection of reinforcement and formwork</p>
M11	Linn Mill	Network	<p>Backfilling at pier S7 Excavation and temporary drainage works at launch Stabilising batters at launch Works at South Abutment, including erection of reinforcement and formwork</p> <p>N.B. No evening, night time or Sunday daytime construction in vicinity.</p>
M13	Clufflat Brae	Crossing	<p>Backfilling at pier S7 Excavation and temporary drainage works at launch Stabilising batters at launch Works at South Abutment, including</p>

			erection of reinforcement and formwork
M14	Springfield	Network	Excavation and temporary drainage works at launch Stabilising batters at launch Excavation of rock at Queensferry gyratory Drainage works at A904/U221 N.B. No evening, night time or Sunday daytime construction in vicinity.
M15	Echline Field	Network	Excavation and temporary drainage works at launch Stabilising batters at launch Excavation of rock at Queensferry gyratory Drainage works at A904/U221 N.B. No evening, night time or Sunday daytime construction in vicinity.
M16	Scotstoun	Network	Drainage works Soil/embankment strip Construction of South bound bus link haul road N.B. No evening, night time or Sunday daytime construction in vicinity.
M17	Dundas Home Farm	Network	Utilities works Soil strip Excavation works N.B. No evening, night time or Sunday daytime construction in vicinity.

Table 2 lists the main construction activities undertaken in the locality of each of the vibration monitors during the period of March 2013.

Table 3: PCNV Predicted PPV & VDV Levels

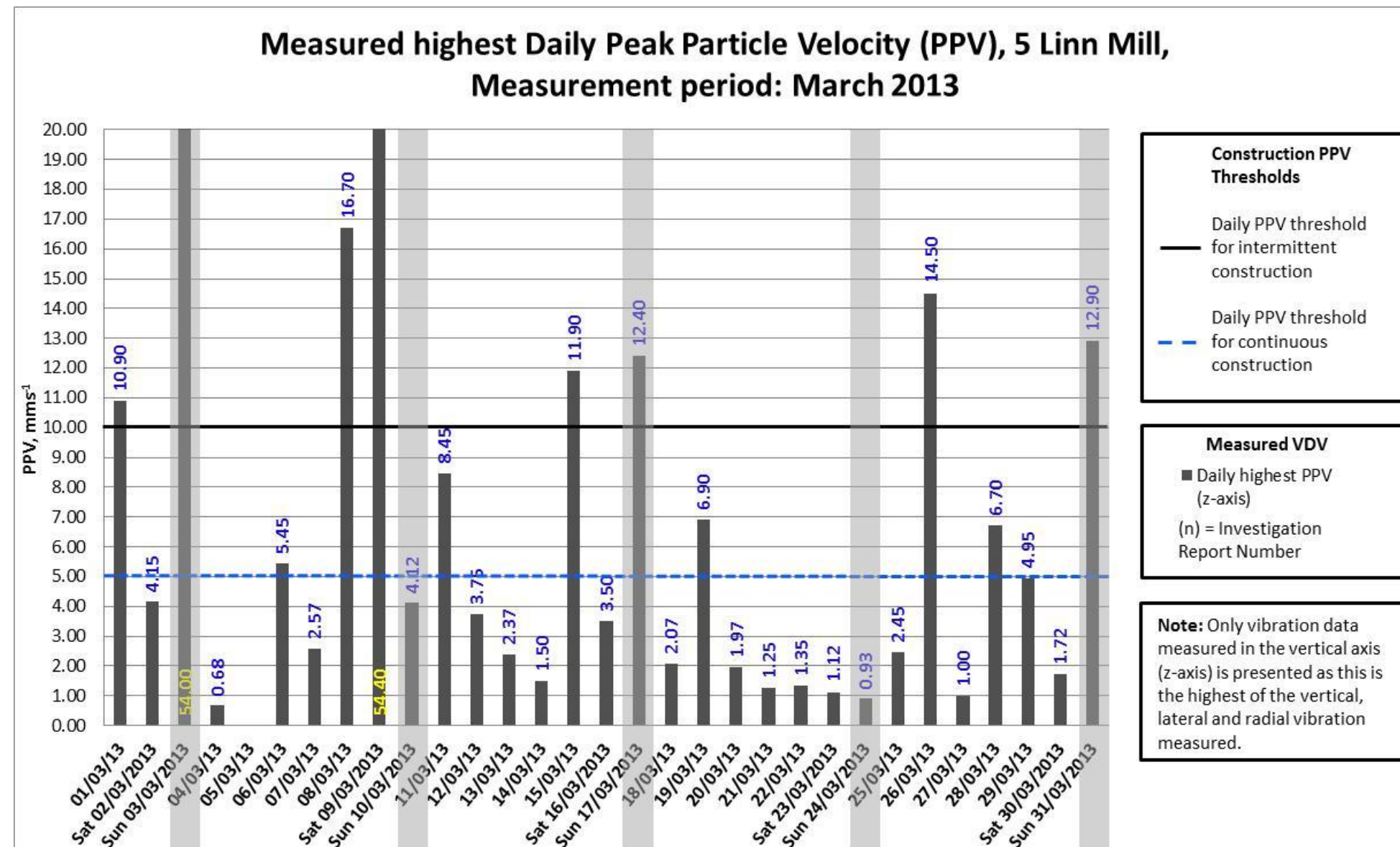
Monitor	Minimum distance from work areas (m)		Type of vibration emitting plant/activity operated at nearest work areas	Worst case predicted vibration levels	
	Day (07:00-19:00)	Night (19:00-07:00)		PPV (mm/s)	eVDV (m.s ^{-1.75})
Butlaw Fisheries	150	230	Roller/Piling	0.39	0.23
Clufflat Brae	40	350	Roller/Whacker	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/Piling	1.77	0.33
Linn Mill	60	500	Roller/Whacker/Piling	1.36	0.33
Scotstoun	50	2000	Roller/Whacker	1.77	0.33
Springfield	50	600	Roller/Whacker	1.77	0.33
Tigh-Na-Grian	200	200	N/A	-	-
Whinny Hill	270	1800	Blast 15	-	-

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

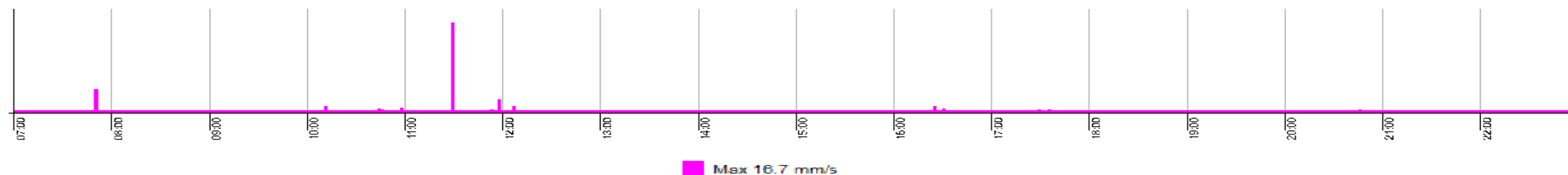
- All plant used during construction activities has been assessed with respect to vibration. The only plant utilised over the period in question considered to generate appreciable levels of vibration was a vibratory roller and a whacker plate (NOTE: Hydraulic rock breakers which typically generate 4.5mm/s @ 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 80m 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 blasts were monitored on an individual basis using a number of monitoring devices at the nearest receptors. There has been no damage to any receptor due to blasting activities. None of the blasts conducted during the period in question registered a PPV on any of the permanent vibration monitors.
- All roller eVDV values in the table above are based on the worst case scenario of a vibratory roller remaining in continuous operation for 4 hours a minimum 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.

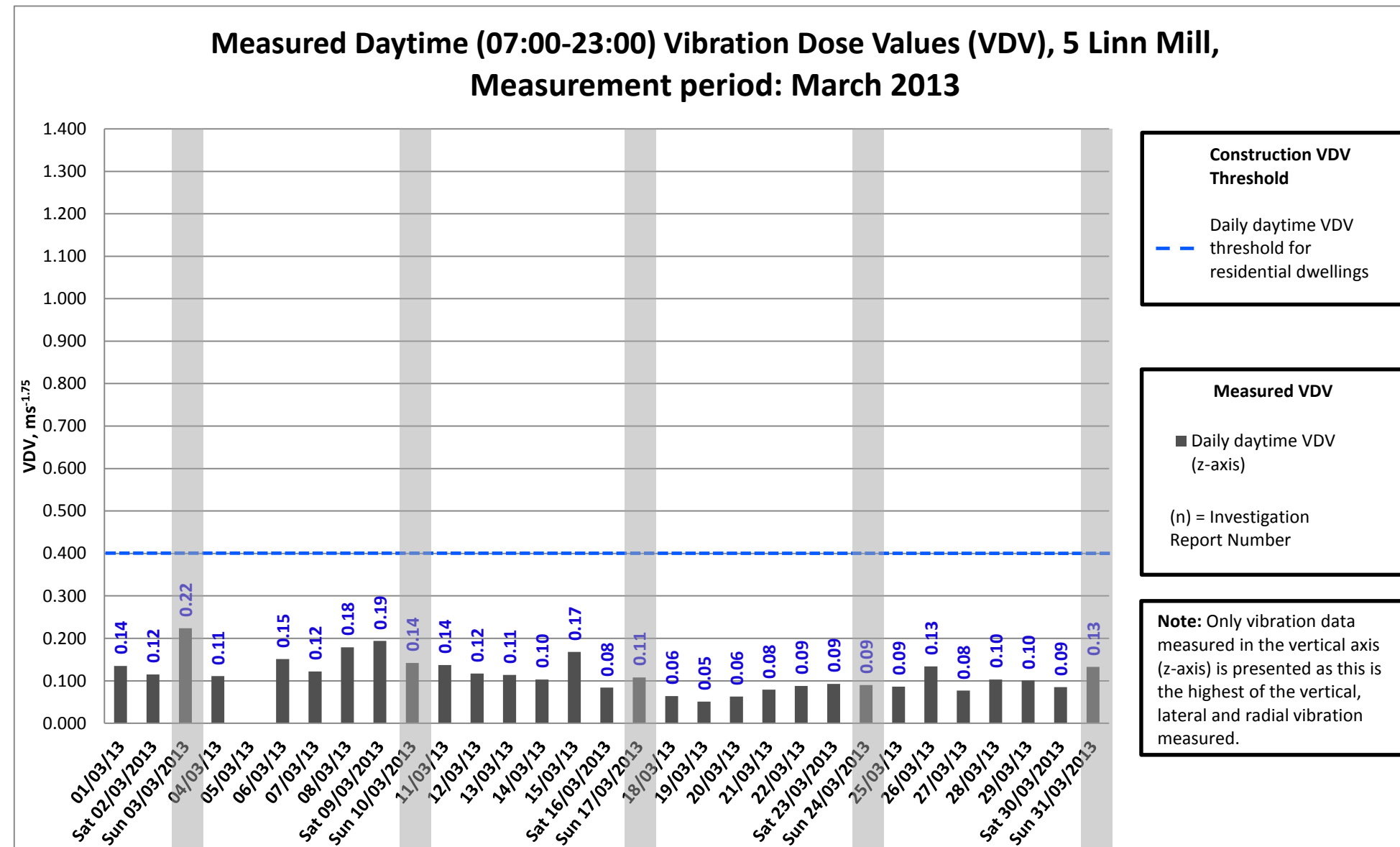
APPENDIX B – VIBRATION GRAPHS



Notes:

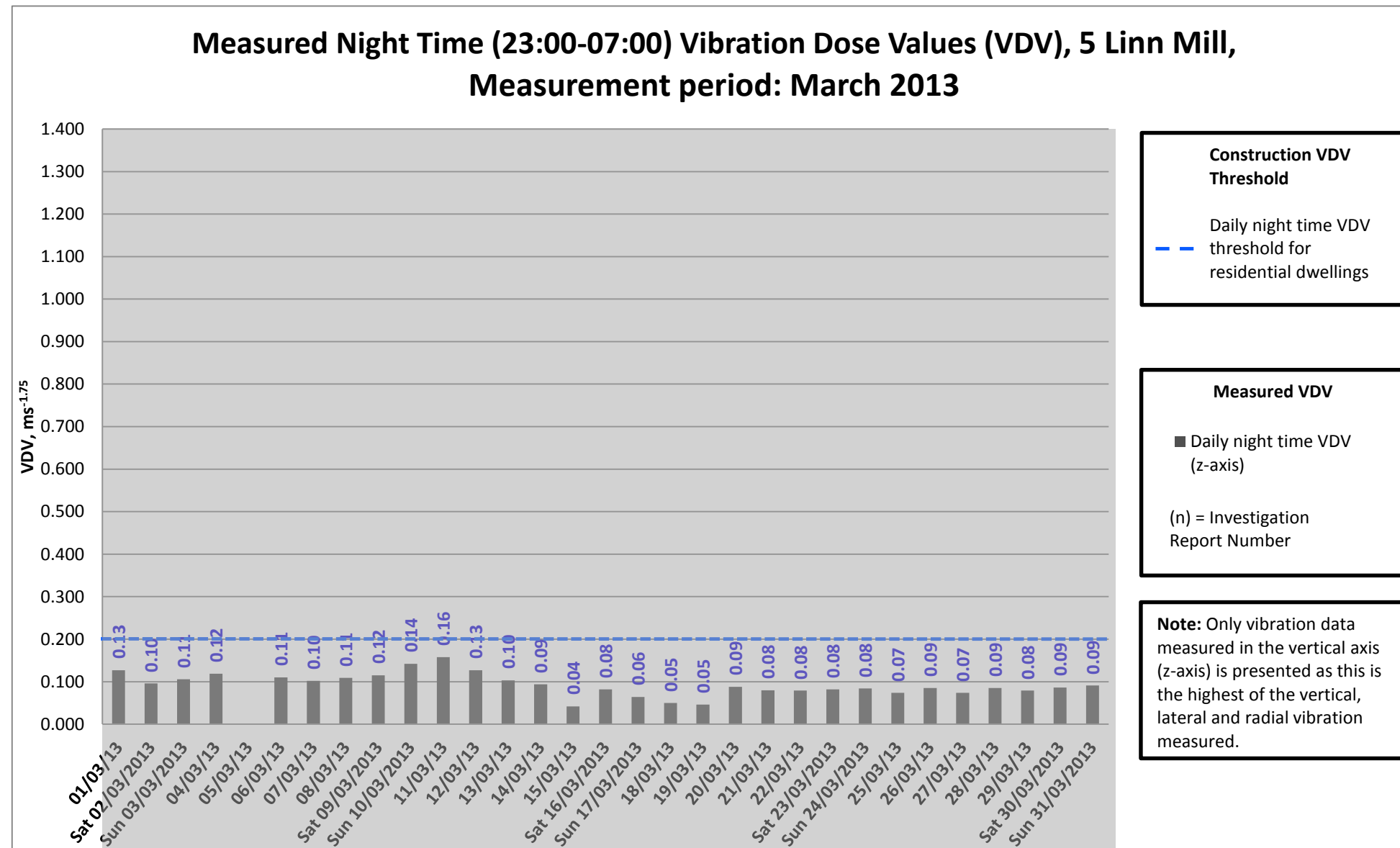
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 01/03/13, 06/03/13, 08/03/13, 09/03/13, 11/03/13, 15/03/13, 19/03/13, 26/03/13 & 28/03/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 08/03/13). Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were backfill works at pier S7 and reinforcement and formwork at South Abutment, which did not involve any vibration inducing plant or equipment.
- Data is missing from 05/03/13 due to device error.





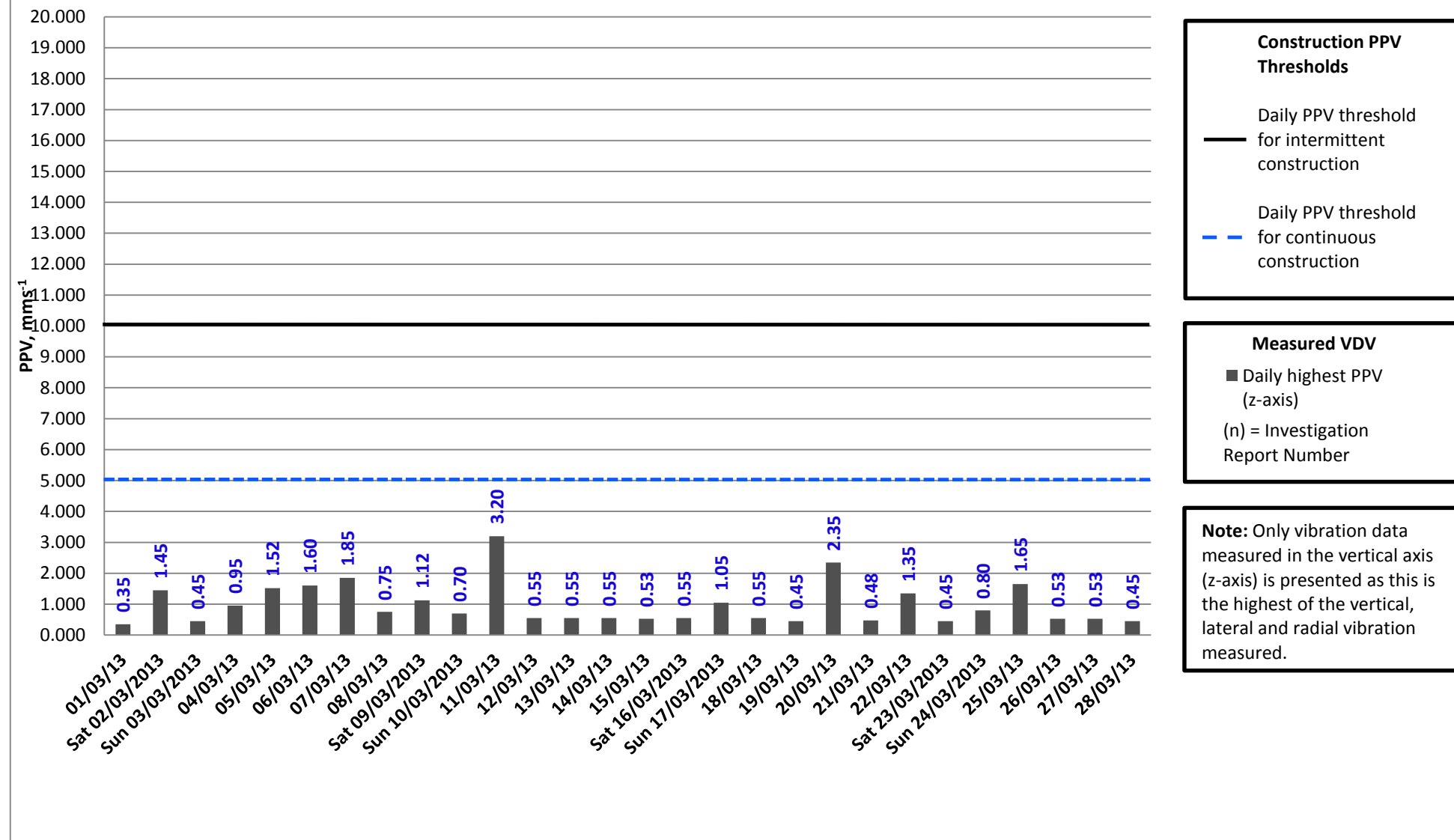
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 05/03/13 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 Linn Mill vibration monitor throughout the month of March 2013. This graph is included for illustrative purposes only.

Measured highest Daily Peak Particle Velocity (PPV), Butlaw Fisheries, Measurement period: March 2013



Construction PPV Thresholds

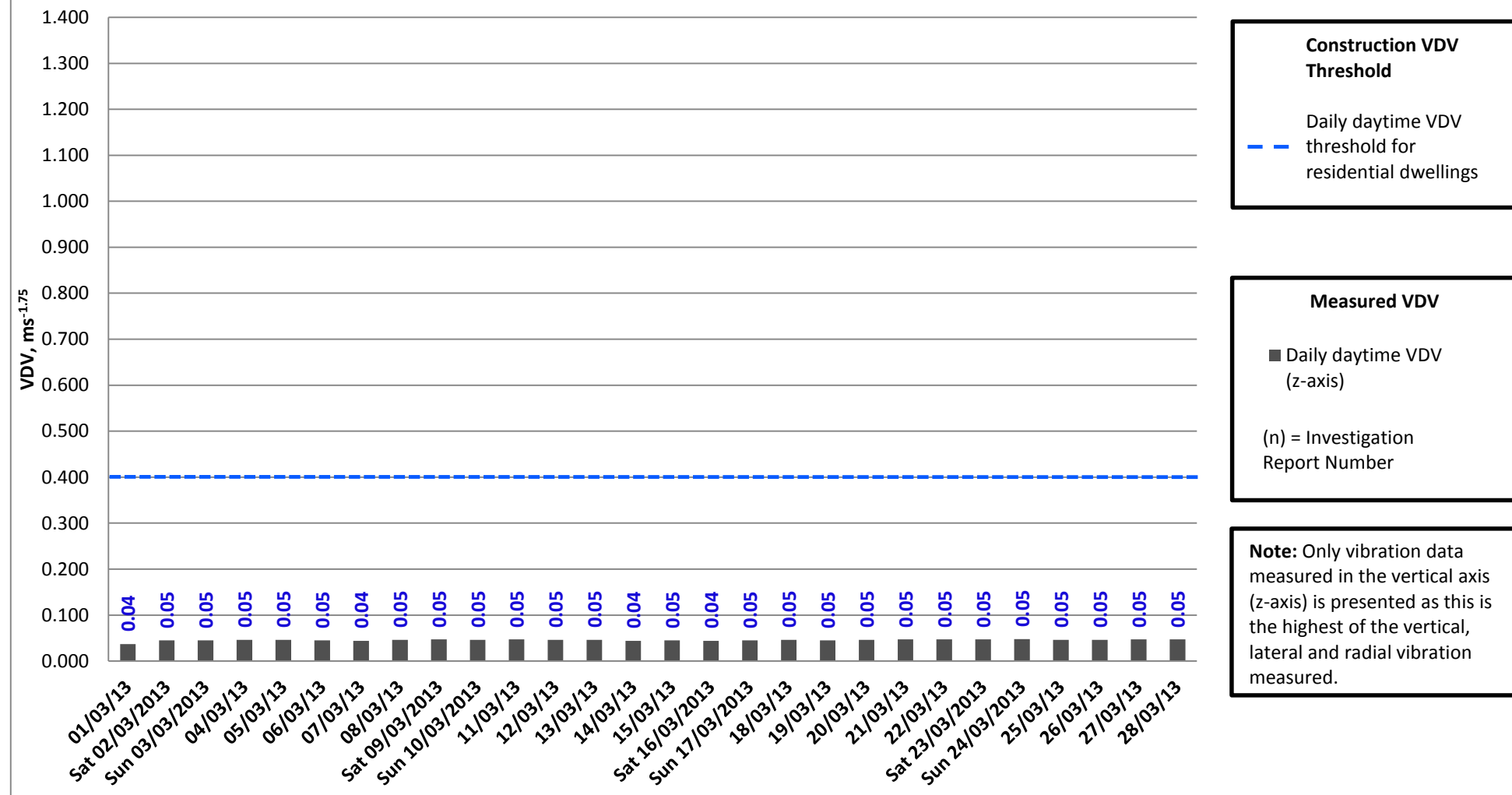
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

Measured VDV

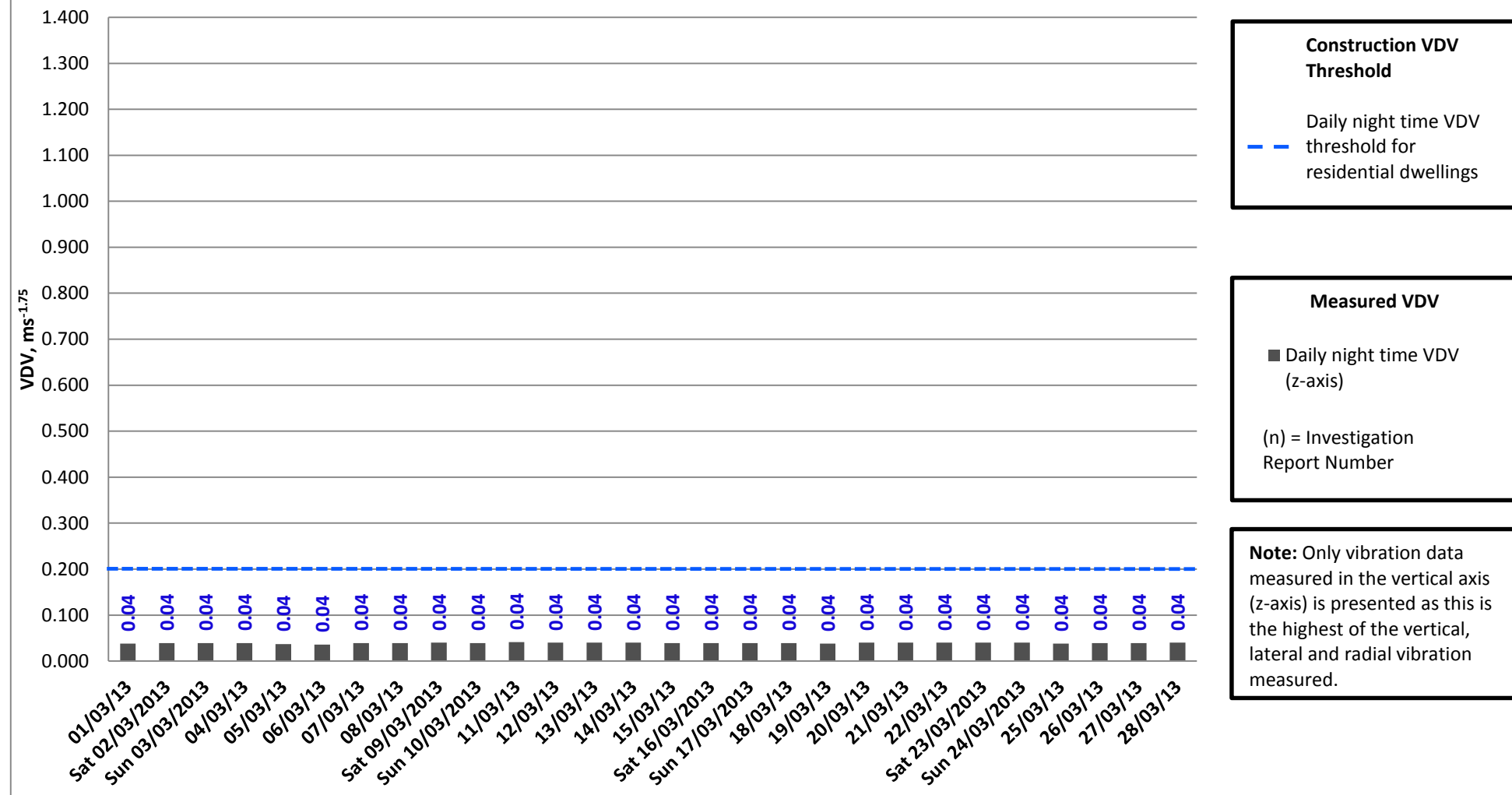
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

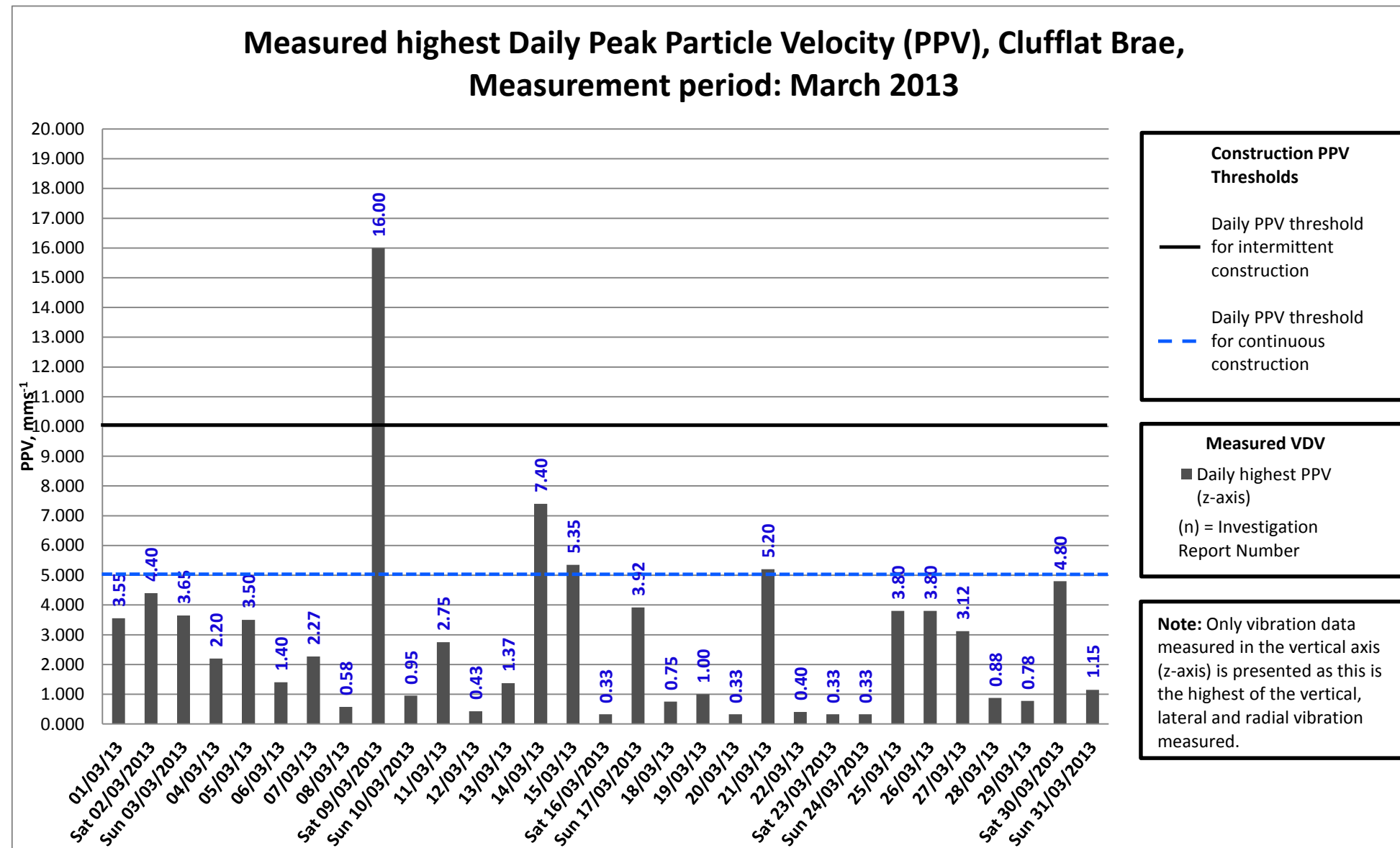
Note: Only vibration data measured in the vertical axis (z-axis) is presented as this is the highest of the vertical, lateral and radial vibration measured.

Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: March 2013



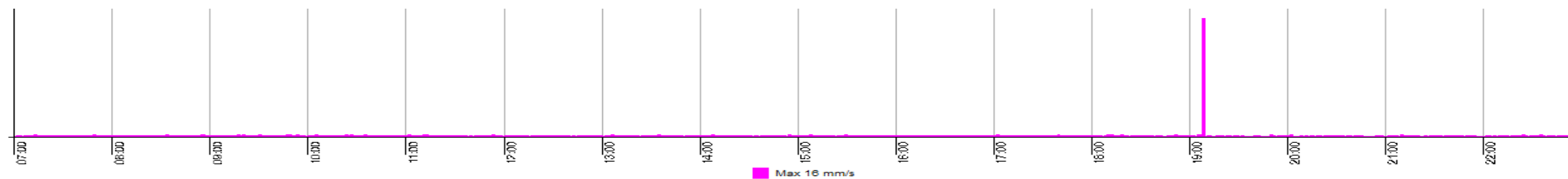
Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Butlaw Fisheries, Measurement period: March 2013



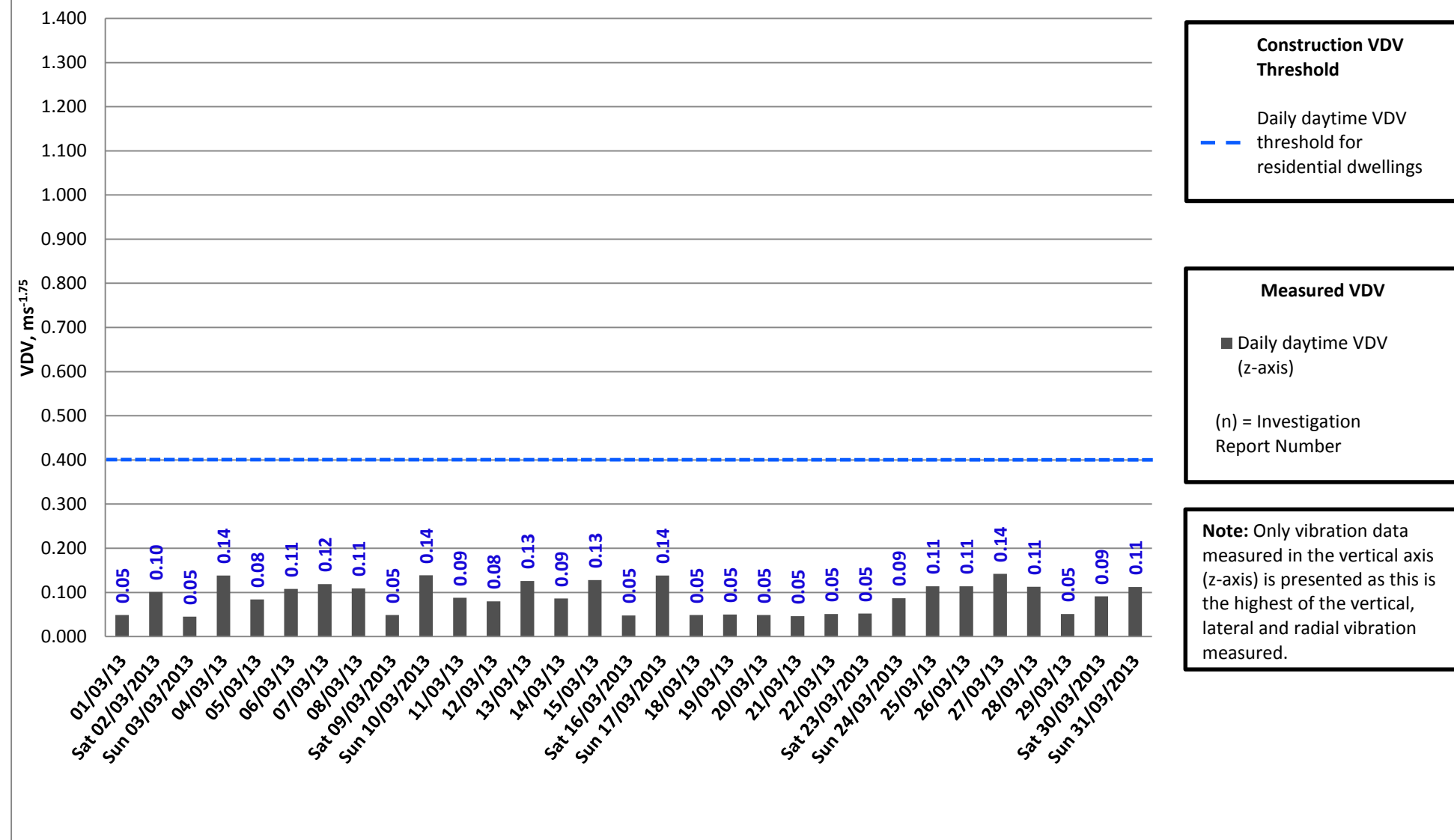


Notes:

- 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 09/03/13, 14/03/13, 15/03/13 and 21/03/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 09/03/13). The latter three of these PPVs 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 works to be conducted on these dates in the vicinity of the monitor, were backfill works at pier S7 and reinforcement and formwork at South Abutment, which did not involve any vibration inducing plant or equipment.

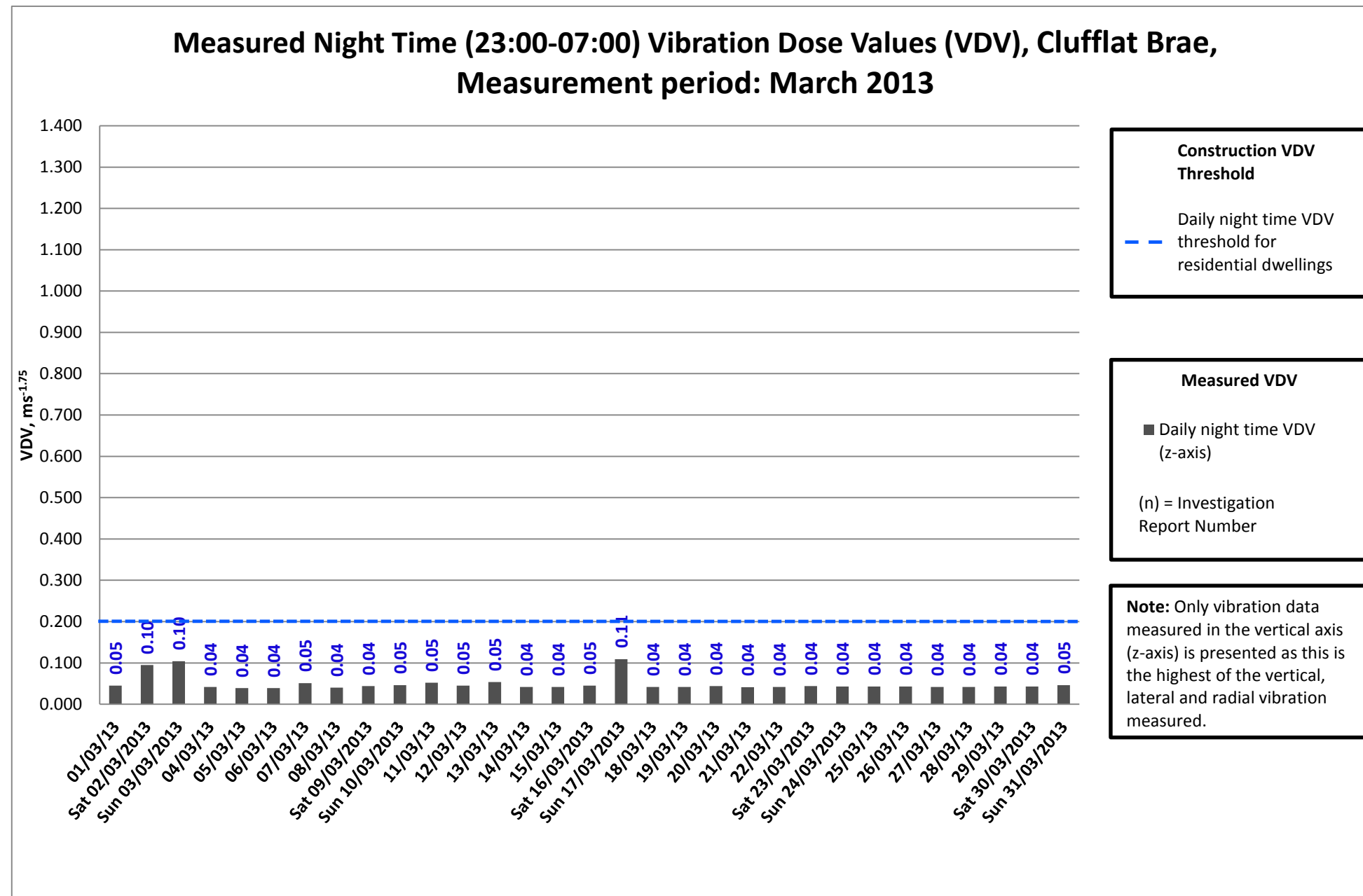


**Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Clufflat Brae,
 Measurement period: March 2013**



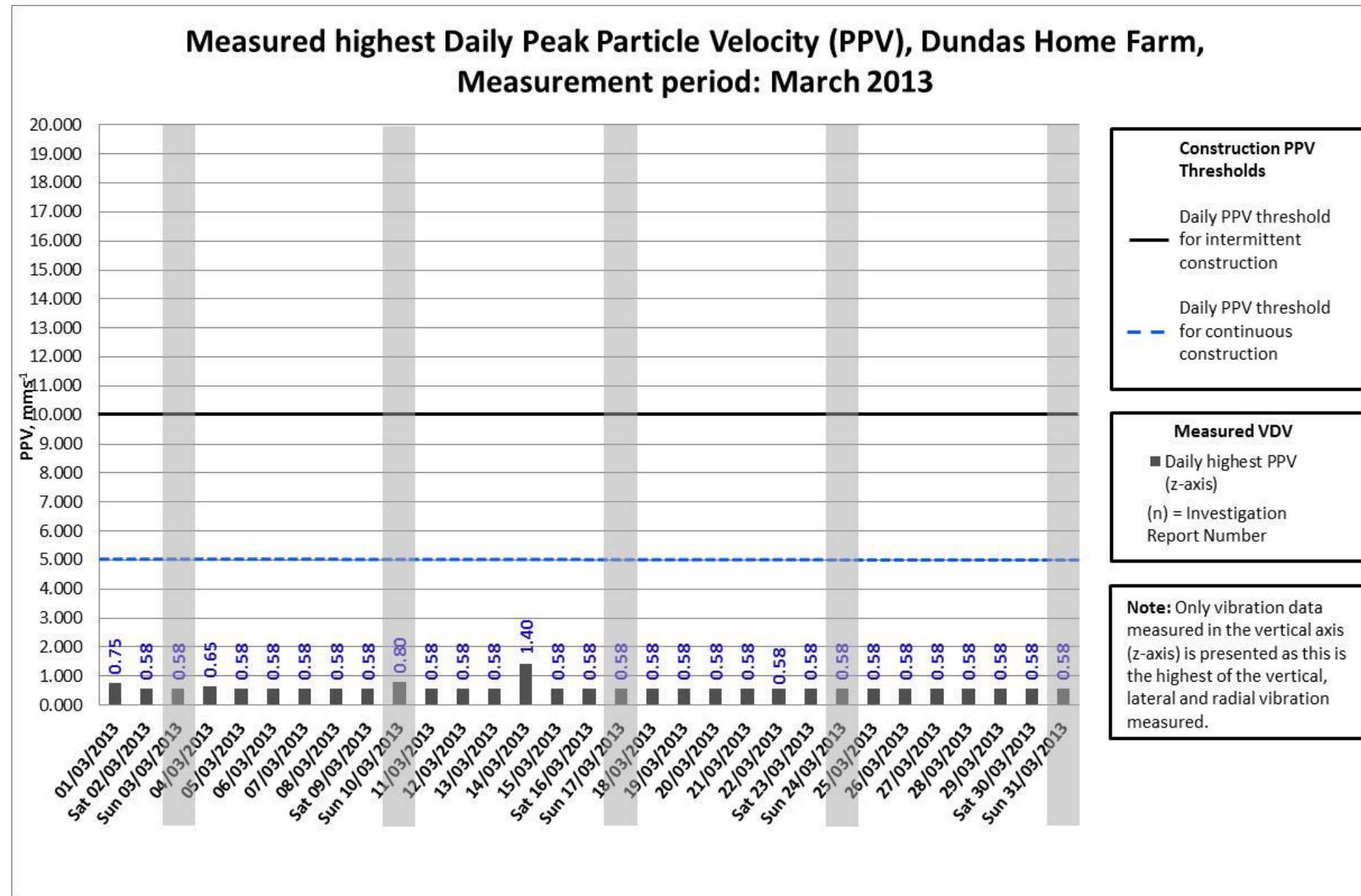
Notes:

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



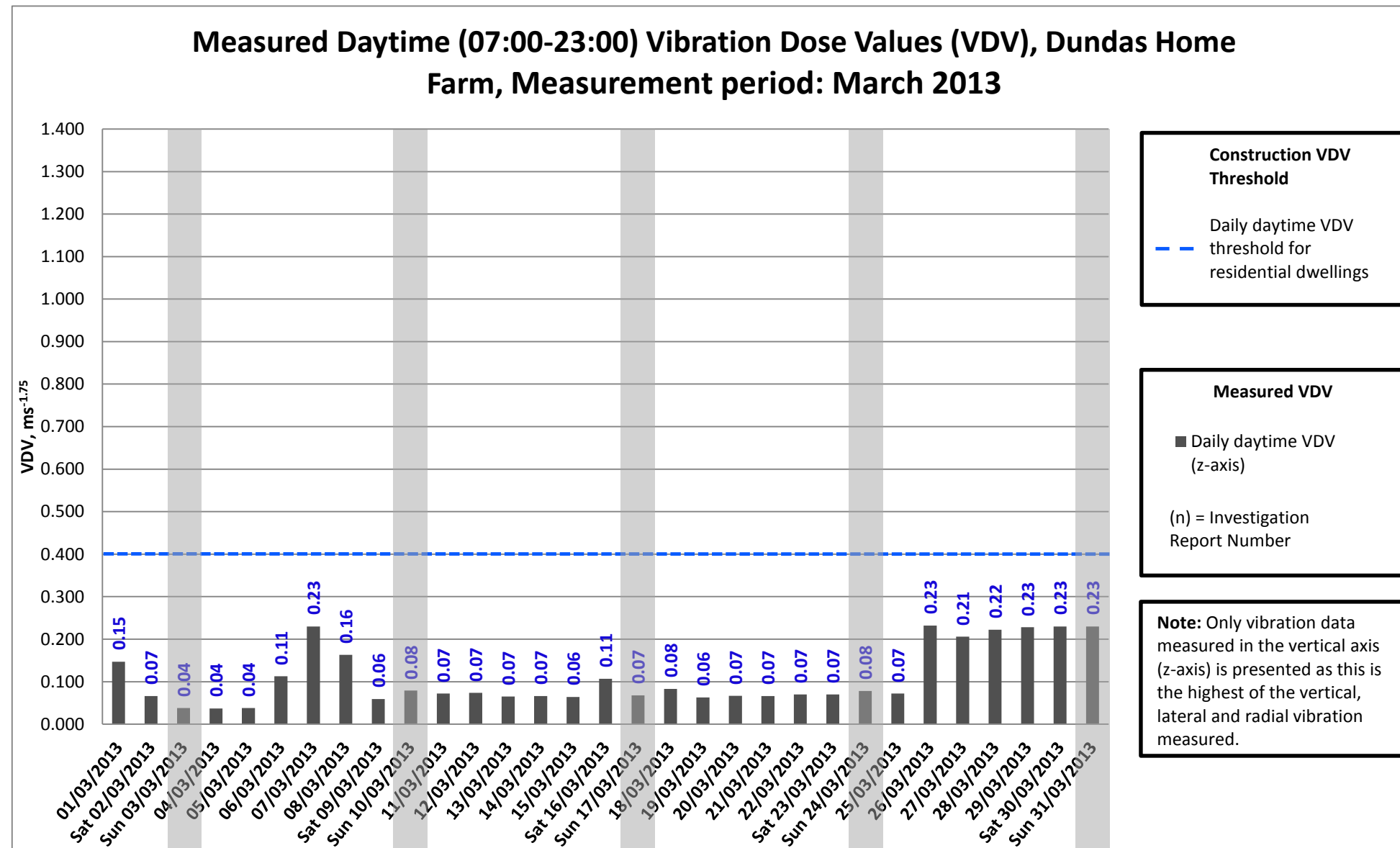
Notes:

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



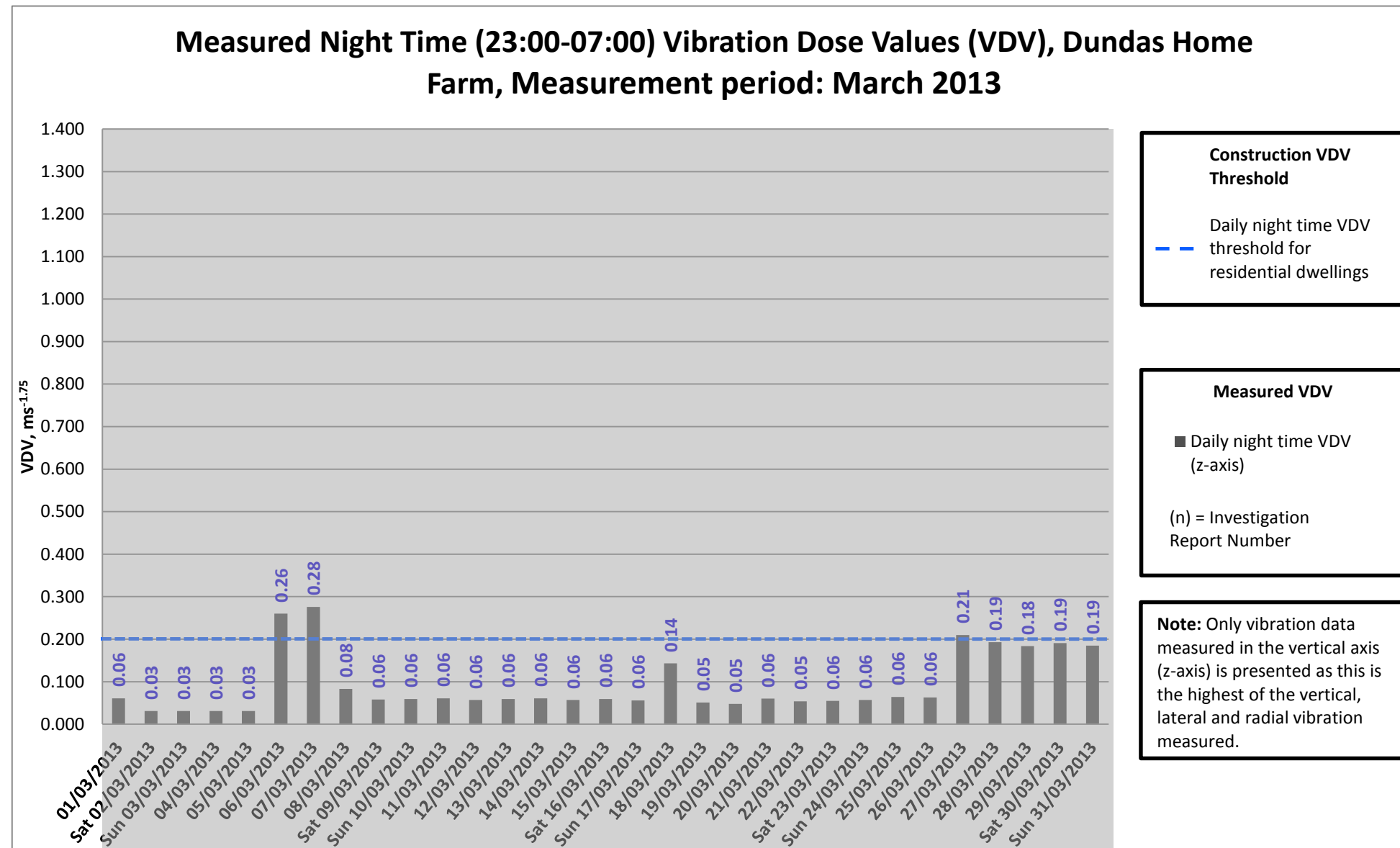
Notes:

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

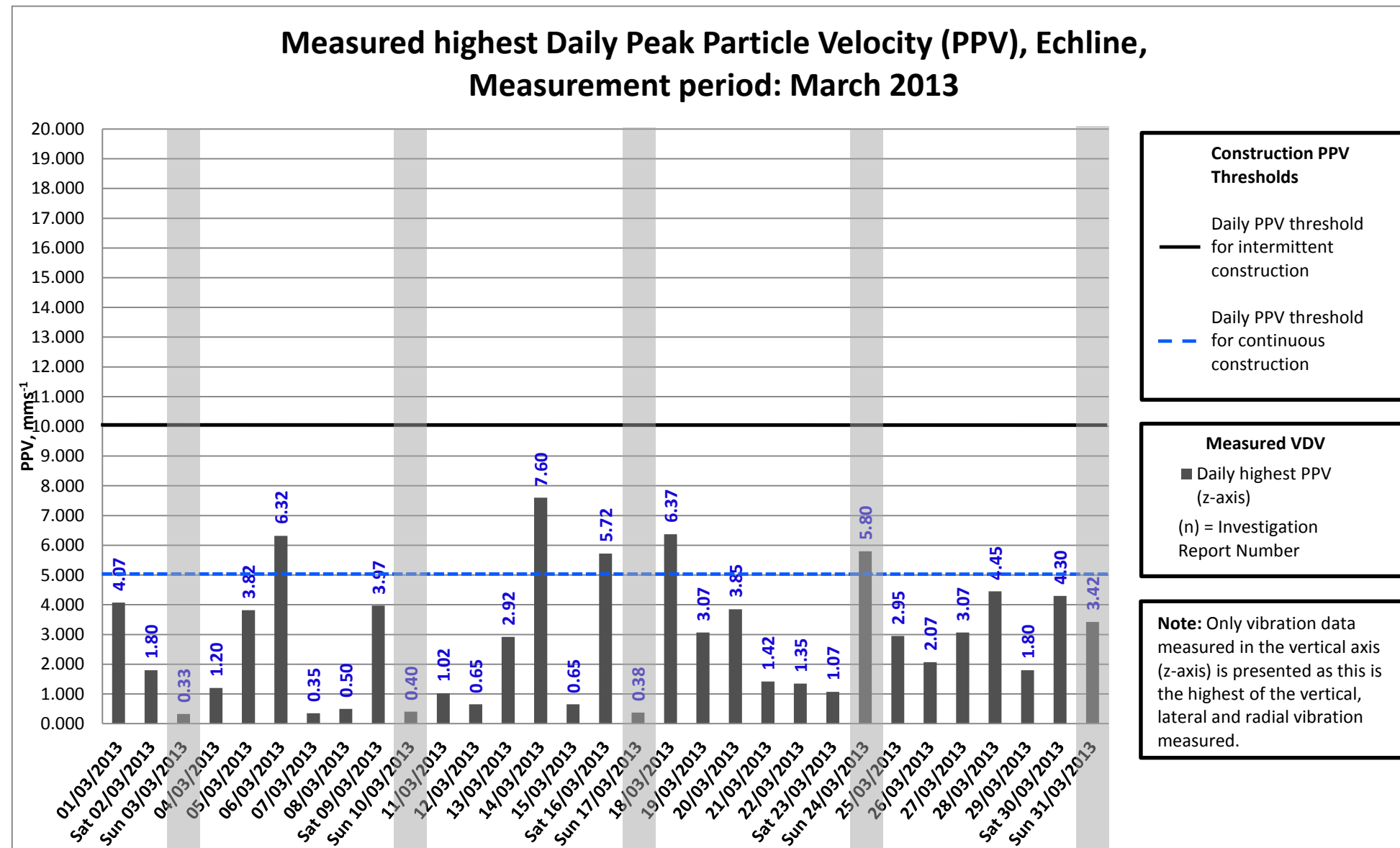


Notes:

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

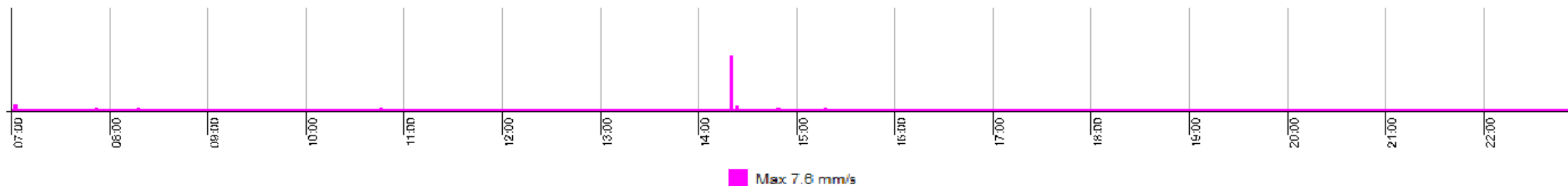


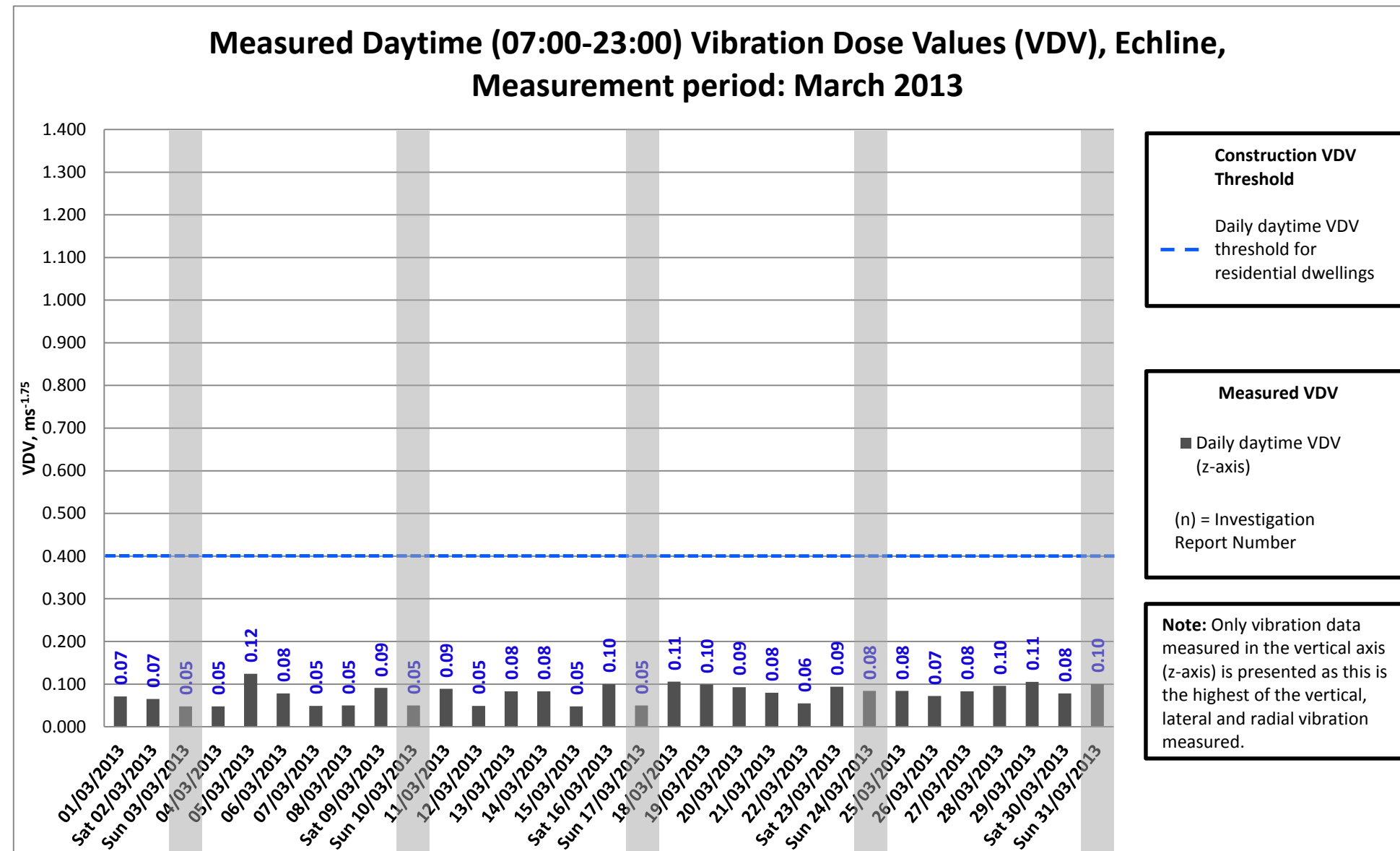
- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Dundas vibration monitor throughout the month of February 2013. This graph is included for illustrative purposes only.



Notes:

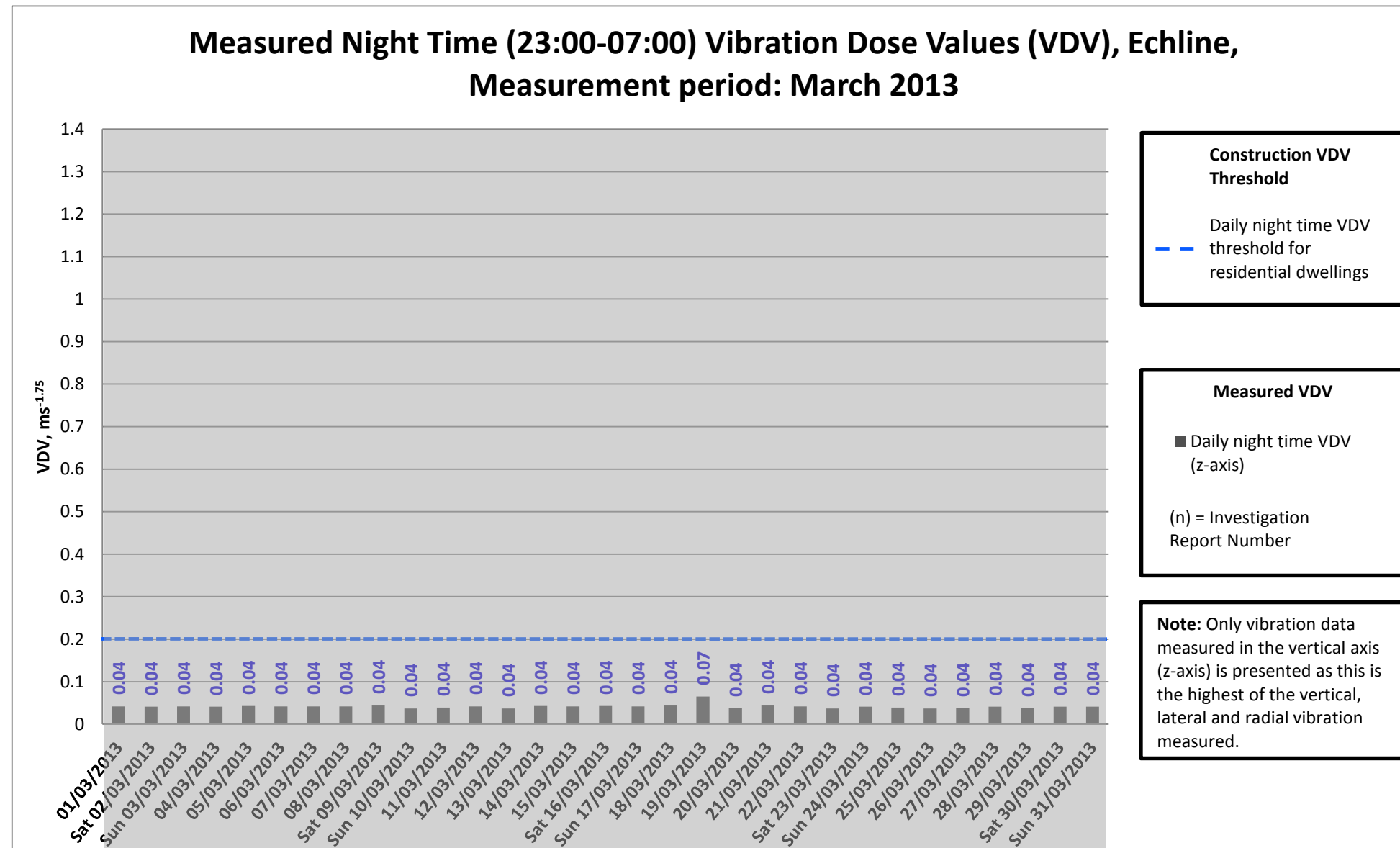
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 06/03/13, 14/03/13, 16/03/13 & 18/03/13 have all been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 05/02/13), and are all within the intermittent threshold of 10mm/s. Furthermore, these particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were excavation of rock at Queensferry gyratory, and drainage works at A904/U221. The only vibration inducing plant or equipment involved in these activities were rock breakers, which were operated a minimum distance of 40m from the monitor (and nearest receptors), and a vibratory rollers, which were operated a minimum distance of 80m from the monitor (and nearest receptors), and can thus be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels are likely due to road traffic (e.g. occasional HGVs passing by).





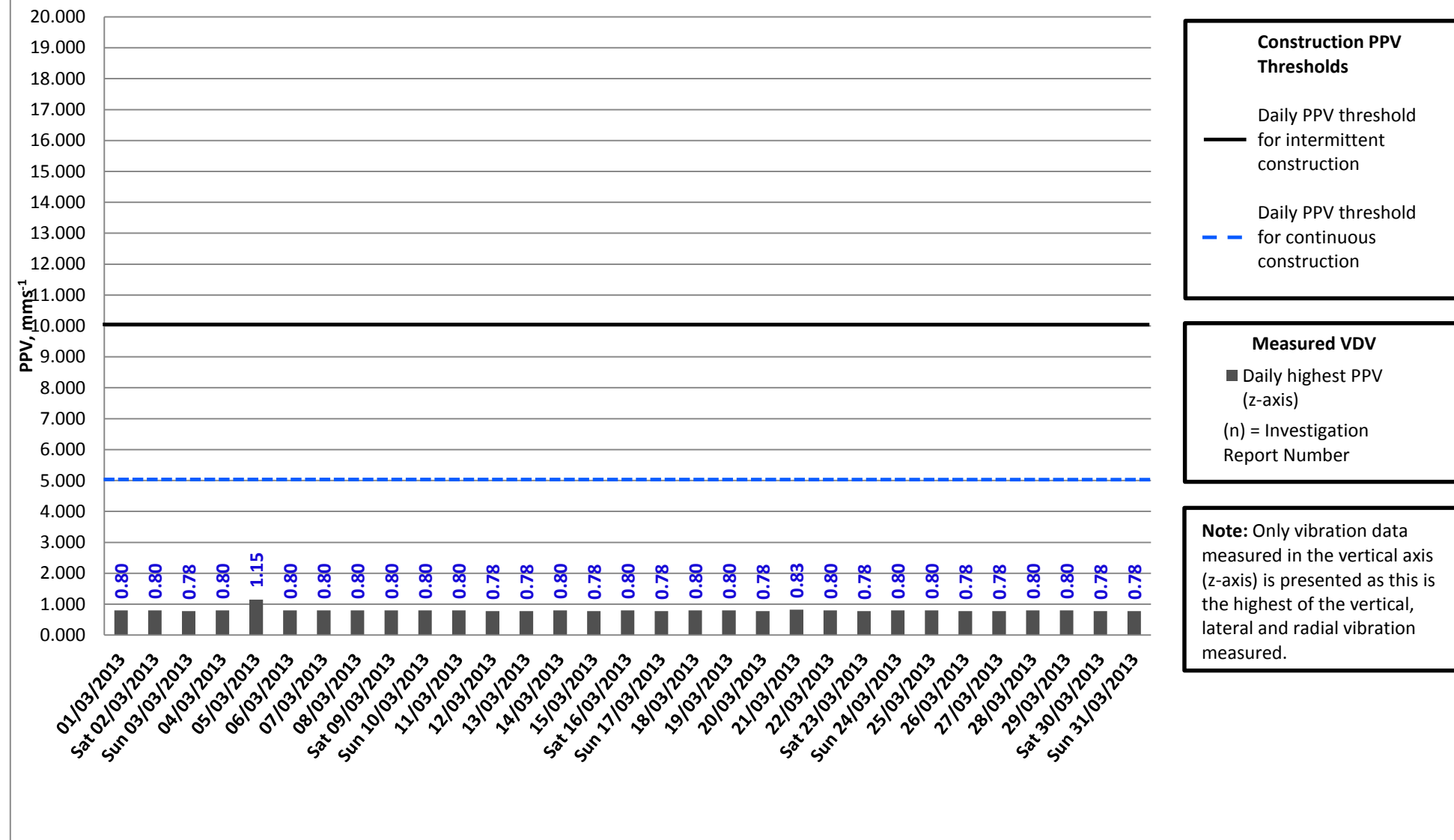
Notes:

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



- 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 March 2013. This graph is included for illustrative purposes only.

Measured highest Daily Peak Particle Velocity (PPV), Inchgarvie Lodge, Measurement period: March 2013



Construction PPV Thresholds

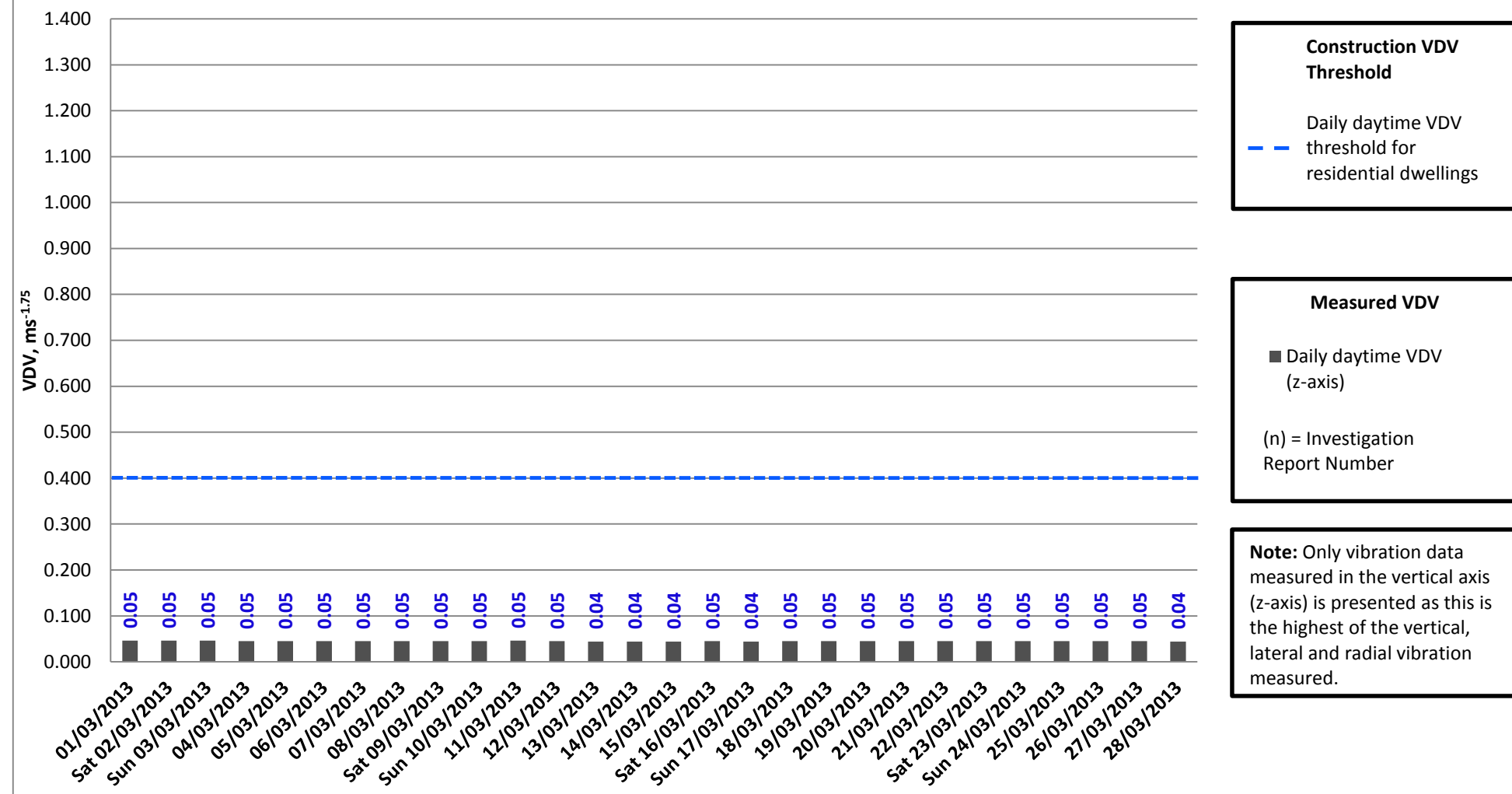
- Daily PPV threshold for intermittent construction
- Daily PPV threshold for continuous construction

Measured VDV

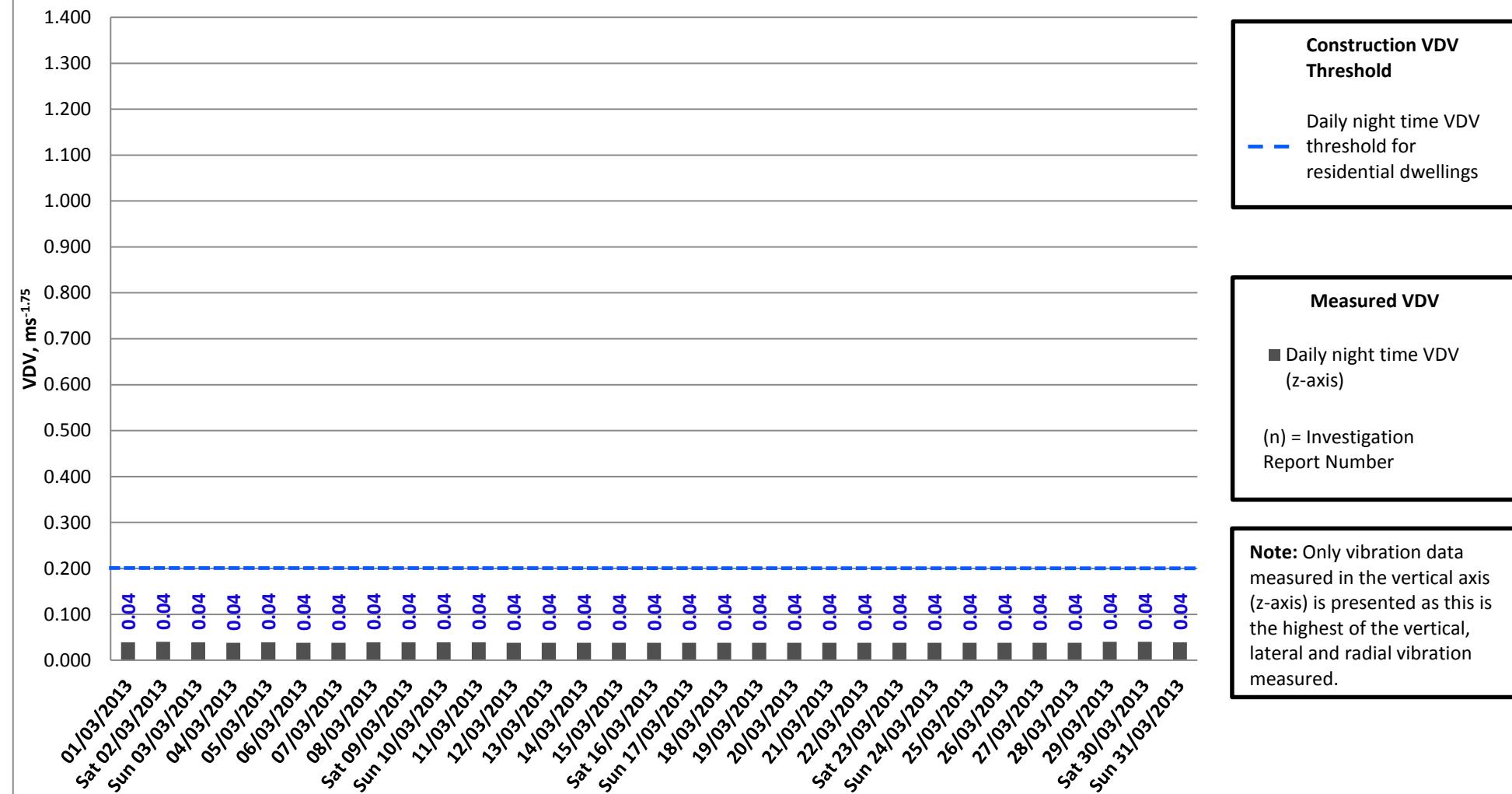
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

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: March 2013



Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Inchgarvie Lodge, Measurement period: March 2013



Construction VDV Threshold

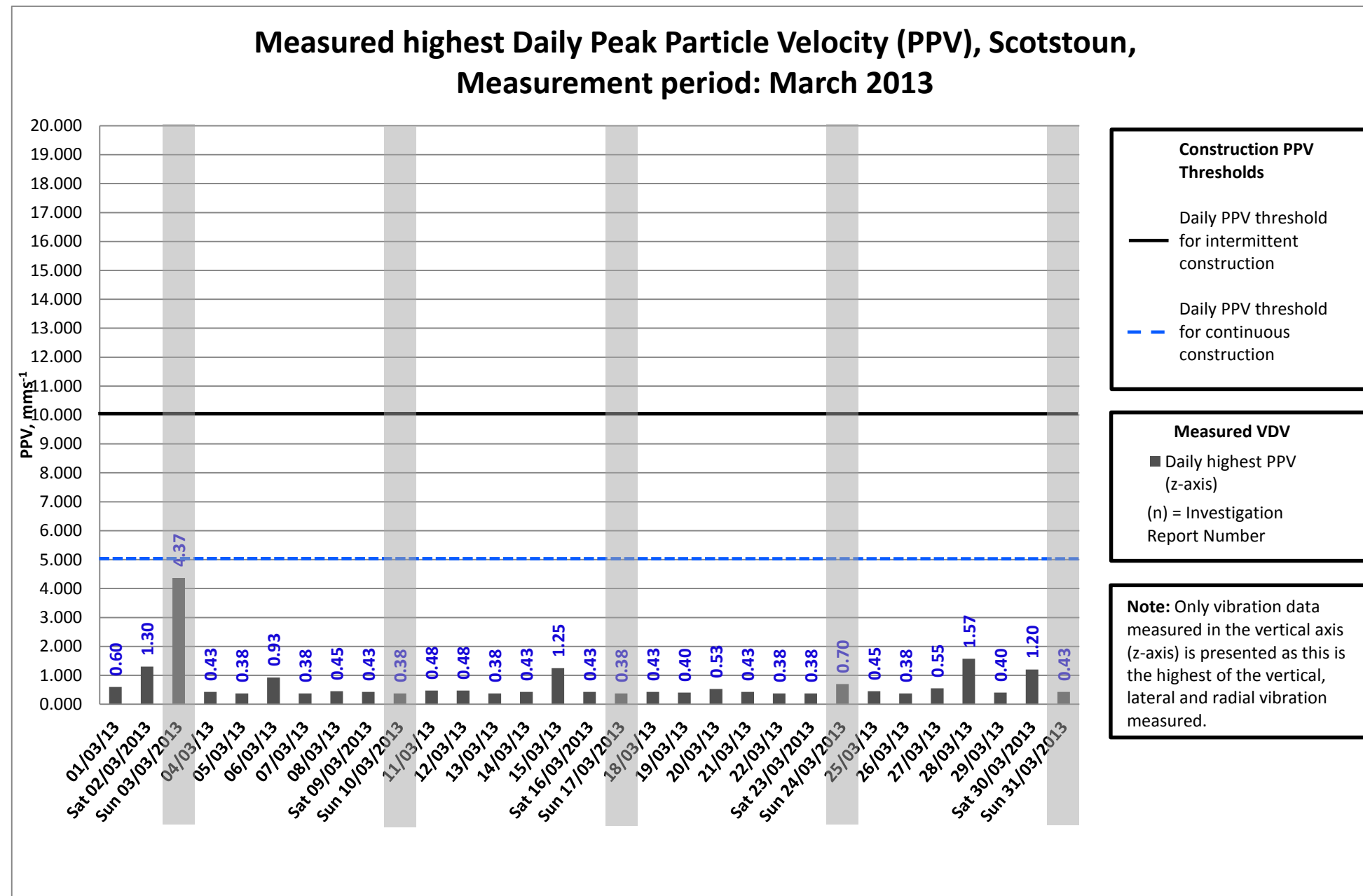
Daily night time VDV threshold for residential dwellings

Measured VDV

■ Daily night time VDV (z-axis)

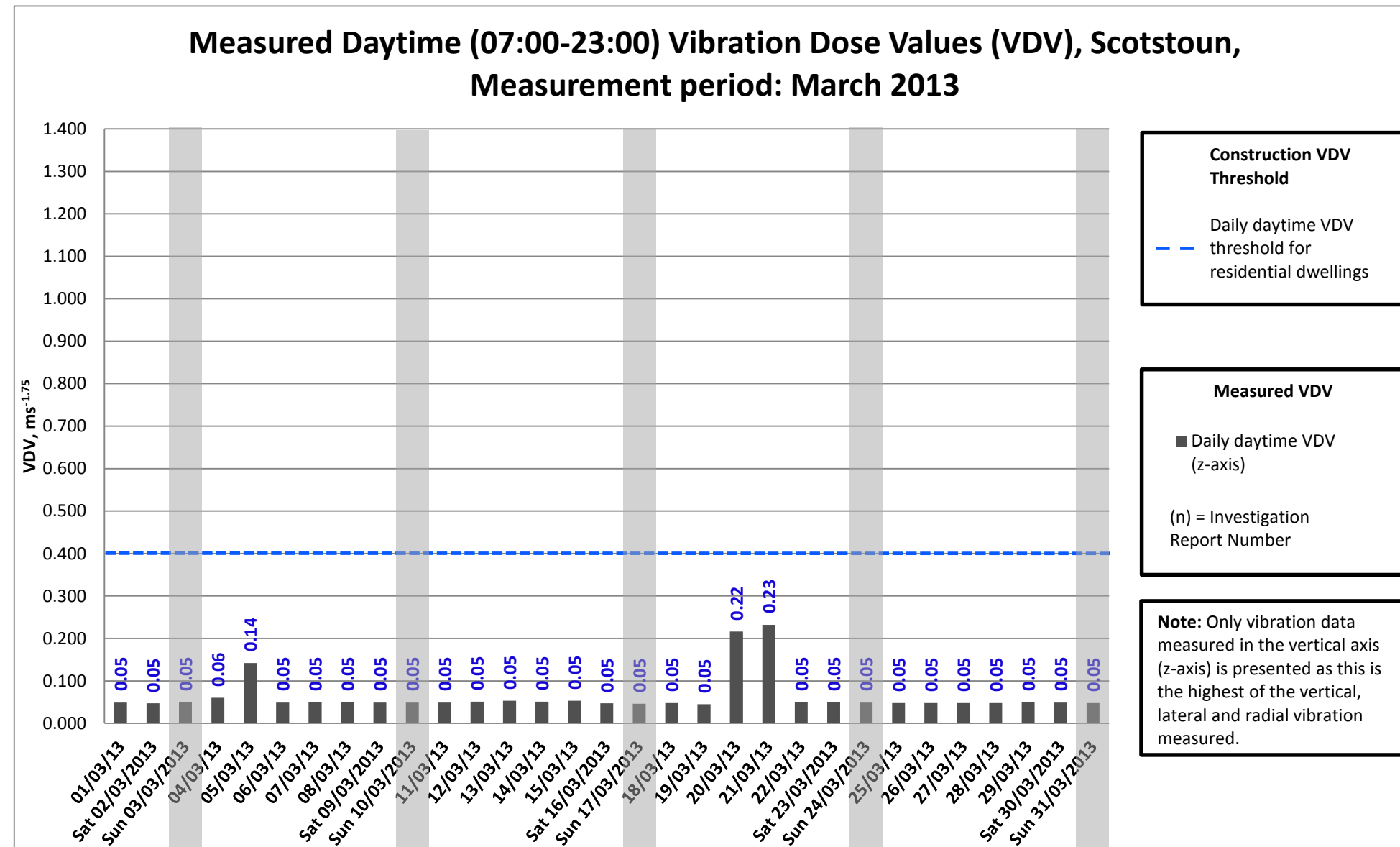
(n) = Investigation Report Number

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.



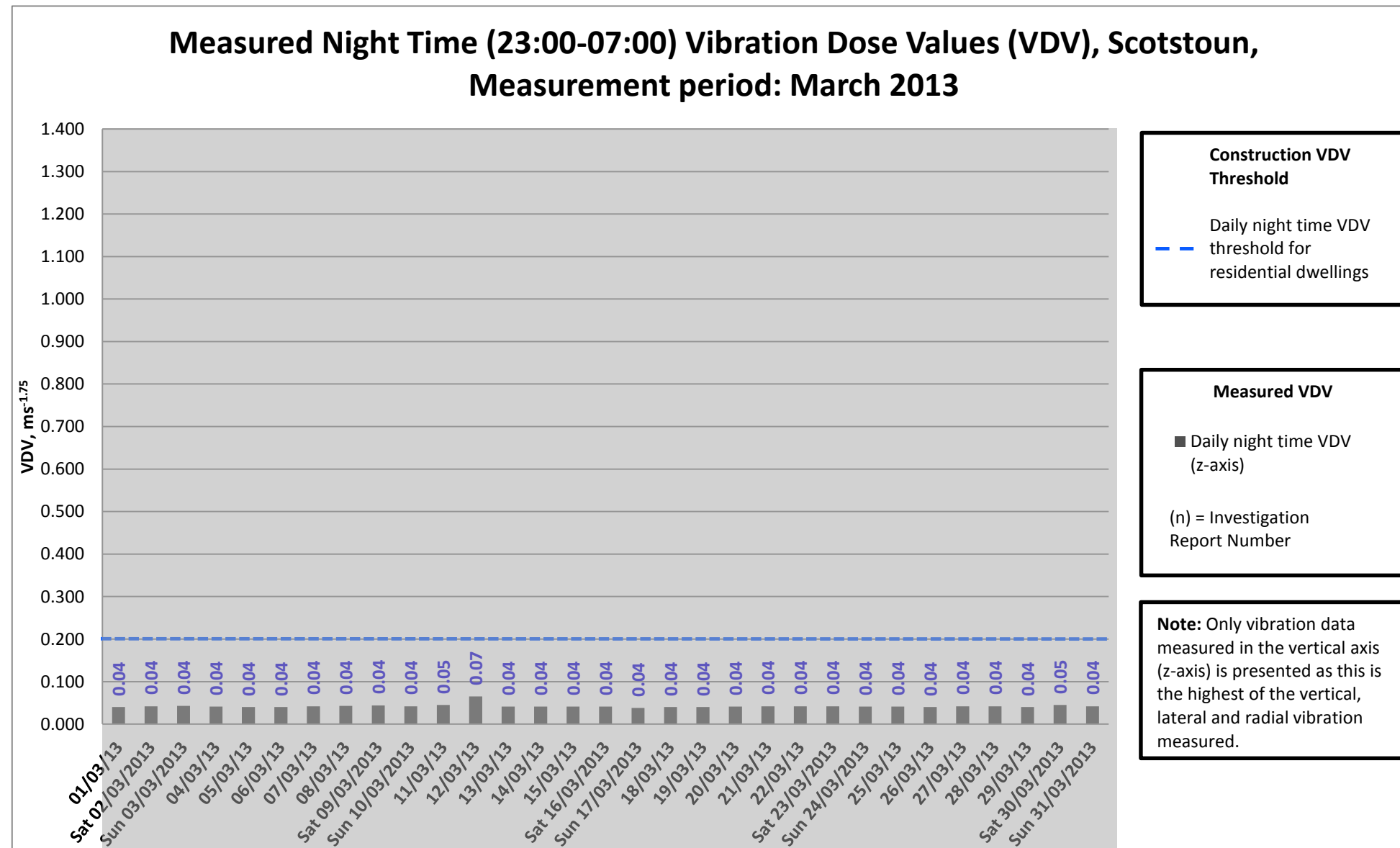
Notes:

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

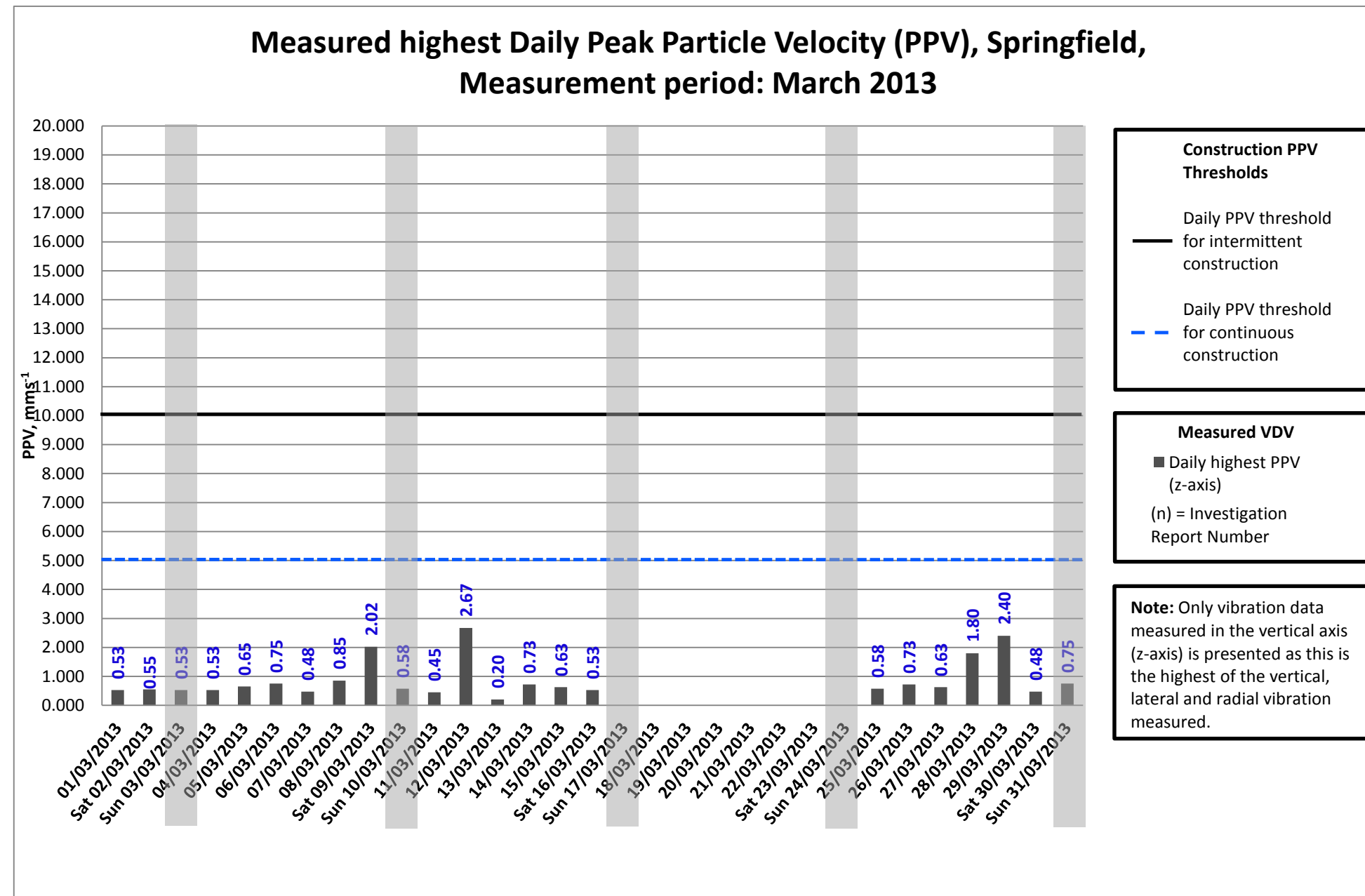


Notes:

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

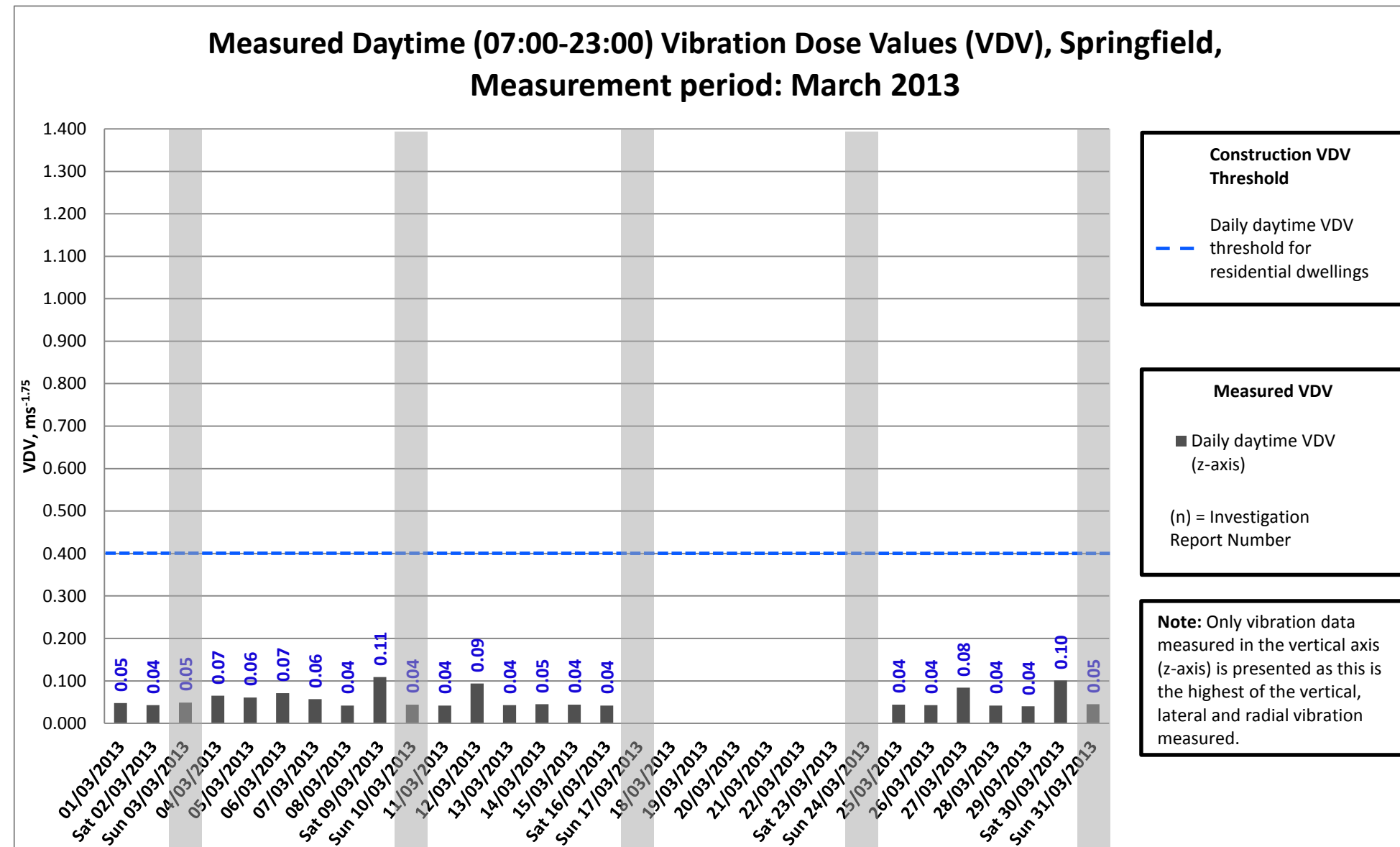


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Scotstoun vibration monitor throughout the month of March 2013. This graph is included for illustrative purposes only.



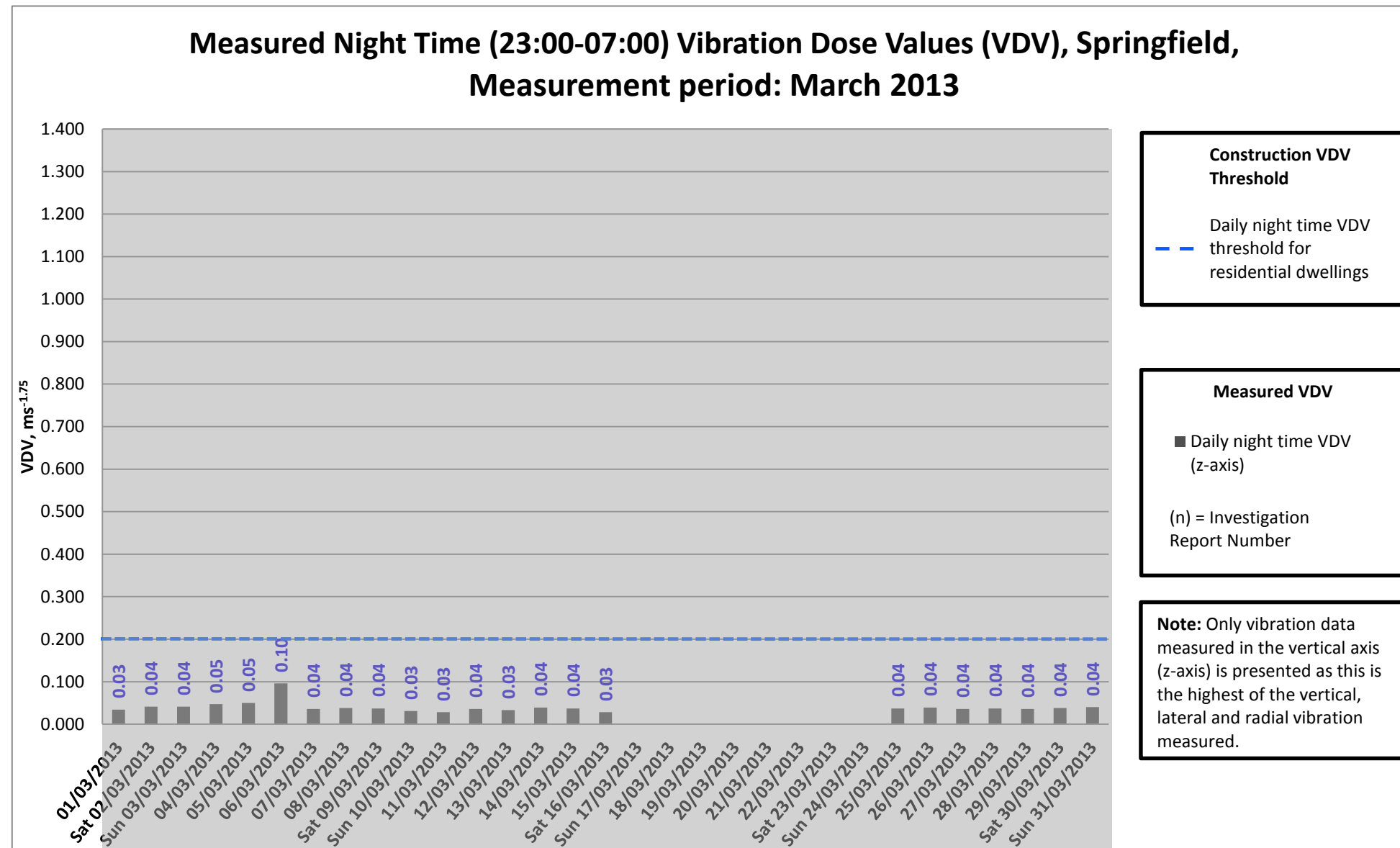
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- Data is missing from 17/03/13 – 24/03/13 due to device error.

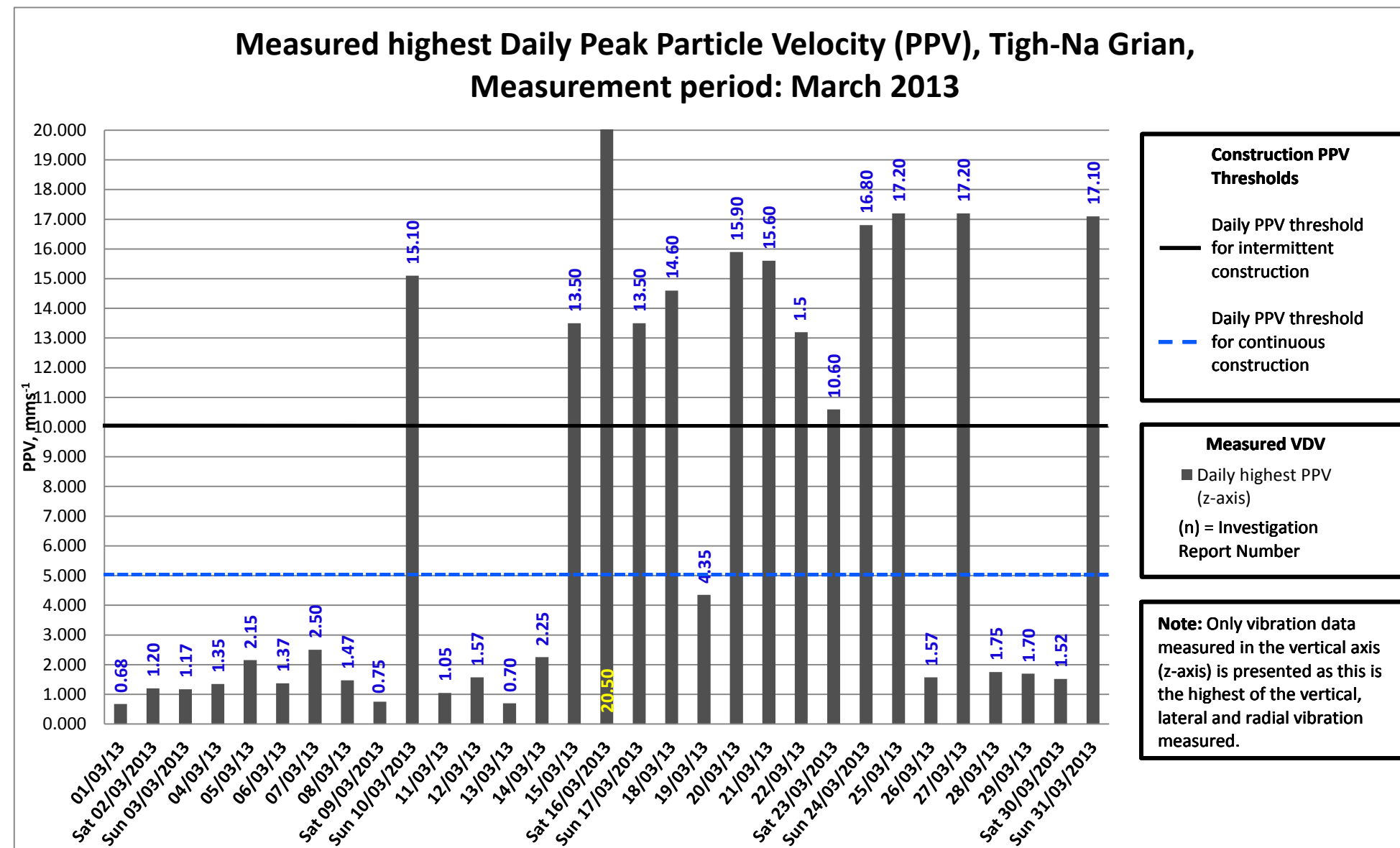


Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sunday.
- Data is missing from 17/03/13 – 24/03/13 due to device error.

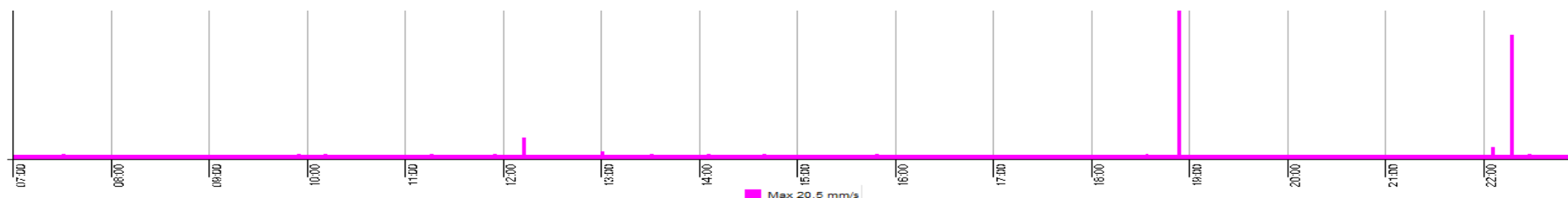


- Notes:**
- The grey areas of the chart represent the days on which no construction works were undertaken; no night time works were conducted in the vicinity of the Springfield vibration monitor throughout the month of March 2013. This graph is included for illustrative purposes only.
 - Data is missing from 17/03/13 – 24/03/13 due to device error.

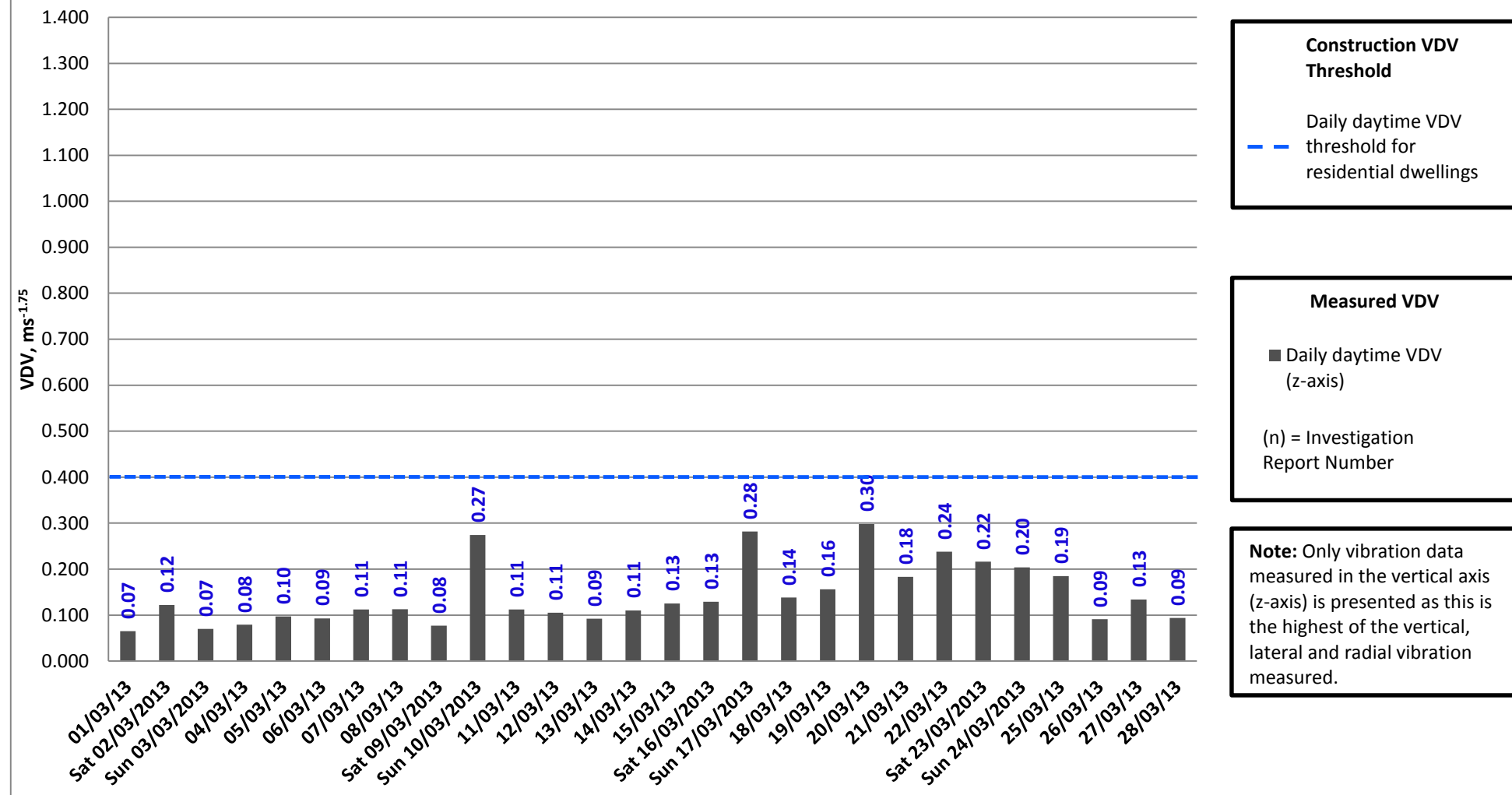


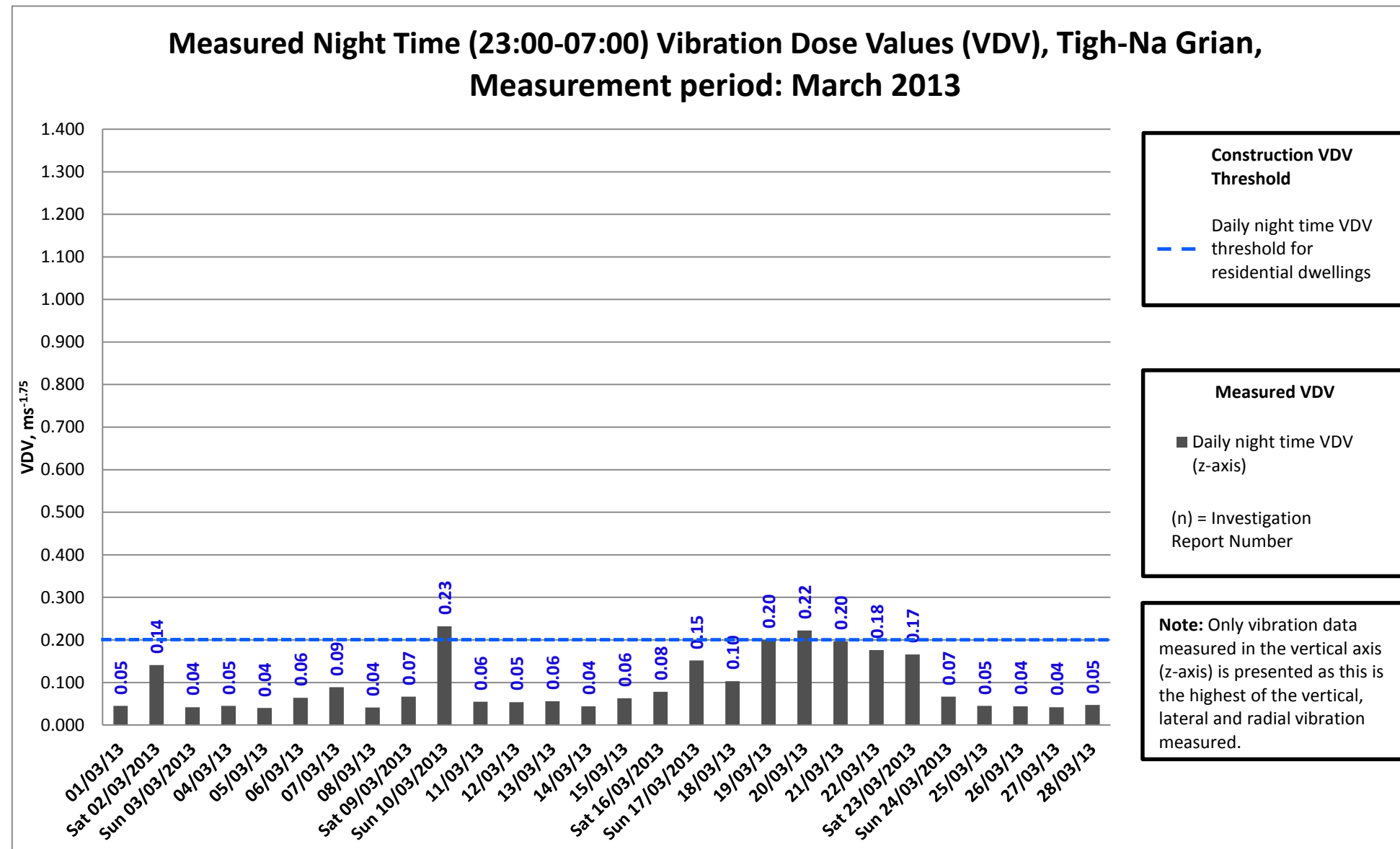
Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- The PPV values on 10/03/13, 15/03-18/03/13, 20/03-25/03/13, 27/03/13 and the 31/03/13 have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 16/03/13). These particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were caisson excavation at the North Tower. There was no vibration inducing plant or equipment involved in this activity, thus it can be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).



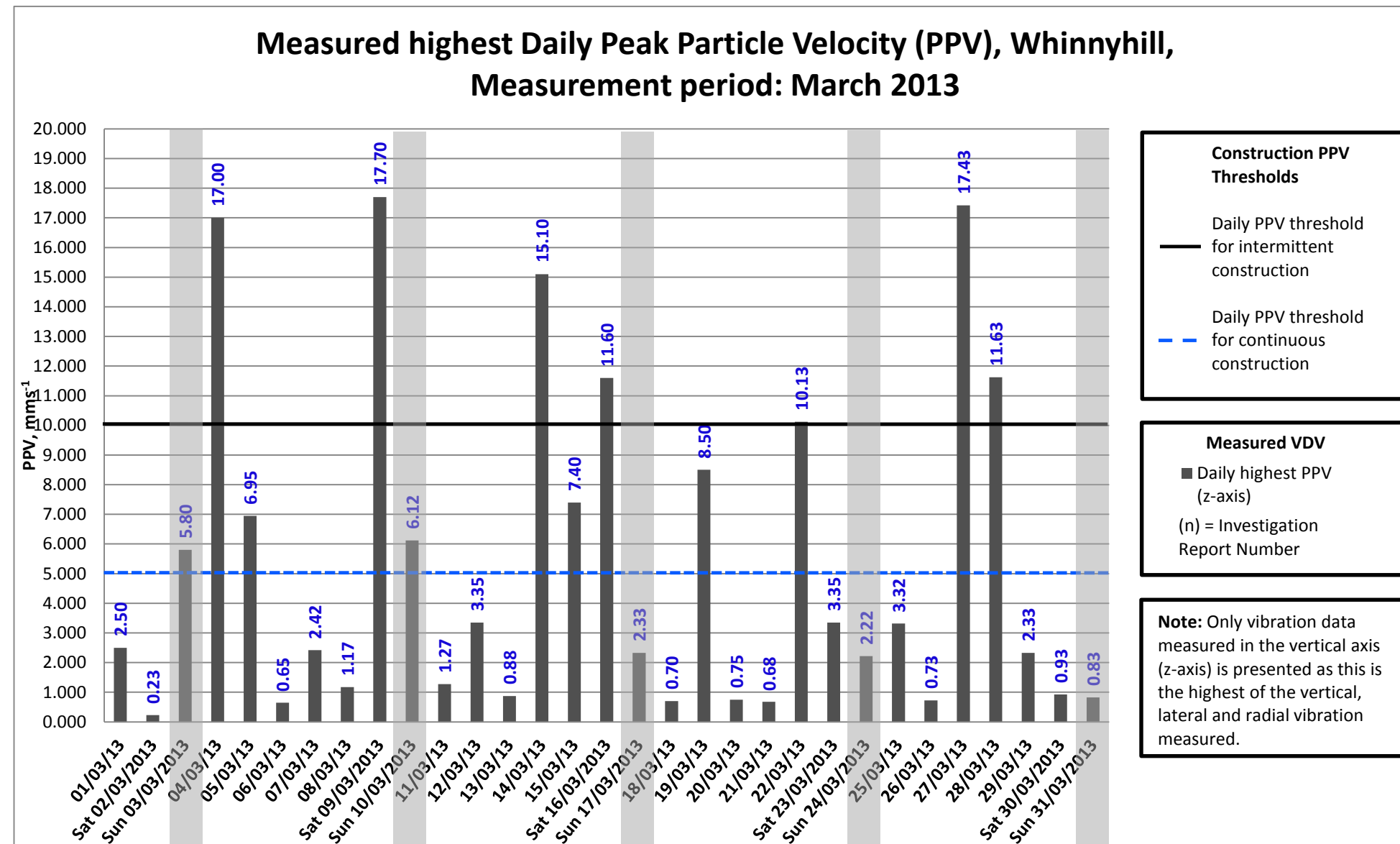
Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Tigh-Na Grian, Measurement period: March 2013





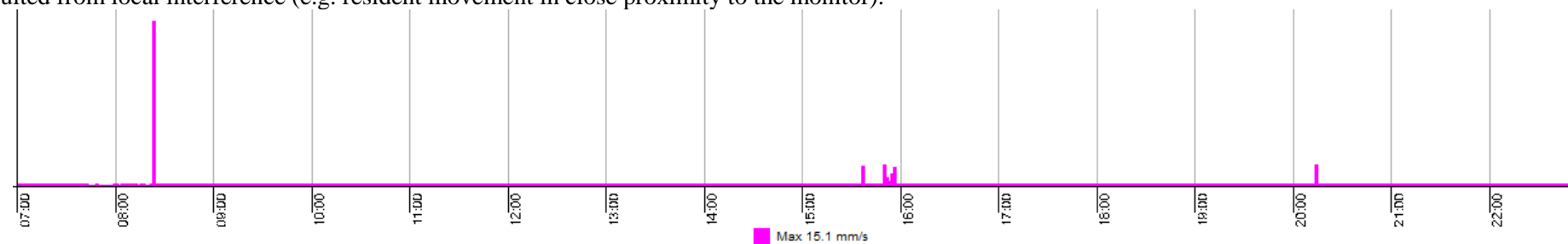
Notes:

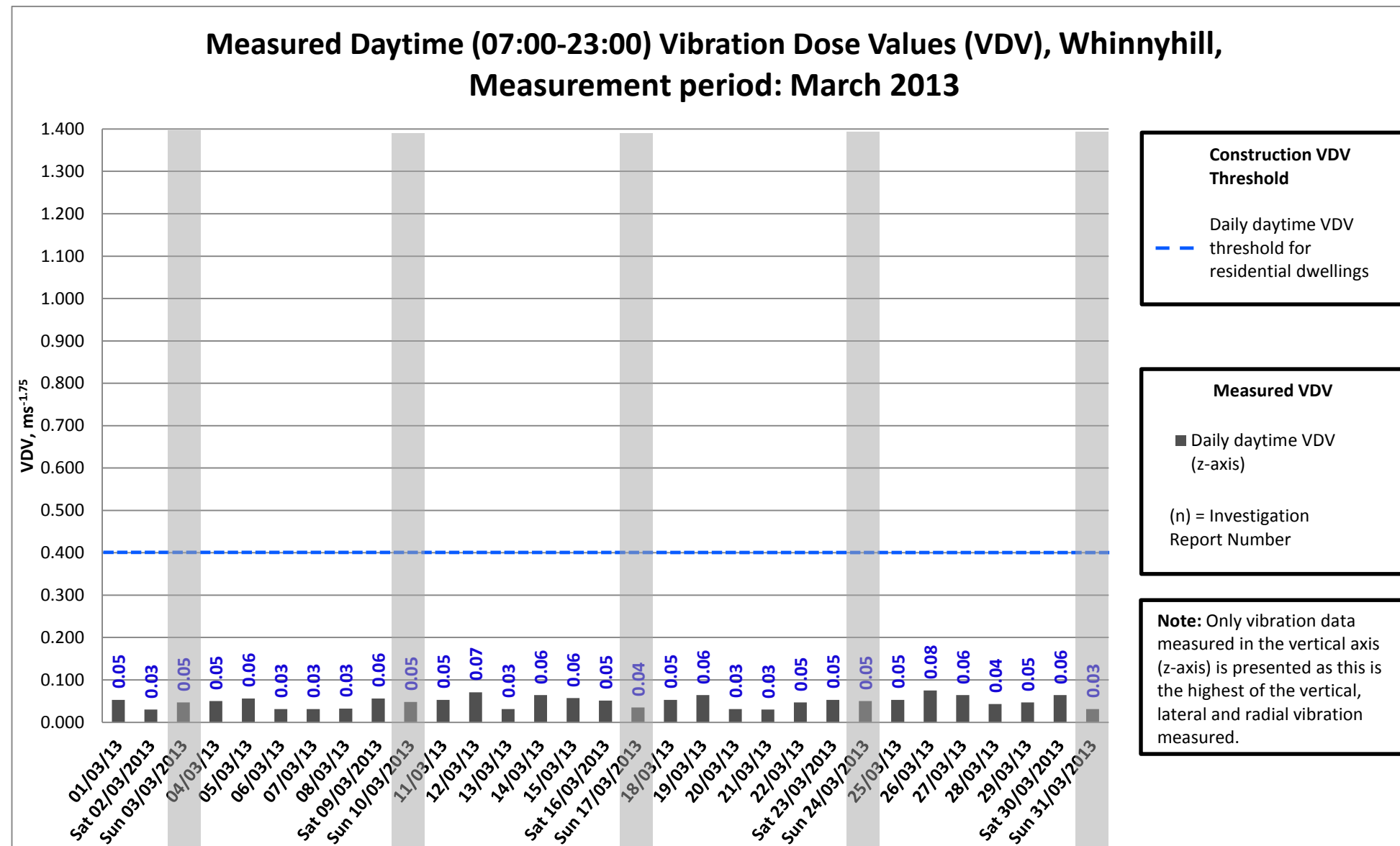
- VDV exceedances on the 10/03/13 and the 20/03/13 have been investigated. These particular levels cannot have been generated as a result of FCBC construction, as the only works to be conducted on these dates in the vicinity of the monitor, were caisson excavation at the North Tower. There was no vibration inducing plant or equipment involved in this activity, thus it can be discounted as the source of these particular VDV's.



Notes:

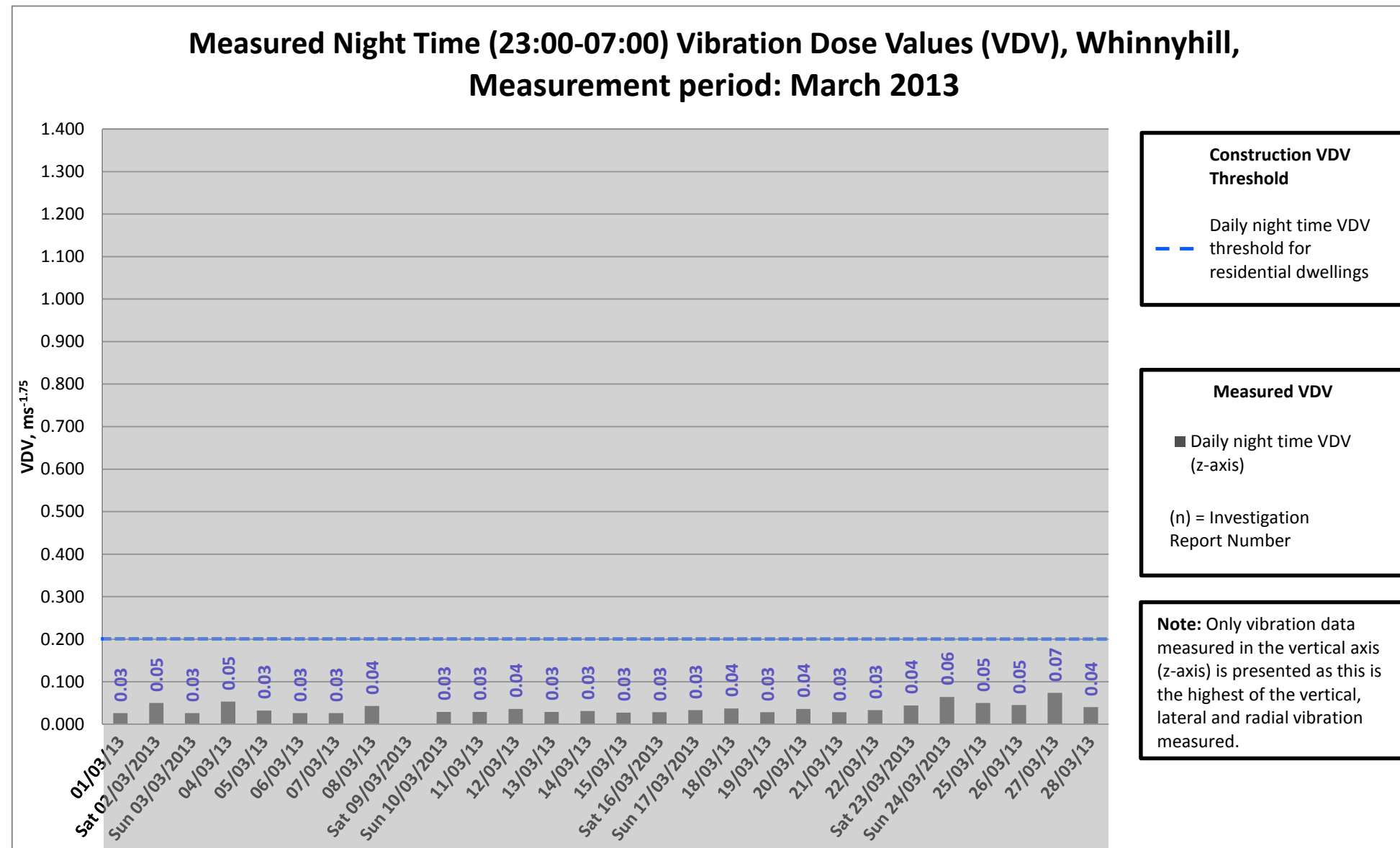
- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted on Sundays.
- All PPV exceedances have been investigated, and have been seen to be individual, isolated events within each period (see Vibrock PPV graph below from 14/03/13). The only vibration inducing plant or equipment involved in these activities were rock breakers, which were operated a minimum distance of 270m from the monitor (and nearest receptors), and can thus be discounted as the source of these particular PPVs. Considering the location of the monitor, these levels likely resulted from local interference (e.g. resident movement in close proximity to the monitor).





Notes:

- The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted 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 March 2013. This graph is included for illustrative purposes only.
 - Data is missing for 09/03/13 due to device error.

**APPENDIX C - VIBRATION MONITORING REPORT FOR CONSTRUCTION OF PIER
S6 COFFERDAM**



TRANSPORT
SCOTLAND

An agency of



The Scottish Government

Contractor



Forth Crossing Bridge Constructors

HOCHTIEF Solutions
American Bridge International
DRAGADOS
Morrison Construction

Project

FORTH REPLACEMENT CROSSING

Document title

**VIBRATION MONITORING REPORT
CONSTRUCTION OF PIER S6 COFFERDAM**

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

Appendices:

Appendix A: Vibration Monitoring Results

1. 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 works undertaken during the construction of the Pier S6 Foundation, in particular the construction of the earth bund and the sheet piling works associated with the construction of the cofferdam. These works were conducted during December 2012 and January 2013 respectively. The objective of this report is to detail the results of the vibration monitoring that has been undertaken, in relation to these activities, at the nearest sensitive receptor - Port Edgar Barracks Bunker.

- 1.2. FCBC are required to risk assess noise and vibration resulting from all construction activities, prior to their commencement, through the production of Plans for Control of Noise & Vibration (PCNVs). During the preparation of PCNVs for the two relevant activities associated with the construction of the Pier S6 cofferdam, the assessments/predictions of vibration levels illustrated that the only equipment to be utilised with potential to generate appreciable levels of vibration at the Port Edgar Barracks Bunker were the vibratory roller and vibratory piling rig. These items of plant were to be used during the compaction of the earth bund and insertion of the sheet piles respectively.

- 1.3. Monitoring of construction vibration levels apparent at the Port Edgar Barracks Bunker has been undertaken in accordance with the relevant PCNVs for these activities;
 - *PCNV-00011 – Mod 03A – S6 Tidal Working (S6 Earth Bund)*
 - *PCNV-00011 – Rev 04 – Land Based Piers (S6 Piling)*

2. MONITORING SUMMARY

- 2.1.** 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).

- 2.2.** The PPV 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. For the construction of the earth bund and the piling activities associated with the Pier S6 cofferdam the agreed thresholds, as detailed in the relevant PCNVs, at the Port Edgar Barracks Bunker were 12 mm.s^{-1} for continuous construction (e.g. piling, vibratory rolling etc.), and 15 mm.s^{-1} for intermittent construction (e.g. blasting).

- 2.3.** These thresholds, along with the working methods and monitoring procedures outlined in the relevant PCNVs, are set to protect against structural damage.

- 2.4.** For initial works, a process of testing and monitoring with an incremental increase in the vibration levels (decrease in distance between vibration inducing plant and the bunker) was adopted, in order to demonstrate certainty, regarding the avoidance of impacts on the Port Edgar Barracks Bunker. This approach was utilised in conjunction with 'tell-tales' (glass slides glued across existing structural cracks) as a visual reference in order to provide immediate identification of any structural damage should it occur, however unlikely.

- 2.5.** During compaction works associated with the construction of Pier S6 earth bund, the required levels of compaction were achieved through operating the roller as a dead weight, hence it was not necessary to utilise the vibratory roller in 'vibration mode'. For this reason the levels of vibration associated with this activity were considerably lower than originally forecast and were well within the threshold values.

- 2.6.** For the majority of the piling works associated with the Pier S6 cofferdam (circa 85%) a method of vibrational-piling utilising 'Z-piles' was adopted. However, for piling works in closest proximity to the Port Edgar Barracks Bunker a minimal vibration 'push-pull' method of piling utilising 'U-piles' was adopted. The exact point of transference between piling methods was determined by the monitoring results.
- 2.7.** The vibration monitoring approach adopted for the piling works is outlined below;
- Measurements of vibration levels, with incremental reduction in distance between piling rig & structure (commencing at distance >25m from the structure).
 - Attended vibration monitoring at structure and inspection of 'tell-tales' for each significant reduction in distance between piling rig and structure (each 5m reduction).
 - Revert to U-piling if/when vibration thresholds are approached/exceeded or if 'tell-tales' identify any structural variation or damage.
 - Daily analysis of vibration monitoring data and inspection of 'tell-tales' for duration of works.
- 2.8.** The locations of the 3 vibration monitors installed in the vicinity of the Port Edgar Barracks Bunker for the duration of these works are illustrated in Figure 1 and listed below;
- (1) On the step at the entrance to the structure.
 - (2) Adjacent to the structure boundary, at the point closest to the works.
 - (3) On top of the structure.

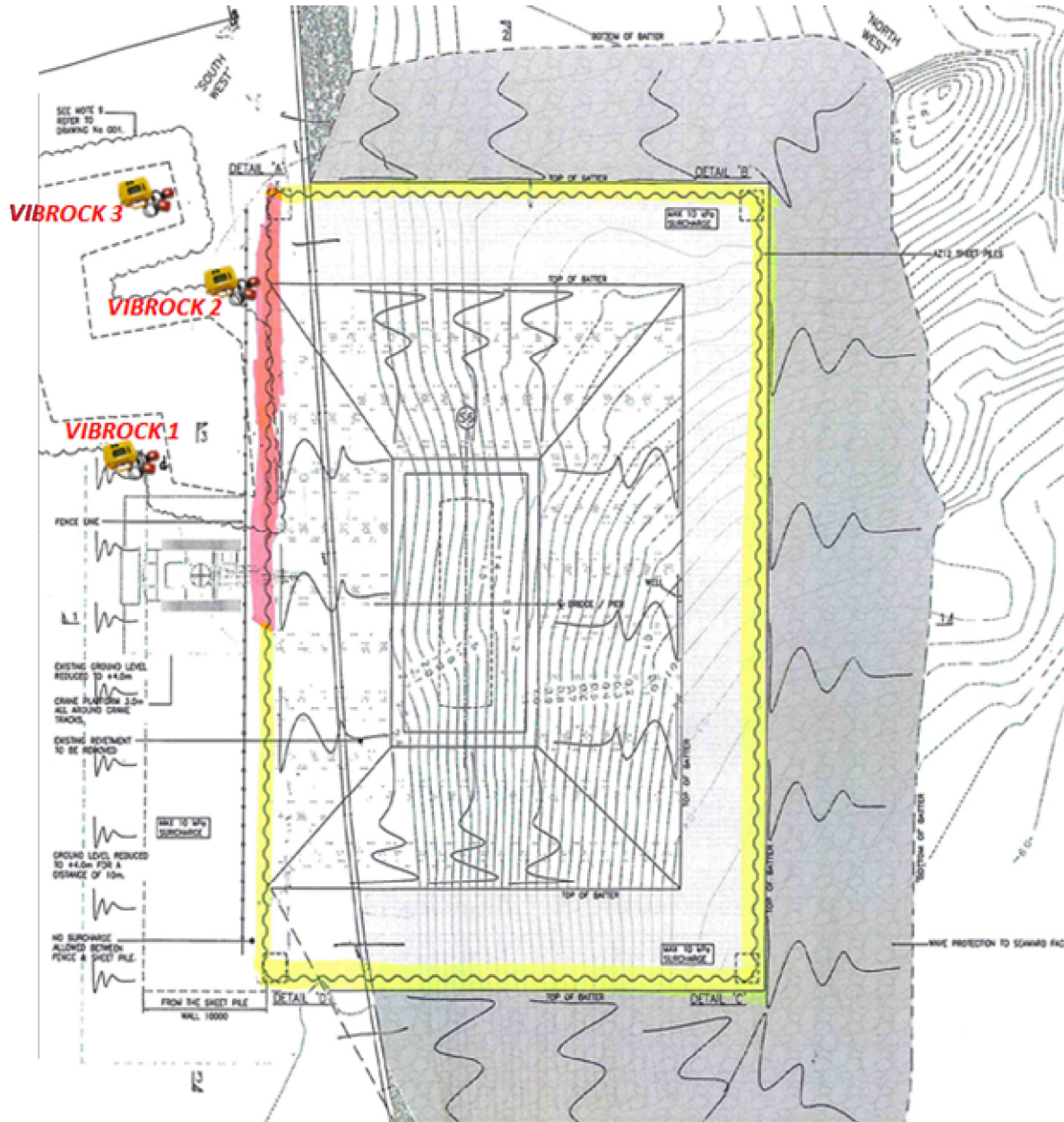


Figure 1: Monitor & Piling Locations

Notes on Figure 1

- Yellow line denotes 'Z piled' area & boundaries (utilising vibrational piling rig).
- Red line denotes 'U piled' area & boundaries (utilising push pull piling rig).
- These are estimated boundaries areas only. Exact boundaries were determined by vibration monitor & visual reference results.

3. MONITORING RESULTS

- 3.1.** Graphs displaying results from each of the vibration monitors in Figure 1 for the period relating to the construction of the Pier S6 cofferdam, the months of December 2012 and January 2013, are included in Appendix A. These results illustrate that there were no vibration threshold exceedances at the Port Edgar Bunker throughout this period.

4. CONCLUSION

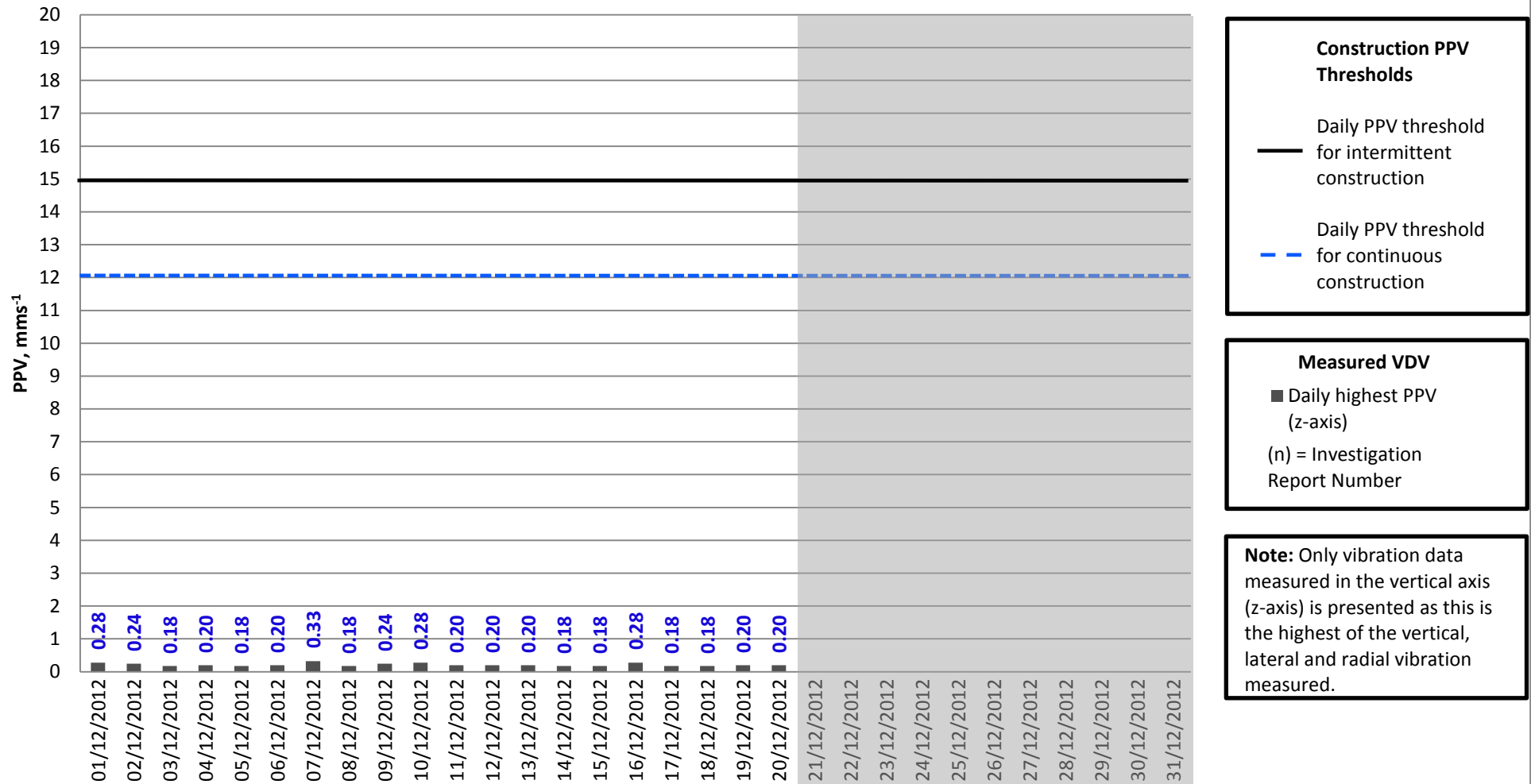
- 4.1.** The working methods adopted in conjunction with the rigorous monitoring approach employed, which included a combination of attended vibration monitoring and the utilisation of glass slides ('tell tales') as a visual reference, have ensured the occurrence of no threshold exceedances throughout the execution of the works associated with the construction of the Pier S6 cofferdam.
- 4.2.** Considering the results displayed in Appendix A of this report, in conjunction with the fact that the glass slides utilised as visual references remained unchanged throughout the completion of these works, the risk of damage to the Port Edgar Barracks Bunker (or any other structure) resulting from vibration associated with the construction of the Pier S6 cofferdam is highly unlikely.



APPENDIX A – VIBRATION MONITORING RESULTS

Measured highest daily Peak Particle Velocity (PPV), Bunker Steps (VIBROCK 1)

Measurement period: December 2012



Construction PPV Thresholds

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

Measured VDV

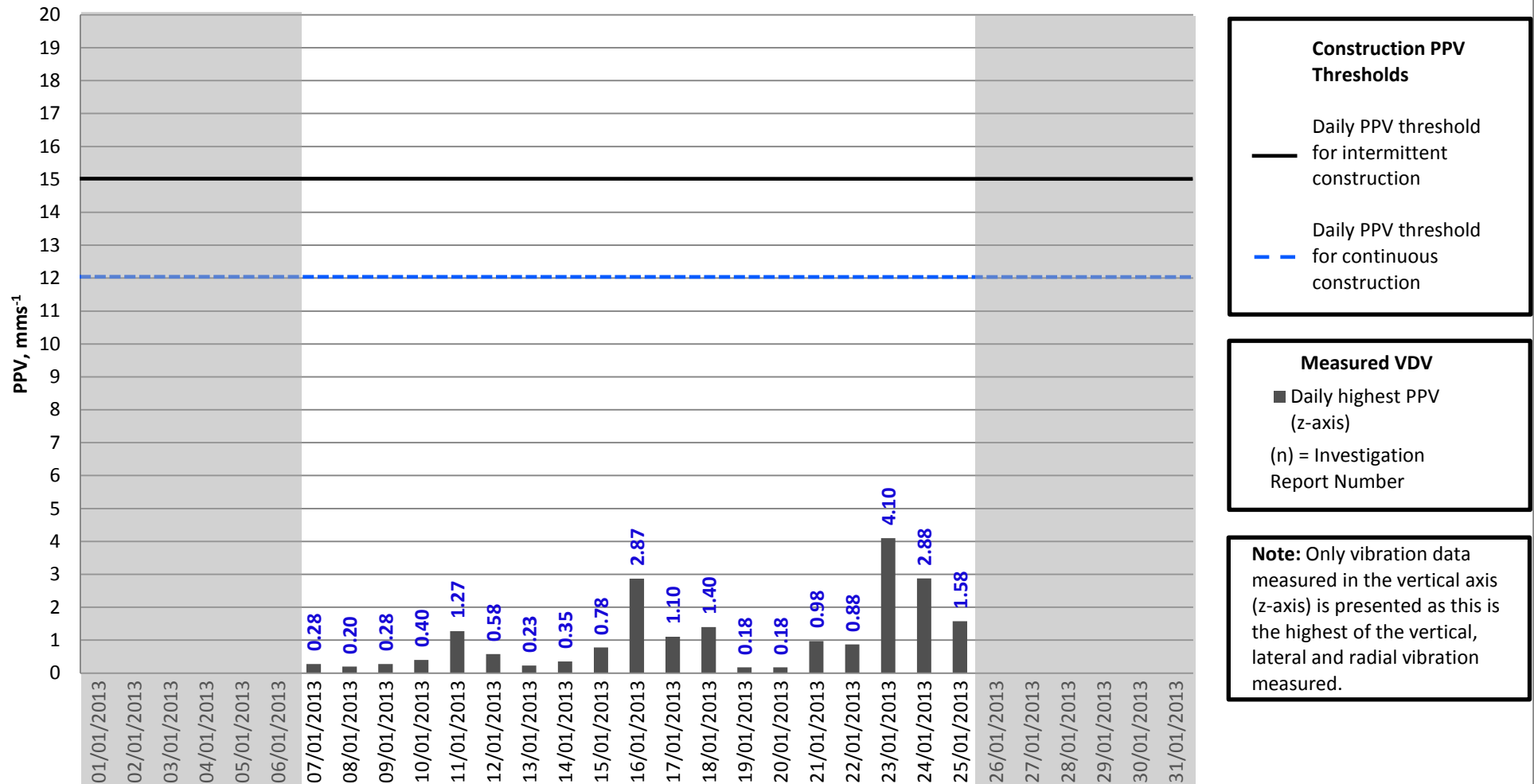
- Daily highest PPV (z-axis)
- (n) = Investigation Report Number

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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/13

Measured highest daily Peak Particle Velocity (PPV), Bunker Steps (VIBROCK 1)

Measurement period: January 2013



Construction PPV Thresholds

— Daily PPV threshold for intermittent construction

- - - Daily PPV threshold for continuous construction

Measured VDV

■ Daily highest PPV (z-axis)

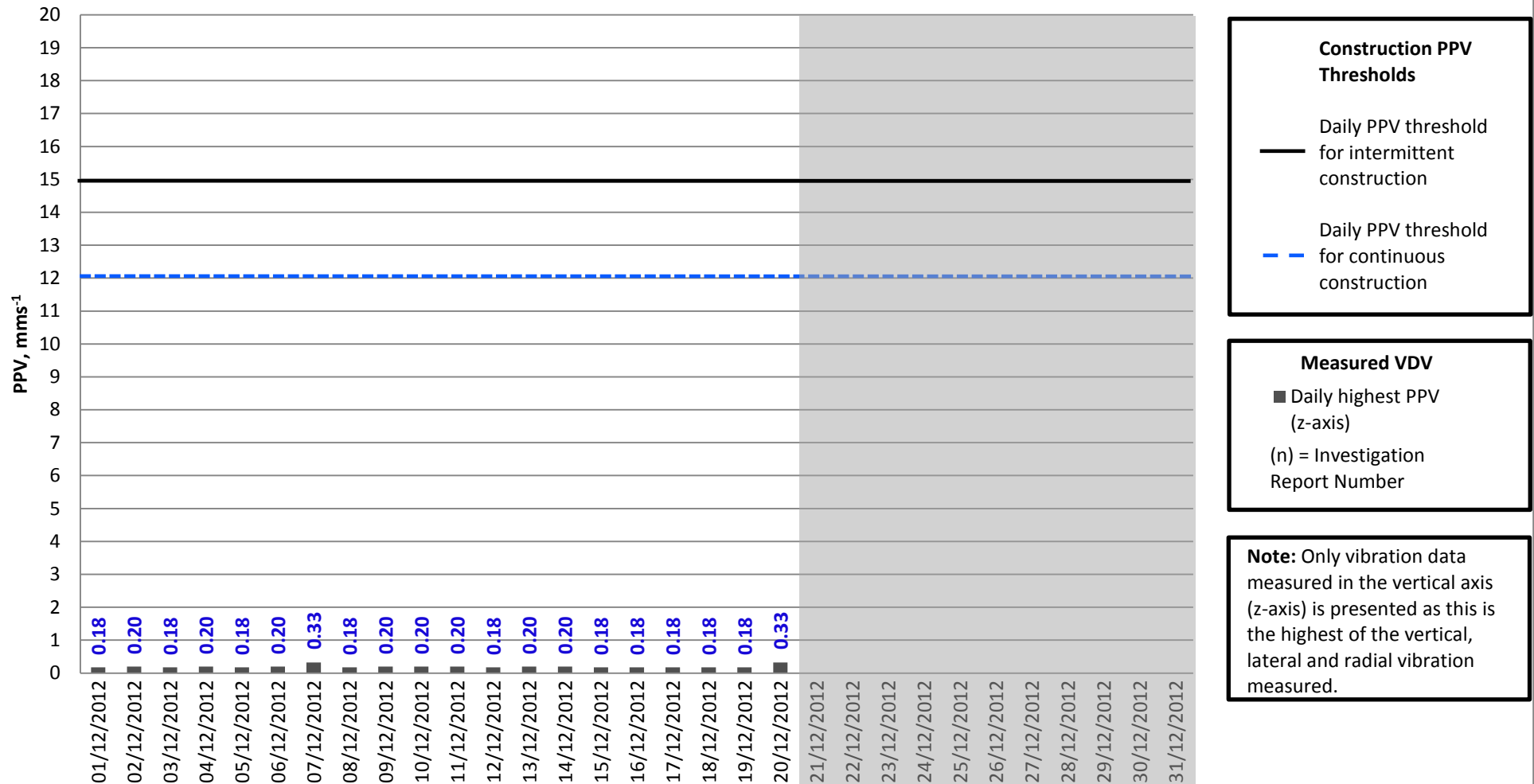
(n) = Investigation Report Number

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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/13. Piling works were completed at Pier S6 on 25/01/13.

Measured highest daily Peak Particle Velocity (PPV), Bunker Ground (VIBROCK 2)

Measurement period: December 2012



Construction PPV Thresholds

— Daily PPV threshold for intermittent construction

- - - Daily PPV threshold for continuous construction

Measured VDV

■ Daily highest PPV (z-axis)

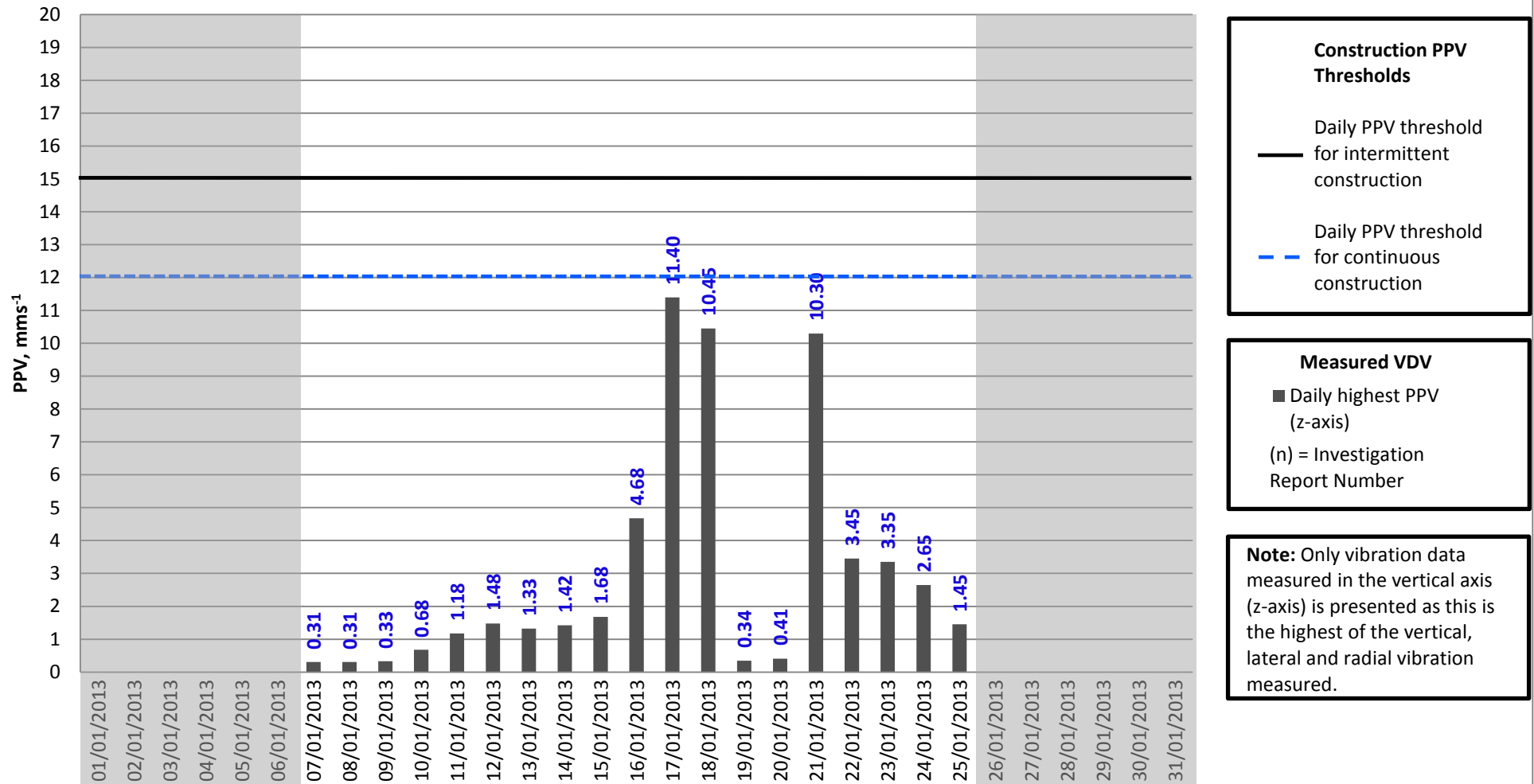
(n) = Investigation Report Number

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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/13

Measured highest daily Peak Particle Velocity (PPV), Bunker Ground (VIBROCK 2)

Measurement period: January 2013



Construction PPV Thresholds

- Daily PPV threshold for intermittent construction (solid black line)
- Daily PPV threshold for continuous construction (dashed blue line)

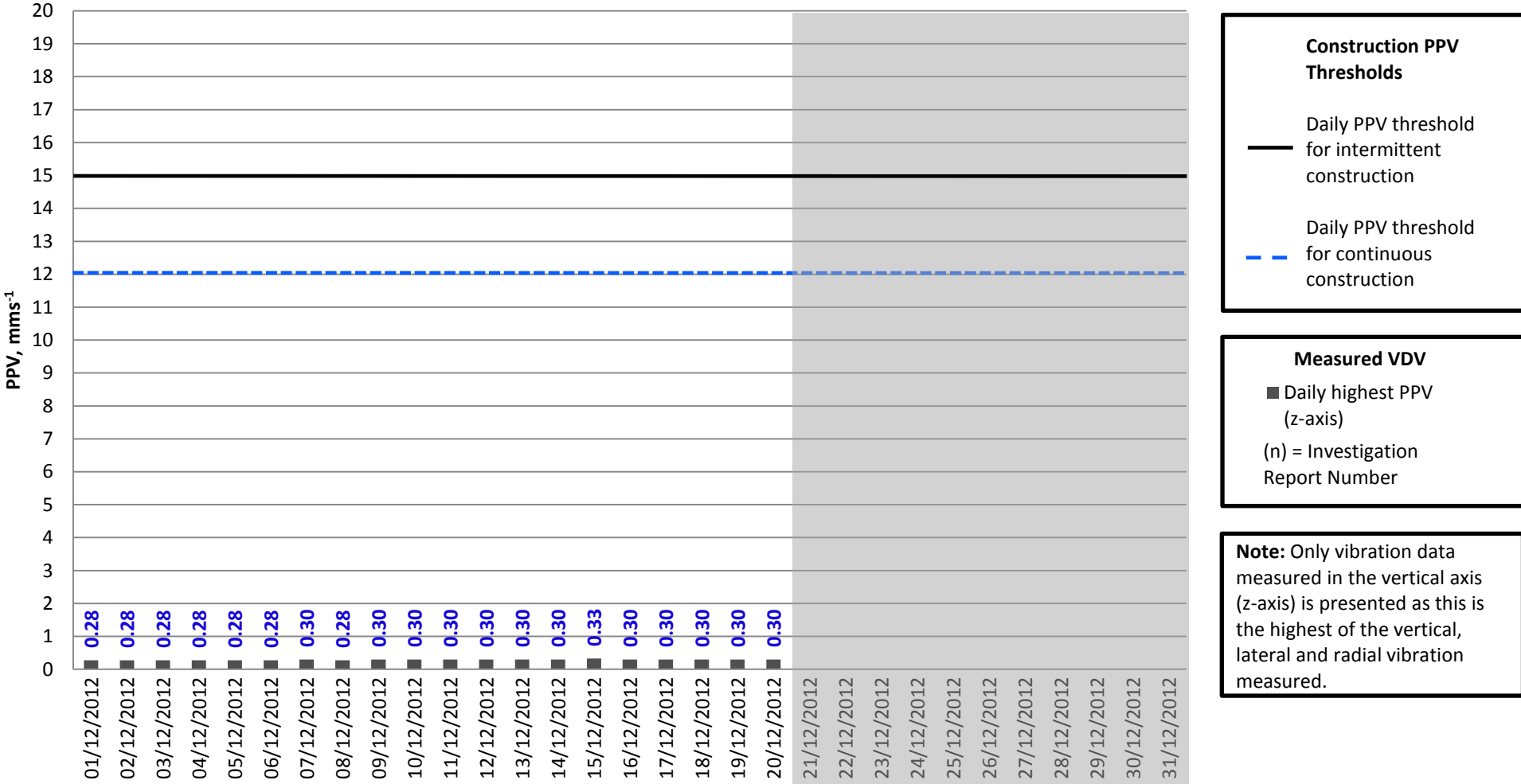
Measured VDV

- Daily highest PPV (z-axis) (grey bar)
- (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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/13. Piling works were completed at Pier S6 on 25/01/13.

Measured highest daily Peak Particle Velocity (PPV), Bunker Roof (VIBROCK 3) Measurement period: December 2012



Construction PPV Thresholds

— Daily PPV threshold for intermittent construction

- - - Daily PPV threshold for continuous construction

Measured VDV

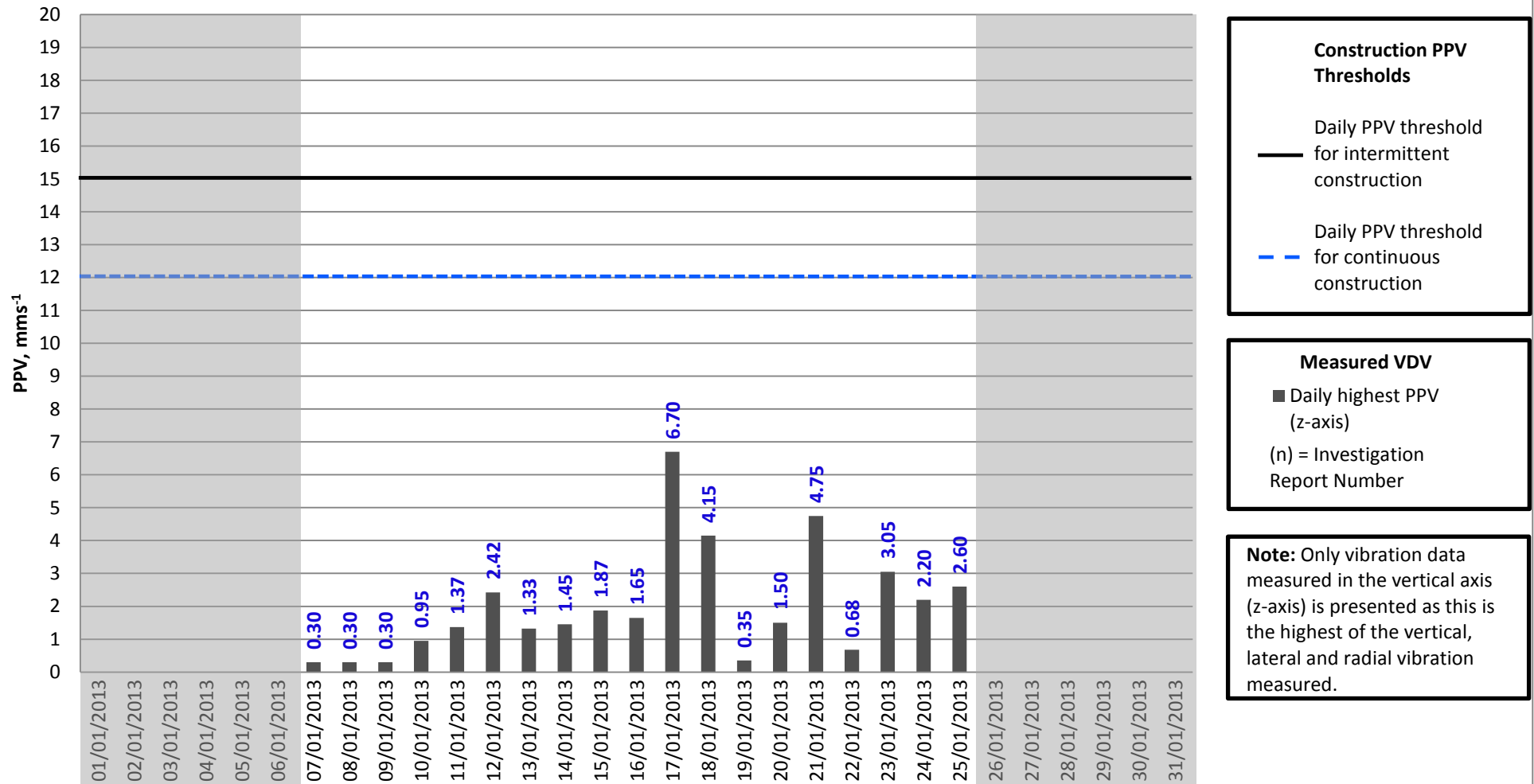
■ Daily highest PPV (z-axis)

(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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/13

Measured highest daily Peak Particle Velocity (PPV), Bunker Roof (VIBROCK 3) Measurement period: January 2013



Construction PPV Thresholds

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

Measured VDV

- 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.

Note: The grey areas of the chart represent the days on which no construction works were undertaken; no works were conducted at Pier S6 over the Christmas period - 20/01/13 to 06/01/14. Piling works were completed at Pier S6 on 25/01/13.