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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Contents

Appendices:

INTRODUCTION

1.1. In accordance with the Code of Construction Practice (CoCP) and Noise and Vibration Management Plan, FCBC have risk assessed all construction activities through the PCNV process.

1.2. During the preparation of the PCNVs, assessment/prediction of vibration levels showed that no plant or equipment used, or construction activity carried out was envisaged to induce any level of vibration at receptors that would exceed the vibration threshold levels stated in the CoCP. This assessment/prediction was confirmed by means of permanent vibration monitoring.

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 any significant movements occurring close to the monitoring equipment.

2.2. According to the BS5228-2 (2009) there is hardly any documented proof of actual damage to structures or their finishes, 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. It is not possible to ascertain the exact cause of vibration, though it is possible to rule out construction as a cause on an activity basis.

2.3. The works carried out in each construction areas as well as vibration assessments of the works are summarised in Appendix A.

2.4. Due to the distance between the works and the receptors and the methods of working the risk of damage to structures or nuisance to the residents due to vibration is highly unlikely.

2.5. The numbers of exceedances during construction are shown in Table 1 below.

Table 1- Exceedances of thresholds set out in the COCP

November

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$^{-1.75}$)*
5 Linn Mill	3	4	2	12
Butlaw Fisheries	0	0	0	0
Dundas Home Farm	0	0	2	5
Echline	1	0	0	0
Inchgarvie Lodge	1	2	0	0
Scotstoun	2	1	0	0
Springfield	1	0	20	20
Tigh-Na-Grian	4	3	0	0
Whinnyhill	8	7	0	18

December

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$^{-1.75}$)*
5 Linn Mill	11	8	5	10
Butlaw Fisheries	0	0	0	0
Dundas Home Farm	0	1	0	12
Echline	10	0	0	0
Inchgarvie Lodge	1	2	1	0
Scotstoun	0	0	0	0
Springfield	3	6	14	15
Tigh-Na-Grian	4	10	1	3
Whinnyhill	3	6	0	16

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 be generated due to standalone, instantaneous events resulting from unknown local interferences.

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 VDVs in $m.s^{-1.75}$.

2.10. During the monitoring period, vibratory rollers were used intermittently at several locations around the site in the construction of haul roads. Due to the distances of the rollers away from any receptors none of the exceedances in VDV levels can be associated with the use of vibratory rollers.

2.11. 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 occurred close to the monitoring transducer.

2.12. Within the Appendix B, there are short gaps of missing data in the PPV and VDV graphs. These occurred as a result of:

- Server problems which resulted in the loss of data over the first two weeks of November 2012.
- The monitoring devices corrupting some logged data.

3. Conclusion

3.1. Considering the distance between construction works and the above 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 OF RELEVANT PCNVs

Table 2: Monitoring Locations

Ref.	Monitoring Location	Crossing or Network	Main Construction Activities During November & December 2012
M1	Whinny Hill	Network	Drilling for blasting Blasting Breaking and excavation of rock Haulage of rock N.B. No evening, night time or Sunday daytime construction in vicinity.
M3	Tigh-Na-Grian	Crossing	On-going works at Central Tower North Tower Caisson Excavation Installation of Pier N1 platform
M7	Butlaw Fisheries	Crossing	On-going works at Central Tower South Tower jet grouting S1 caisson excavation Pier S4 excavation Works at Piers S7 & S8 Pier S6 Access Track drainage works & Earth Bund Verge clearance at Society Road
M10	Inchgarvie Lodge	Crossing	On-going works at Central Tower South Tower jet grouting Pier S4 excavation Works at piers S7 & S8 Pier S6 Access Track drainage works & Earth Bund Excavation of material from launch and South Abutment Concreting works Verge clearance at Society Road
M11	Linn Mill	Network	Excavation of material from launch and South Abutment Concreting works N.B. No evening, night time or Sunday daytime construction in vicinity.
M14	Springfield	Network	Break out rock & excavation of material from launch N.B. No evening, night time or Sunday daytime construction in vicinity.
M15	Echline Field	Network	Cut/Fill from Queensferry gyratory Generate rock from Queensferry gyratory Works on A904 N.B. No evening, night time or Sunday

			daytime construction in vicinity.
M16	Scotstoun	Network	Import of materials Site Clearance Utility works N.B. No evening, night time or Sunday daytime construction in vicinity.
M17	Dundas Home Farm	Network	Utilities works Earthworks 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 November and December 2012.

Table 3: Monitoring Locations

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 -23:00)	Night (23:00-07:00)		PPV (mm/s)	eVDV ($m.s^{-1.75}$)
Butlaw Fisheries	150	230	Roller	0.36	0.19
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	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	Blasts	-	-

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 to 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 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 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 vibratory roller remaining in continuous operation for 2 hours a minimum distance from the nearest receptor.

Butlaw Fisheries				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00011	Nov 12 to Dec 12	Land Based Piers	1. S7 Foundation – Construction of S7 foundation 2. S8 Foundation – Construction of S8 foundation 3. N2 Foundation – Construction of N2 foundation including drilling shot holes for blasting. 4. Construction of Working Platform at S6 as well as Construction of S6 Earth Bund.	PPV: Nearest property to the works is Inchgarvie House which is an average 64m from foundation S8. All other works are on average over 100m from the works. A predicted vibration level assessment is presented in Appendix 6. The highest levels of vibration are likely to be generated by the vibratory roller during the hard-standing preparation. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: Nearest property to the works is Inchgarvie House which is on average 64m from foundation S8. Therefor this property has been assessed as it will be the most likely to have an effect on the human response to vibration. An estimated VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach. Once works start these levels will be closely monitored and actual VDV levels will be taken from monitoring equipment.

Butlaw Fisheries				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00020	Nov 12 to Dec 12	Marine Foundation Works	Construction of the foundations for S1 to S5, N1 and the North, Central and South Towers.	Due to the distance between the works and the nearest sensitive properties and the method of working renders the risk of damage to structures due to vibration as highly unlikely.
PCNV-00021	Nov 12 to Dec 12	South Earthworks	1. Earthworks – cut and fill operations including excavation and deposition of rock 2. Drainage – pre earthworks, temporary, outfall, attenuation, chambers, headwalls, culverts, carriageway 3. Road work operations 4. Utility diversions – electric, water, sewerage, gas, BT 5. Site Clearance	PPV: The closest building to these activities, which is Inchgarvie House, is 25m in distance (worst case). This will remain unoccupied for the duration of these works. A predicted PPV assessment is presented in Appendix 6 for this receptor. The highest levels of vibration are likely to be generated by the vibratory roller during the compaction of sub-base and various road layers. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: The vibratory roller shall not be operated within 100m distance of any of the occupied receptors from this activity. An estimated (worst case) VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment

Butlaw Fisheries				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
				Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach.

Inchgarvie Lodge				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00011	Nov 12 to Dec 12	Land Based Piers	1. S7 Foundation – Construction of S7 foundation 2. S8 Foundation – Construction of S8 foundation 3. N2 Foundation – Construction of N2 foundation including drilling shot holes for blasting. 4. Construction of Working Platform at S6 as well as Construction of S6 foundation.	PPV: Nearest property to the works is Inchgarvie House which is an average 64m from foundation S8. All other works are on average over 100m from the works. A predicted vibration level assessment is presented in Appendix 6. The highest levels of vibration are likely to be generated by the vibratory roller during the hard-standing preparation. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: Nearest property to the works is Inchgarvie House which is on average 64m from foundation S8. Therefor this property has been assessed as it will be the most likely to have an effect on the human response to vibration. An estimated VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach. Once works start these levels will be closely monitored and actual VDV levels will be taken from monitoring equipment.

Inchgarvie Lodge				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00020	Nov 12 to Dec 12	Marine Foundation Works	Construction of the foundations for S1 to S5, N1 and the North, Central and South Towers.	Due to the distance between the works and the nearest sensitive properties and the method of working renders the risk of damage to structures due to vibration as highly unlikely.
PCNV-00021	Nov 12 to Dec 12	South Earthworks	1. Earthworks – cut and fill operations including excavation and deposition of rock 2. Drainage – pre earthworks, temporary, outfall, attenuation, chambers, headwalls, culverts, carriageway 3. Road work operations 4. Utility diversions – electric, water, sewerage, gas, BT 5. Site Clearance	PPV: The closest building to these activities, which is Inchgarvie House, is 25m in distance (worst case). This will remain unoccupied for the duration of these works. A predicted PPV assessment is presented in Appendix 6 for this receptor. The highest levels of vibration are likely to be generated by the vibratory roller during the compaction of sub-base and various road layers. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: The vibratory roller shall not be operated within 100m distance of any of the occupied receptors from this activity. An estimated (worst case) VDV assessment is presented in Appendix 6.

Inchgarvie Lodge				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
				The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach.

Linn Mill				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00011	Nov 12 to Dec 12	Land Based Piers	1. S7 Foundation – Construction of S7 foundation 2. S8 Foundation – Construction of S8 foundation 3. N2 Foundation – Construction of N2 foundation including drilling shot holes for blasting. 4. Construction of Working Platform at S6 as well as Construction of S6 foundation.	PPV: Nearest property to the works is Inchgarvie House which is an average 64m from foundation S8. All other works are on average over 100m from the works. A predicted vibration level assessment is presented in Appendix 6. The highest levels of vibration are likely to be generated by the vibratory roller during the hard-standing preparation. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: Nearest property to the works is Inchgarvie House which is on average 64m from foundation S8. Therefor this property has been assessed as it will be the most likely to have an effect on the human response to vibration. An estimated VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach. Once works start these levels will be closely monitored and actual VDV levels will be taken from monitoring equipment.

Linn Mill				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00020	Nov 12 to Dec 12	Marine Foundation Works	Construction of the foundations for S1 to S5, N1 and the North, Central and South Towers.	Due to the distance between the works and the nearest sensitive properties and the method of working renders the risk of damage to structures due to vibration as highly unlikely.
PCNV-00021	Nov 12 to Dec 12	South Earthworks	1. Earthworks – cut and fill operations including excavation and deposition of rock 2. Drainage – pre earthworks, temporary, outfall, attenuation, chambers, headwalls, culverts, carriageway 3. Road work operations 4. Utility diversions – electric, water, sewerage, gas, BT 5. Site Clearance	PPV: The closest building to these activities, which is Inchgarvie House, is 25m in distance (worst case). This will remain unoccupied for the duration of these works. A predicted PPV assessment is presented in Appendix 6 for this receptor. The highest levels of vibration are likely to be generated by the vibratory roller during the compaction of sub-base and various road layers. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: The vibratory roller shall not be operated within 100m distance of any of the occupied receptors from this activity. An estimated (worst case) VDV assessment is presented in Appendix 6.

Linn Mill				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
				The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach.

Springfield, Echline				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00008 (Mod02 & 04)	Nov 12 to Dec 12	Construction of BP Protection Works	Extension to the programme of PCNV-0008 with the addition of Construction of BP Protection Works. These works are to allow BP Specialist Works to be carried out on the Oil Line.	As per PCNV-00008 Section 8, all equipment to be used in these activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken.
PCNV-00021	Nov 12 to Dec 12	South Earthworks	1. Earthworks – cut and fill operations including excavation and deposition of rock 2. Drainage – pre earthworks, temporary, outfall, attenuation, chambers, headwalls, culverts, carriageway 3. Road work operations 4. Utility diversions – electric, water, sewerage, gas, BT 5. Site Clearance	PPV: The closest building to these activities, which is Inchgarvie House, is 25m in distance (worst case). This will remain unoccupied for the duration of these works. A predicted PPV assessment is presented in Appendix 6 for this receptor. The highest levels of vibration are likely to be generated by the vibratory roller during the compaction of sub-base and various road layers. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: The vibratory roller shall not be operated within 100m distance of any of the occupied receptors from this activity. An estimated (worst case) VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental

				Statement. This method will over-estimate VDV and therefore represents a conservative approach.

Dundas Home Farm, Scotstoun

Relevant PCNV No.	Relevant Date	PCNV Name	Particulars of works to be carried out	Vibration Assessment
PCNV-00008 (Mod02 & 04)	Nov 12 to Dec 12	Construction of BP Protection Works	Extension to the programme of PCNV-0008 with the addition of Construction of BP Protection Works. These works are to allow BP Specialist Works to be carried out on the Oil Line.	As per PCNV-00008 Section 8, all equipment to be used in these activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken.
PCNV-00021	Nov 12 to Dec 12	South Earthworks	1. Earthworks – cut and fill operations including excavation and deposition of rock 2. Drainage – pre earthworks, temporary, outfall, attenuation, chambers, headwalls, culverts, carriageway 3. Road work operations 4. Utility diversions – electric, water, sewerage, gas, BT 5. Site Clearance	PPV: The closest building to these activities, which is Inchgarvie House, is 25m in distance (worst case). This will remain unoccupied for the duration of these works. A predicted PPV assessment is presented in Appendix 6 for this receptor. The highest levels of vibration are likely to be generated by the vibratory roller during the compaction of sub-base and various road layers. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: The vibratory roller shall not be operated within 100m distance of any of the occupied receptors from this activity. An estimated (worst case) VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3

				Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach.

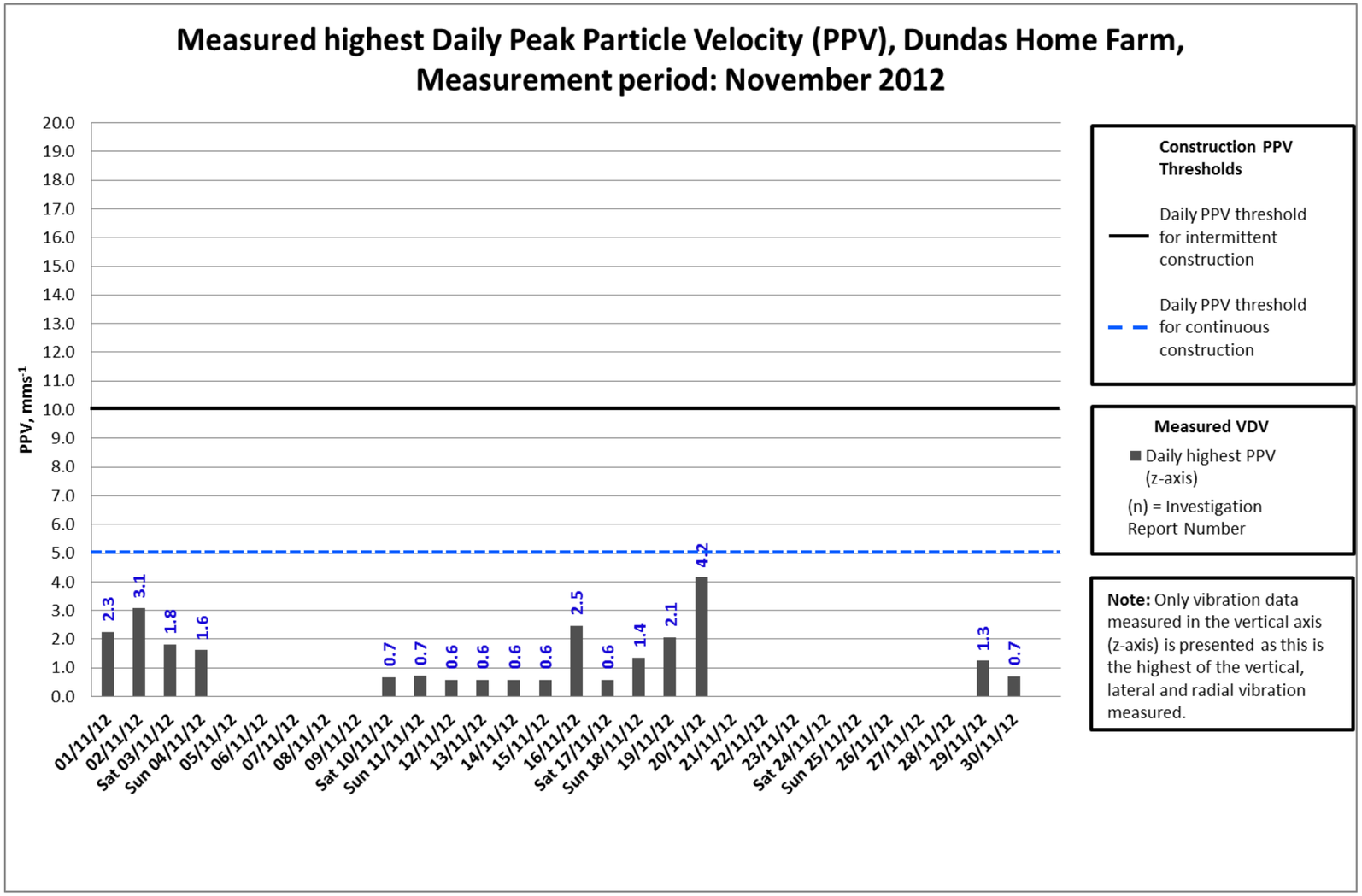
Tigh-Ni-Grian				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00010	Nov 12 to Dec 12	North 1 Works	Drilling Shot Holes; Removal of Blasted Rock; Structure; Filling; Removal of Blasted Rock; Soil Mixing; Piled Embankment; Sewer Diversions; Working Platform; Ground Improvement.	The equipment to be used in these activities do not generate appreciable levels of vibration, also the distances to the closest occupied receptors are over 300m so therefore no assessment has been undertaken.
PCNV-00011	Nov 12 to Dec 12	Land Based Piers	1. S7 Foundation – Construction of S7 foundation 2. S8 Foundation – Construction of S8 foundation 3. N2 Foundation – Construction of N2 foundation including drilling shot holes for blasting. 4. Construction of Working Platform at S6 as well as Construction of S6 foundation.	PPV: Nearest property to the works is Inchgarvie House which is an average 64m from foundation S8. All other works are on average over 100m from the works. A predicted vibration level assessment is presented in Appendix 6. The highest levels of vibration are likely to be generated by the vibratory roller during the hard-standing preparation. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: Nearest property to the works is Inchgarvie House which is on average 64m from foundation S8. Therefor this property has been assessed as it will be the most likely to have an effect on the human response to vibration. An estimated VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment

Tigh-Ni-Grian				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
				Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental Statement. This method will over-estimate VDV and therefore represents a conservative approach. Once works start these levels will be closely monitored and actual VDV levels will be taken from monitoring equipment.
PCNV-00015	Nov 12 to Dec 12	Blasting North Network	Blasting at St Margaret's Hope • Traffic Management • Loading of the explosives. • Firing of the explosives to create a blast at St Margret's Hope.	A protective vibration level of less than 10mm.s^{-1} has been maintained for the Queensferry Hotel. Queensferry Hotel has been identified as the only occupied receptor to be within sufficient distance to be effected by blasting at St Margret's Hope. A review of sensitive properties and structures identifies the following closest receptors to St Margret's Hope: Radar Station, Admiralty House, St Margaret's Hope Lodge, Queensferry Hotel. These receptors are deemed to conservatively protect other structures further away. Vibration monitors for air over pressure and ground vibration have been installed at each location.
PCNV-00020	Nov 12 to Dec 12	Marine Foundation Works	Construction of the foundations for S1 to S5, N1 and the North, Central and South Towers.	Due to the distance between the works and the nearest sensitive properties and the method of working renders the risk of damage to structures due to vibration as highly unlikely.

Whinny Hill				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
PCNV-00010	Nov 12 to Dec 12	North 1 Works	Drilling Shot Holes; Removal of Blasted Rock; Structure; Filling; Removal of Blasted Rock; Soil Mixing; Piled Embankment; Sewer Diversions; Working Platform; Ground Improvement.	The equipment to be used in these activities do not generate appreciable levels of vibration, also the distances to the closest occupied receptors are over 300m so therefore no assessment has been undertaken.
PCNV-00011	Nov 12 to Dec 12	Land Based Piers	1. S7 Foundation – Construction of S7 foundation 2. S8 Foundation – Construction of S8 foundation 3. N2 Foundation – Construction of N2 foundation including drilling shot holes for blasting. 4. Construction of Working Platform at S6 as well as Construction of S6 foundation.	PPV: Nearest property to the works is Inchgarvie House which is an average 64m from foundation S8. All other works are on average over 100m from the works. A predicted vibration level assessment is presented in Appendix 6. The highest levels of vibration are likely to be generated by the vibratory roller during the hard-standing preparation. Hydraulic rock breakers which would typically generate 4.5 mm/s @ 5m, 0.4 @ 20m, 0.1 @ 50m will not generated appreciable levels of vibration levels due to the distance from the closest receptor. Equipment to be used in all other activities does not generate appreciable levels of vibration and therefore no assessment has been undertaken. VDV: Nearest property to the works is Inchgarvie House which is on average 64m from foundation S8. Therefor this property has been assessed as it will be the most likely to have an effect on the human response to vibration. An estimated VDV assessment is presented in Appendix 6. The estimated VDV are calculated using the calculation methodology provided in DMRB Stage 3 Environmental Statement Chapter 19 Section 19.6.21. Assessment Criteria as defined in British Standard 6472:2008 and Tables 19.11 and 19.12 of DMRB Stage 3 Environmental

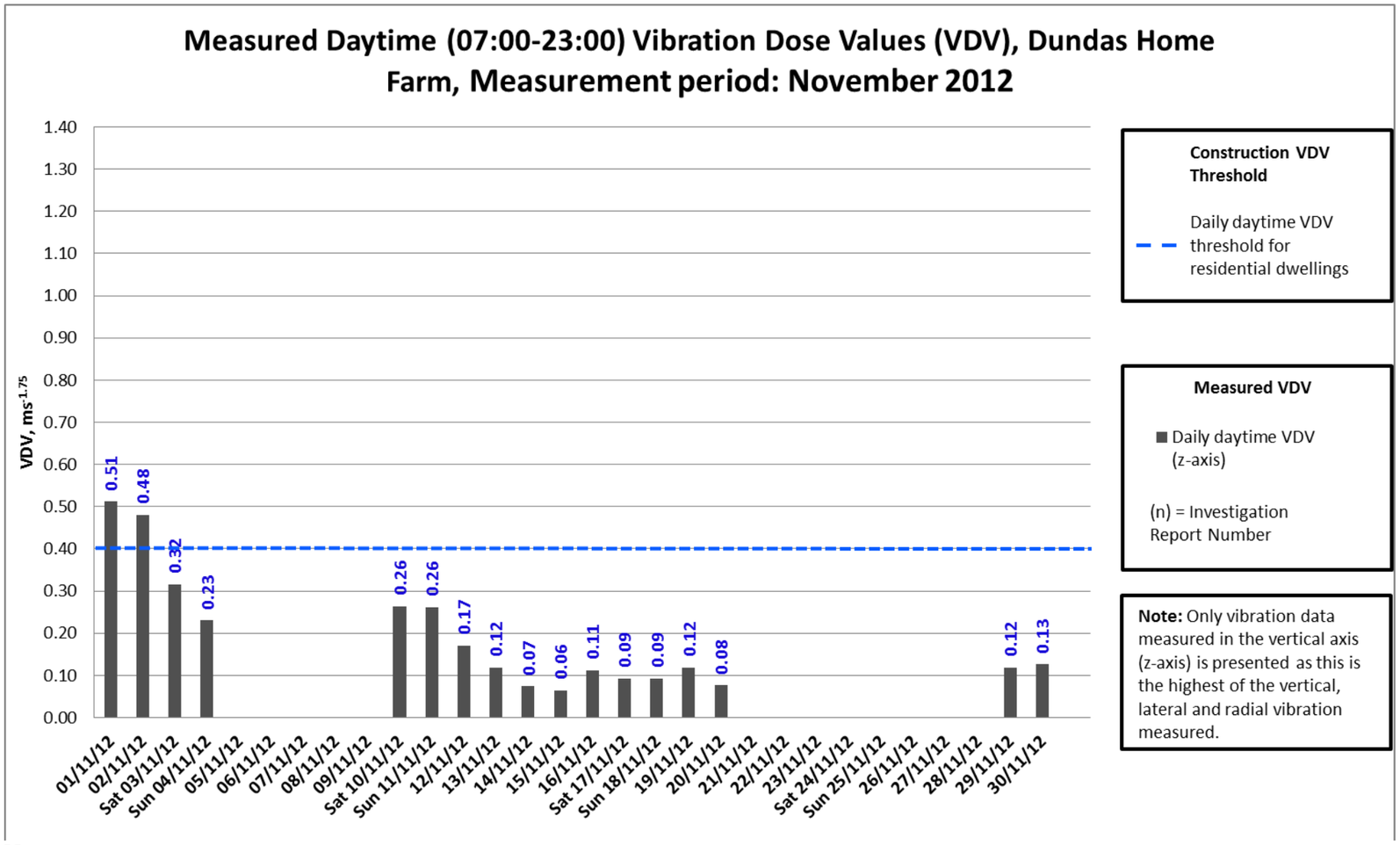
Whinny Hill				
Relevant PCNV No.	**Relevant Date**	**PCNV Name**	**Particulars of works to be carried out**	**Vibration Assessment**
				Statement. This method will over-estimate VDV and therefore represents a conservative approach. Once works start these levels will be closely monitored and actual VDV levels will be taken from monitoring equipment.
PCNV-00015	Nov 12 to Dec 12	Blasting North Network	Blasting at St Margaret's Hope • Traffic Management • Loading of the explosives. • Firing of the explosives to create a blast at St Margret's Hope.	A protective vibration level of less than 10mm.s^{-1} has been maintained for the Queensferry Hotel. Queensferry Hotel has been identified as the only occupied receptor to be within sufficient distance to be effected by blasting at St Margret's Hope. A review of sensitive properties and structures identifies the following closest receptors to St Margret's Hope: Radar Station, Admiralty House, St Margaret's Hope Lodge, Queensferry Hotel. These receptors are deemed to conservatively protect other structures further away. Vibration monitors for air over pressure and ground vibration have been installed at each location.

APPENDIX B – VIBRATION GRAPHS



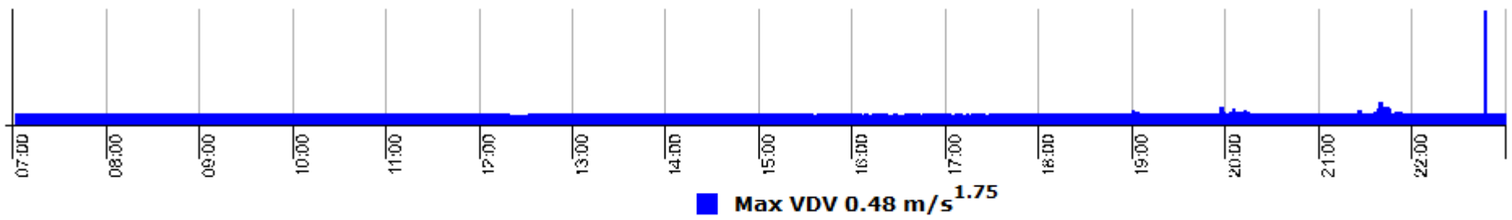
Note:

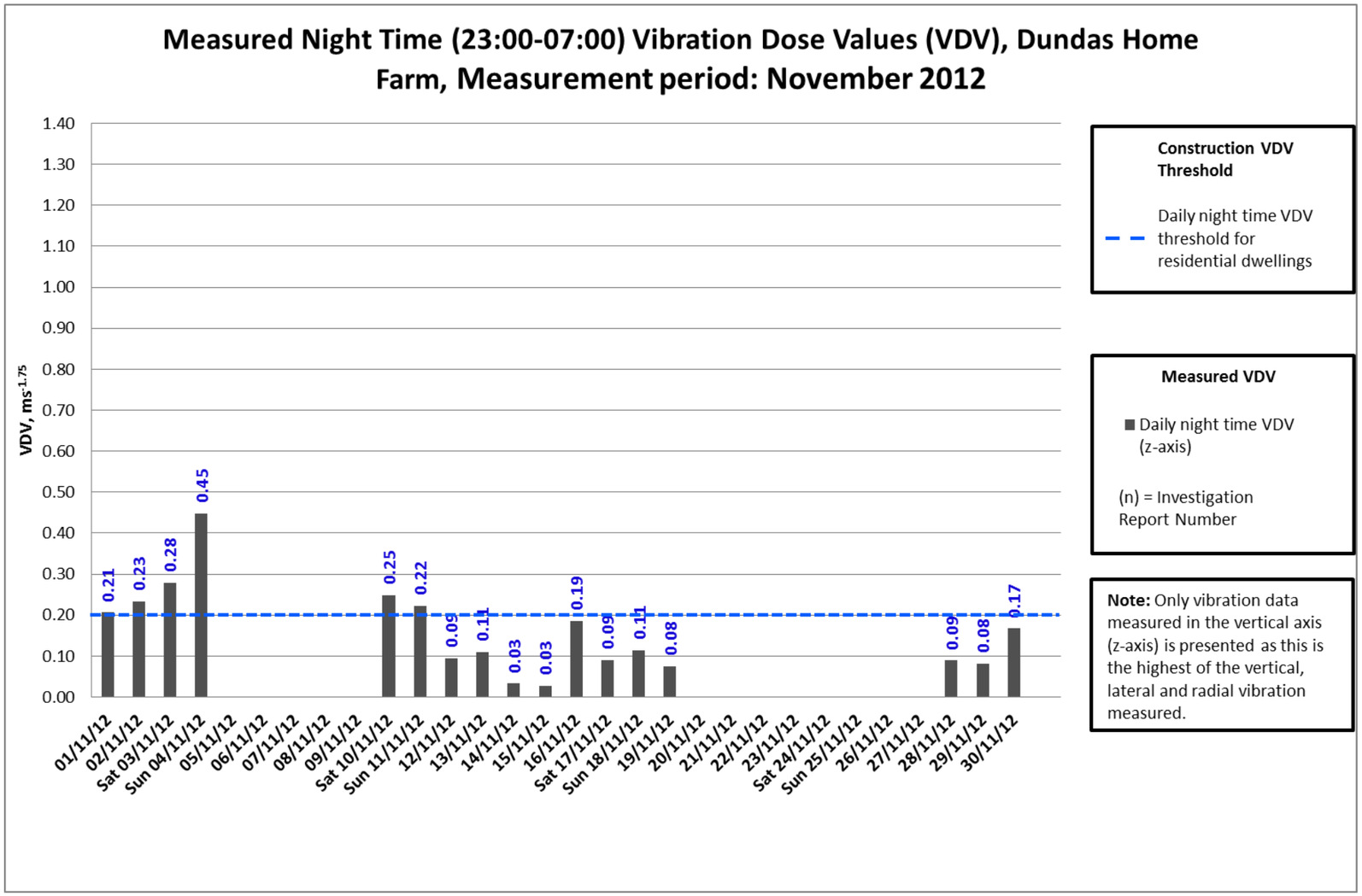
- Due to server issues at the site office some data, recorded for November 2012, was lost.
- Some corrupted data was logged by the device (21/11/12 – 28/11/12).



Notes:

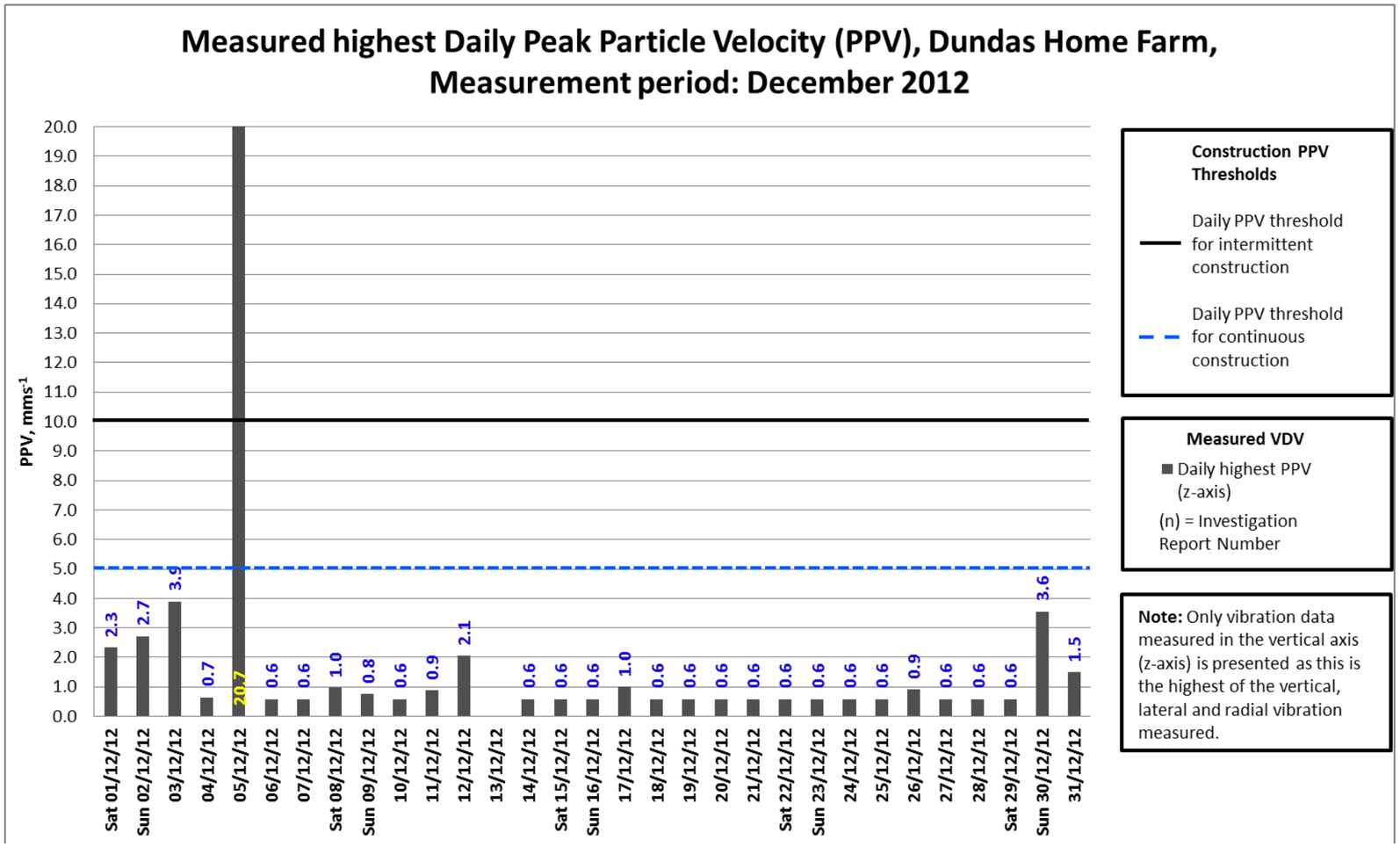
- Due to server issues at the site office some data, recorded for November 2012, was lost, and some corrupted data was logged by the device (21/11/12 – 28/11/12).
- Both of exceedances on 1st and 2nd November, occurred after 10pm, there are no construction works within 2km of this receptor beyond 7pm.





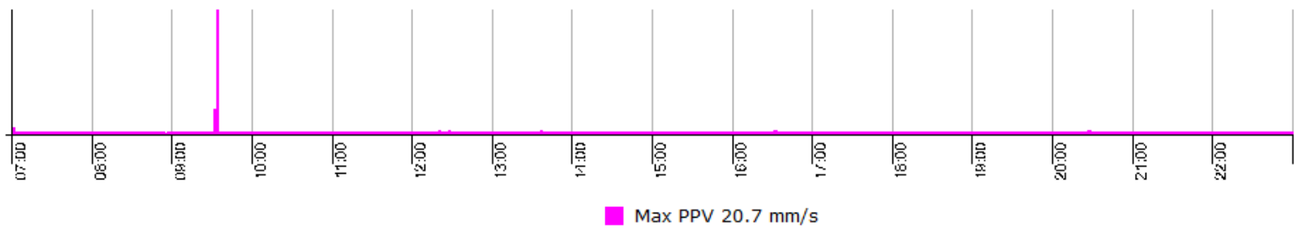
Notes:

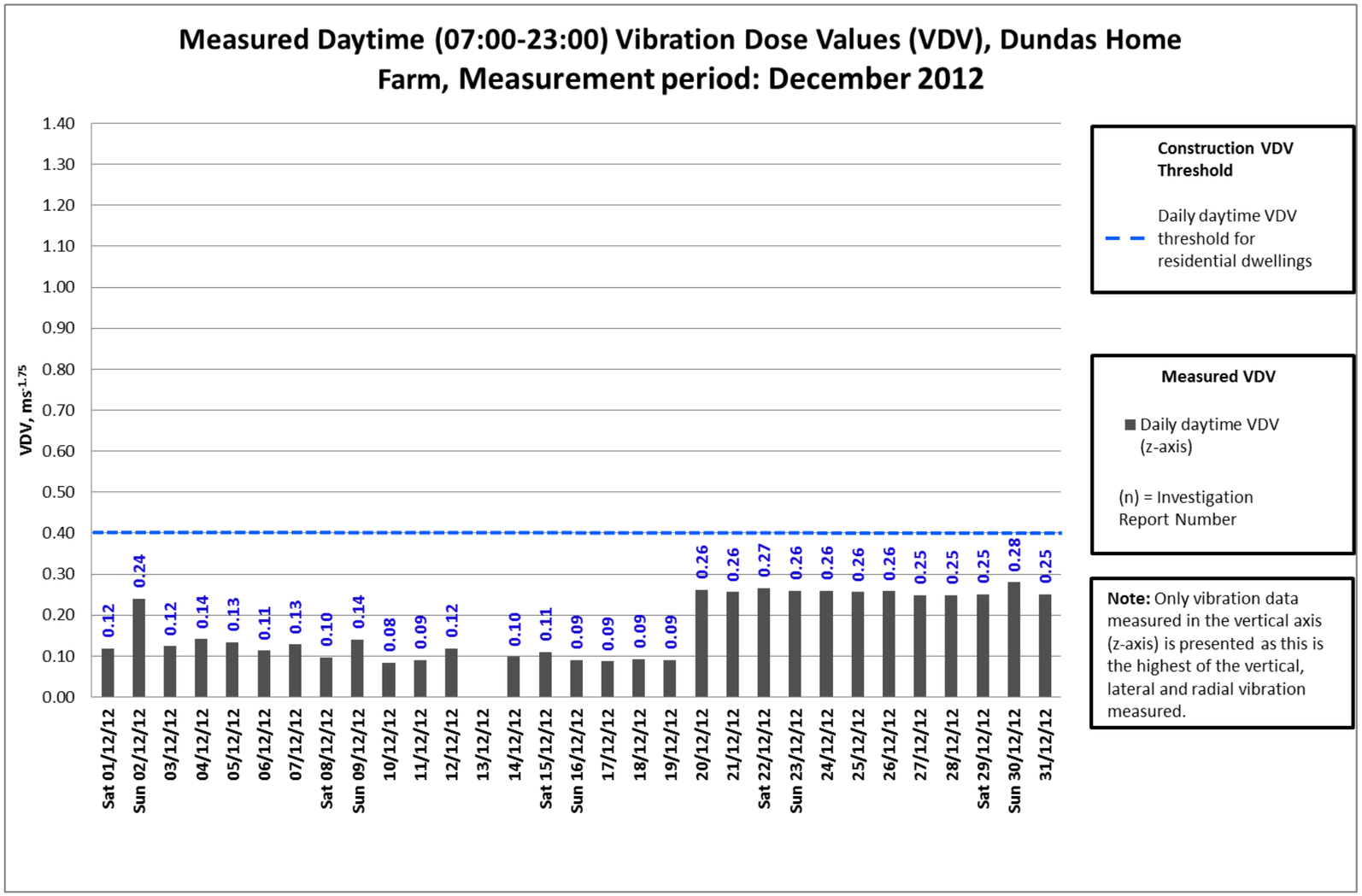
- The date given for the night data is that on which the night started;
- Due to server issues at the site office, some data for this receptor, recorded for November 2012, was lost;
- Some corrupted data was logged by the device (21/11/12 – 28/11/12).
- There were no night-time works within 2km of this receptor; the exceedances are due to local interferences.



Notes:

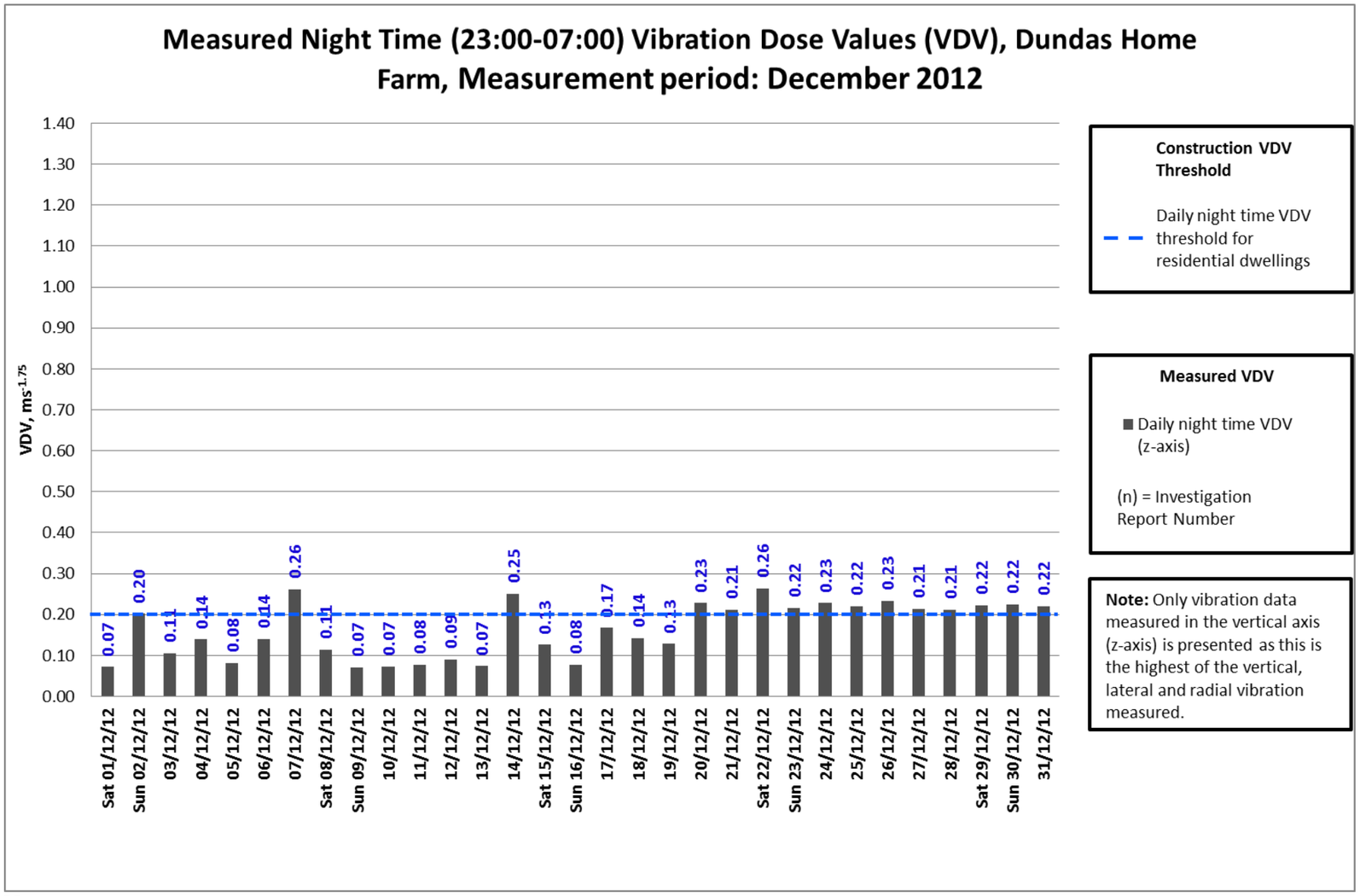
- Corrupted daytime data was logged by the device for 13/12/12;
- As can be seen from the VIBROCK graph below, the single exceedance on 05/12/12 is an isolated event and is unlikely to be due to the continuous construction works;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.





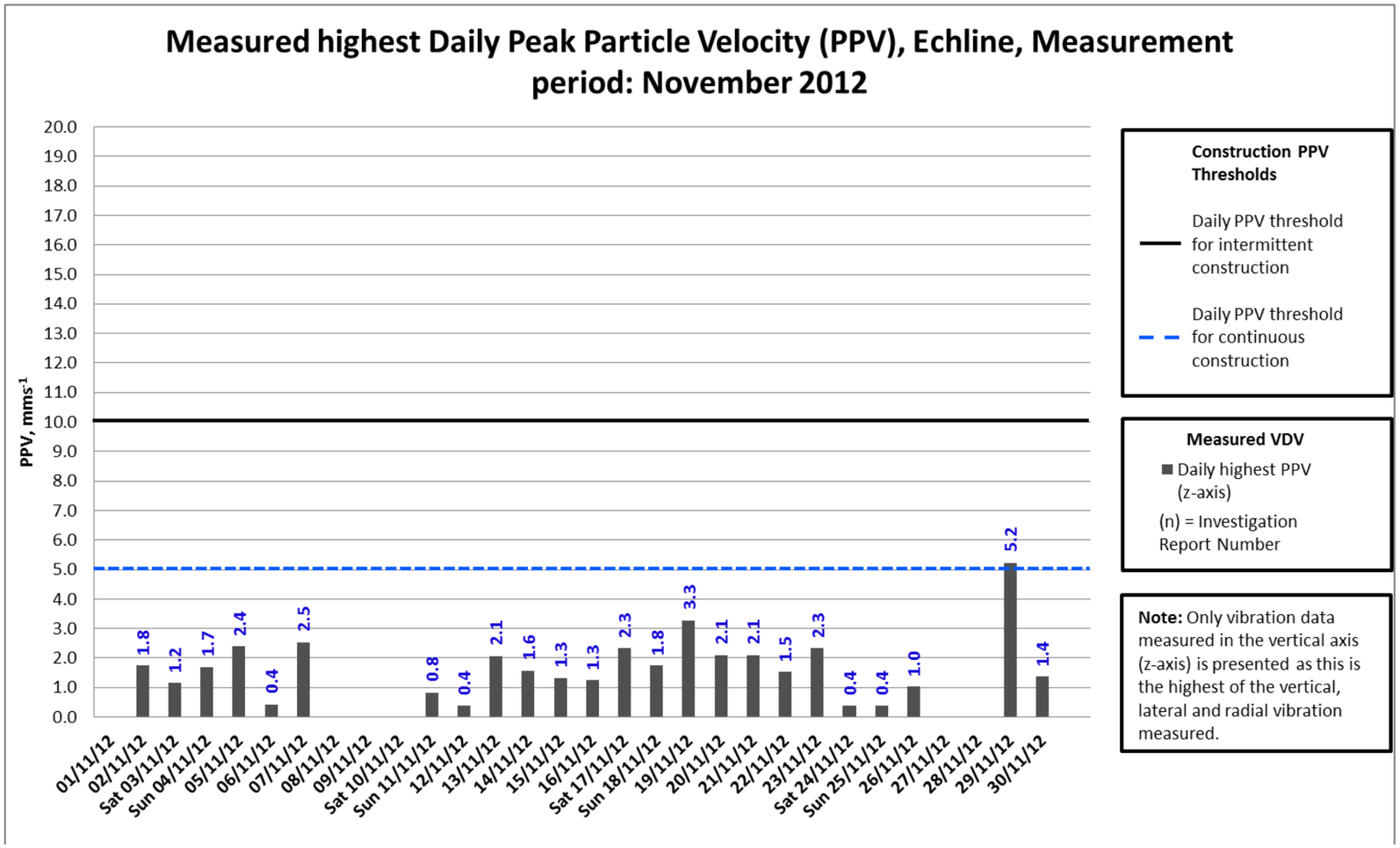
Notes:

- Corrupted daytime data was logged by the device for 13/12/12;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



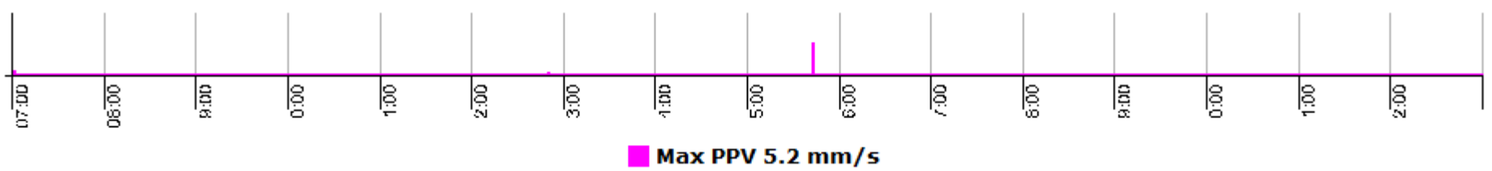
Notes:

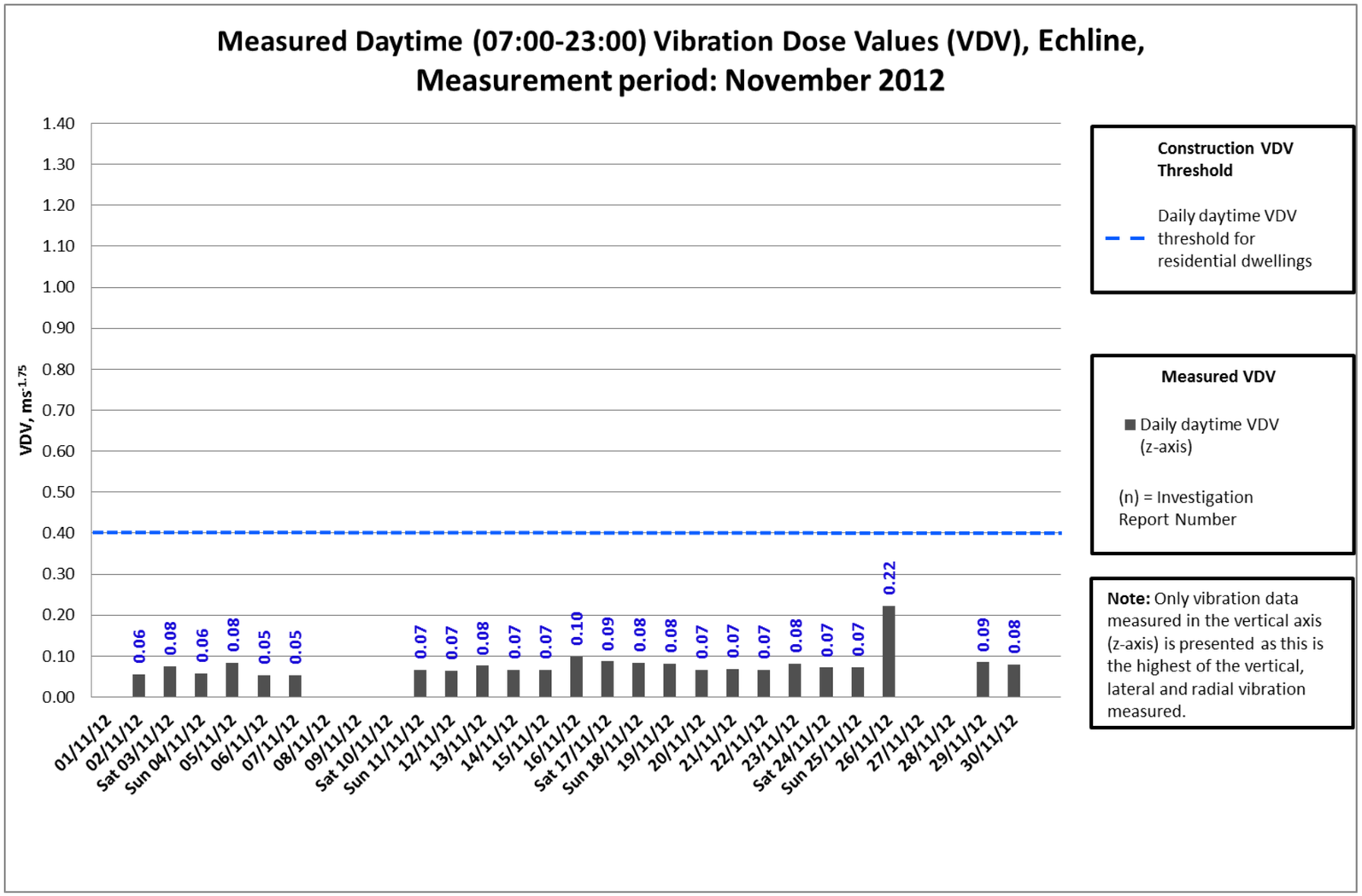
- The date given for the night data is that on which the night started;
- There was no night-time construction works within 2km from this receptor;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



Notes:

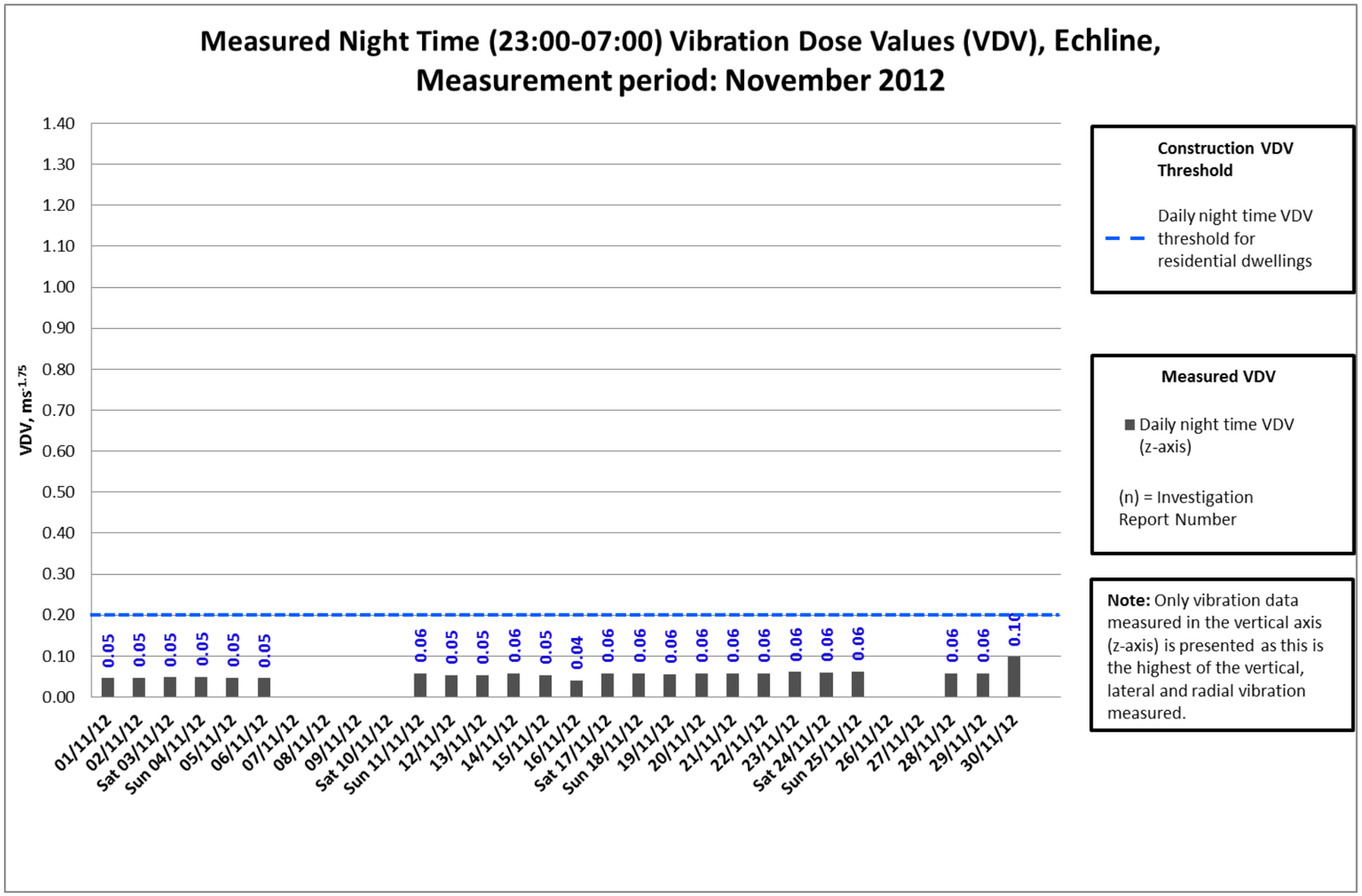
- Some corrupted daytime data was logged by the device;
- As can be seen from the VIBROCK graph below, the single exceedance on 29/11/12 is an isolated event due to monitor maintenance activity;
- No construction activity within 100m of this receptor which could generate such levels of PPV.





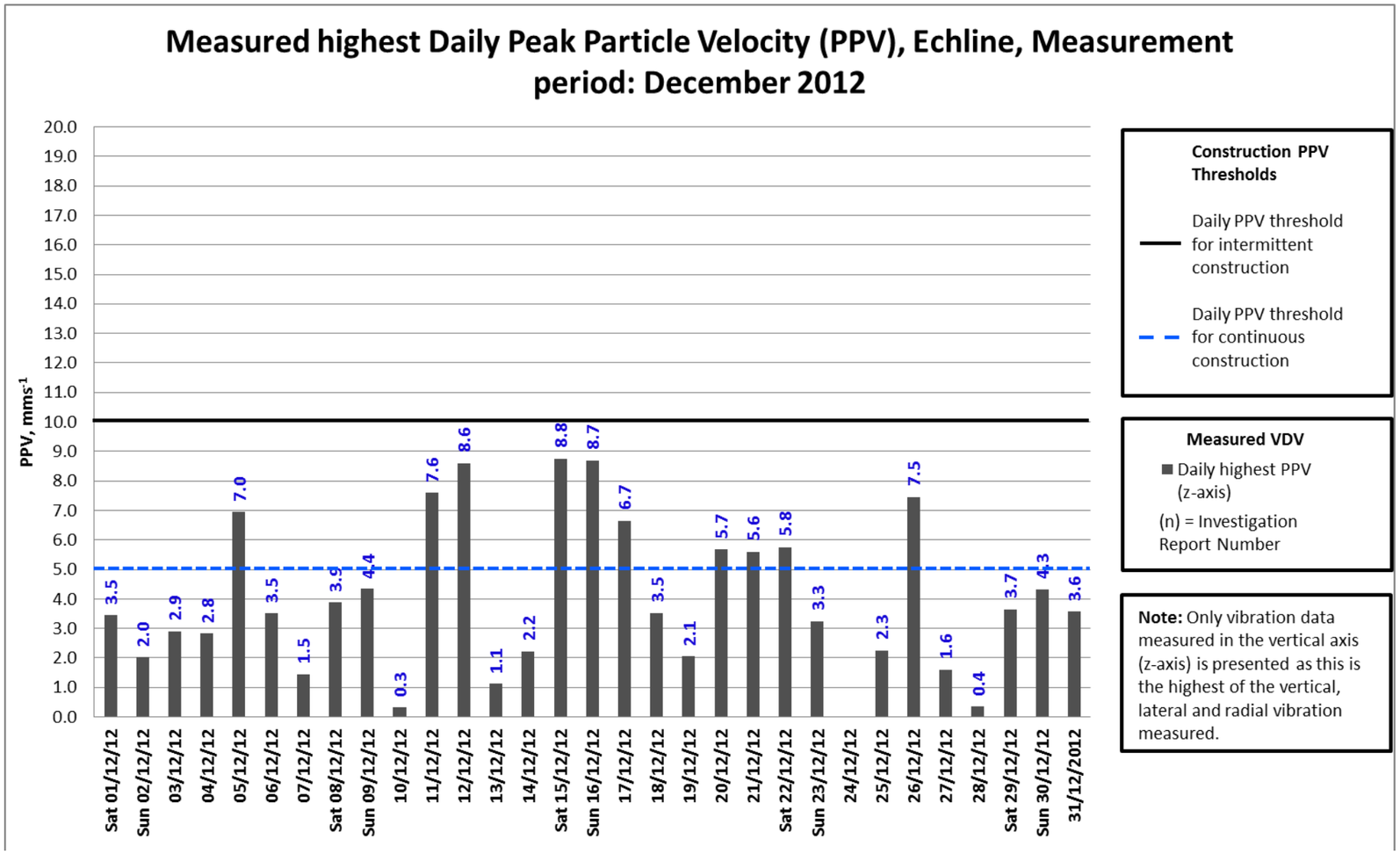
Notes:

- Some corrupted daytime data was logged by the device.



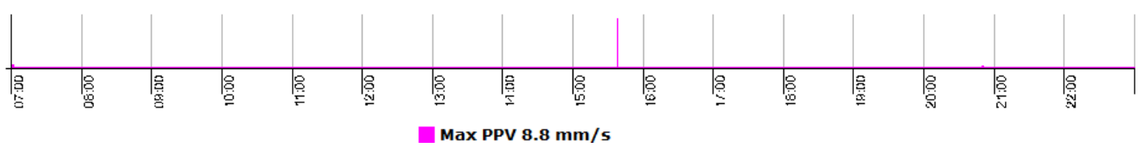
Notes:

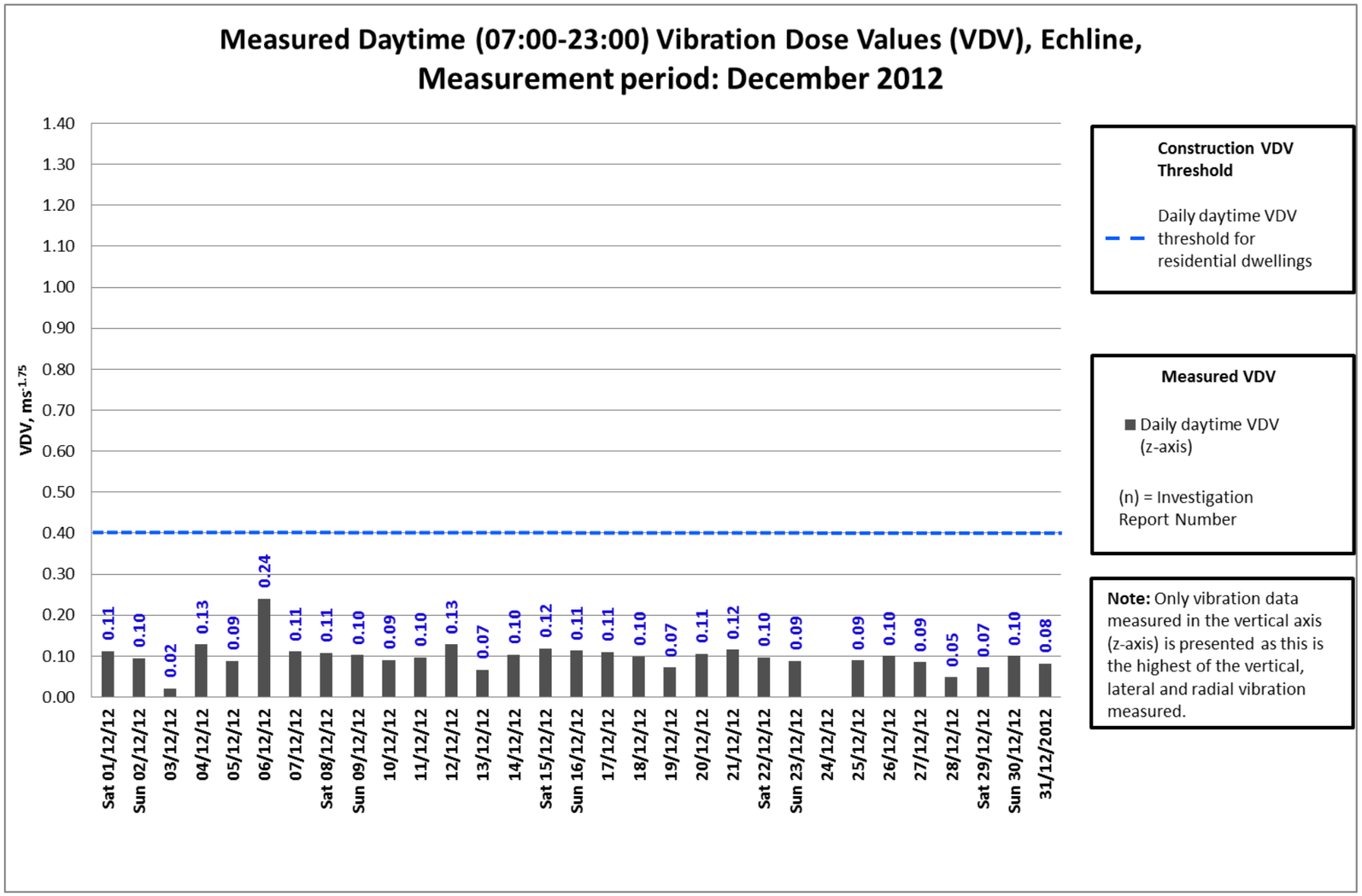
- Some corrupted night-time data was logged by the device.



Notes:

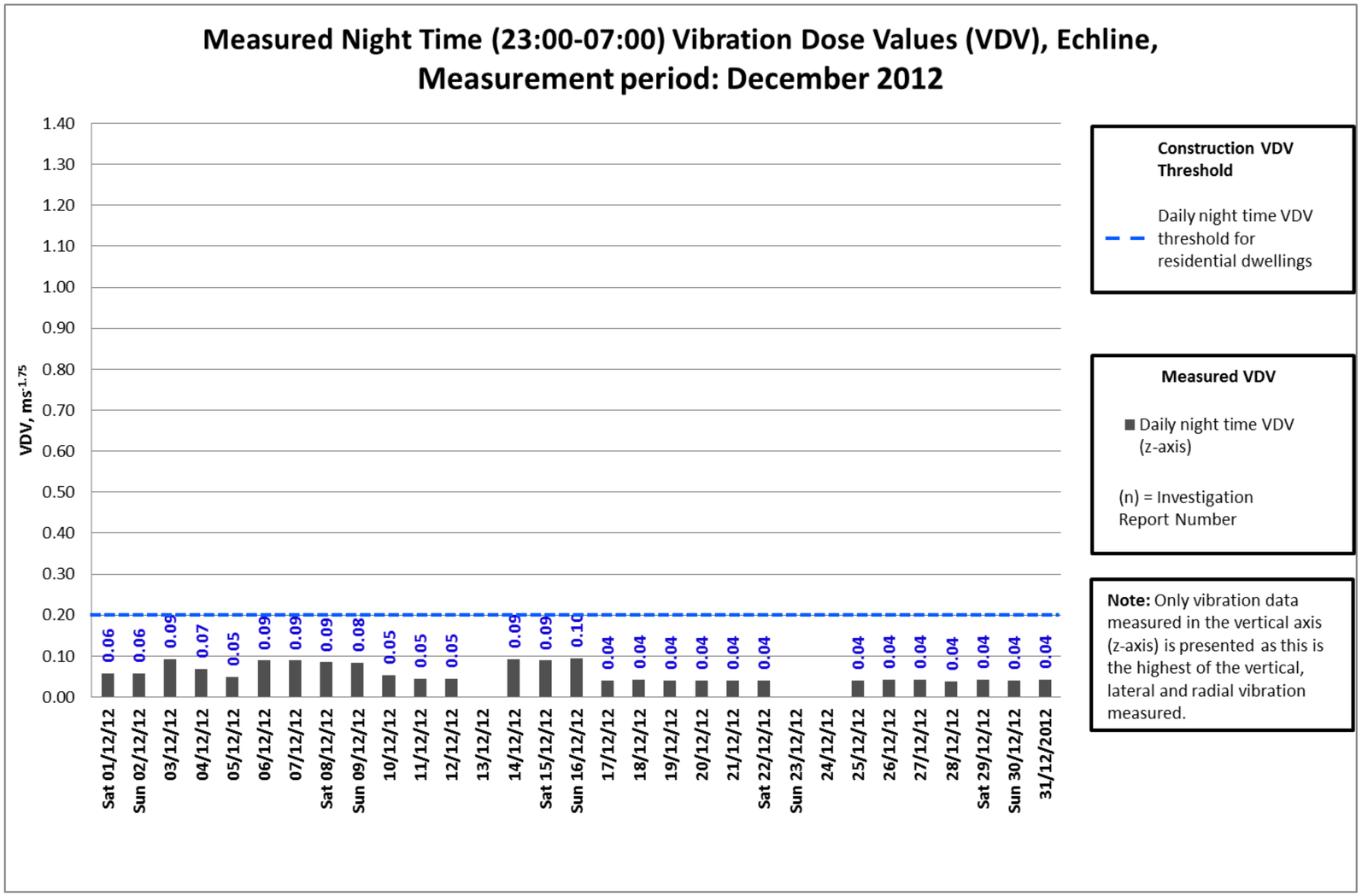
- Corrupted daytime data was logged by the device for 24/12/12;
- The exceedances have been investigated. They are single, isolated events in each day (for example see the VIBROCK graph below for the exceedances on Saturday 15/12/12). This seems to be due to the road traffic (e.g. occasional HGVs passing by) rather than continuous construction;
- Similar exceedances occurred on Sunday 16/12/12 when no construction activities were carried out. All the construction works (daytime and night-time) stopped from 22/12/12 onwards. Some of the exceedances are due to the interferences occurred during the device maintenance.





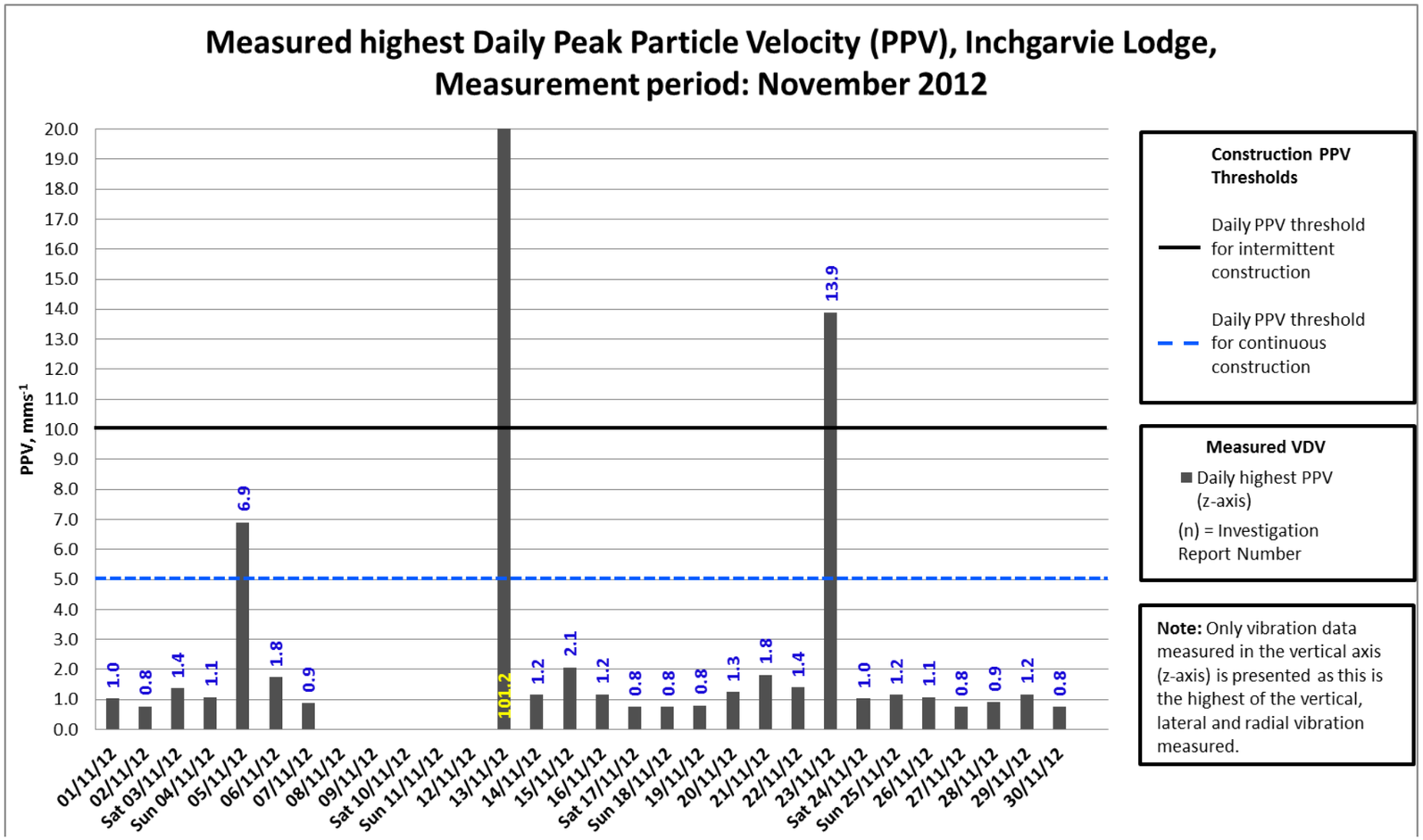
Note:

- All the construction works (daytime and night-time) stopped from 22/12/12 onwards;
- Daytime data for 13/12/12 corrupted due to unknown reason.



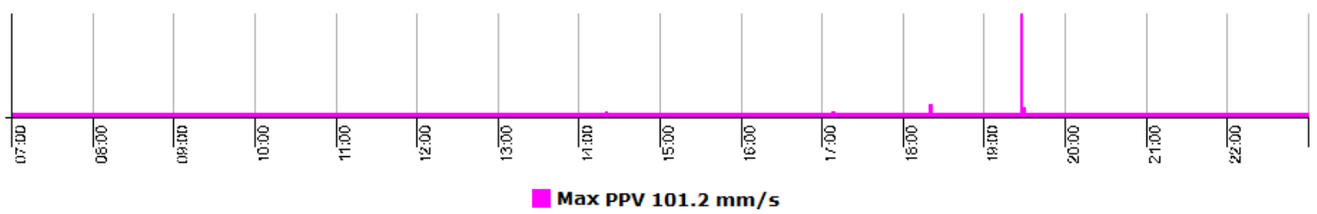
Note:

- All the construction works (daytime and night-time) stopped from 22/12/12 onwards;
- Some of the night-time data corrupted due to unknown reason.

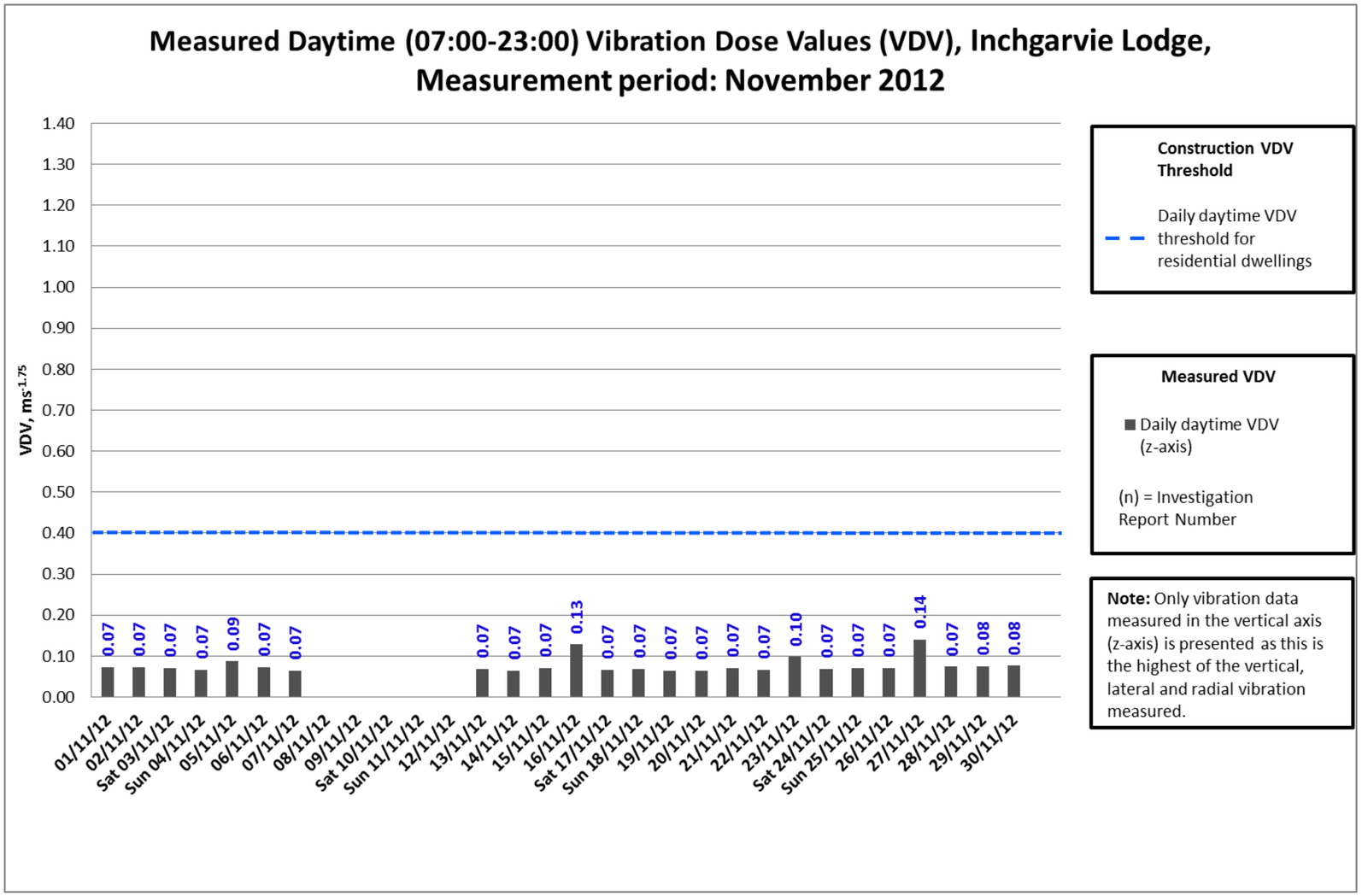


Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The exceedance on 05/11/12 is due to the interference occurred during the device maintenance.
- As can be seen from the VIBROCK graph below the exceedance on 13/11/12 occurred outside the working hour (i.e. beyond 7pm)

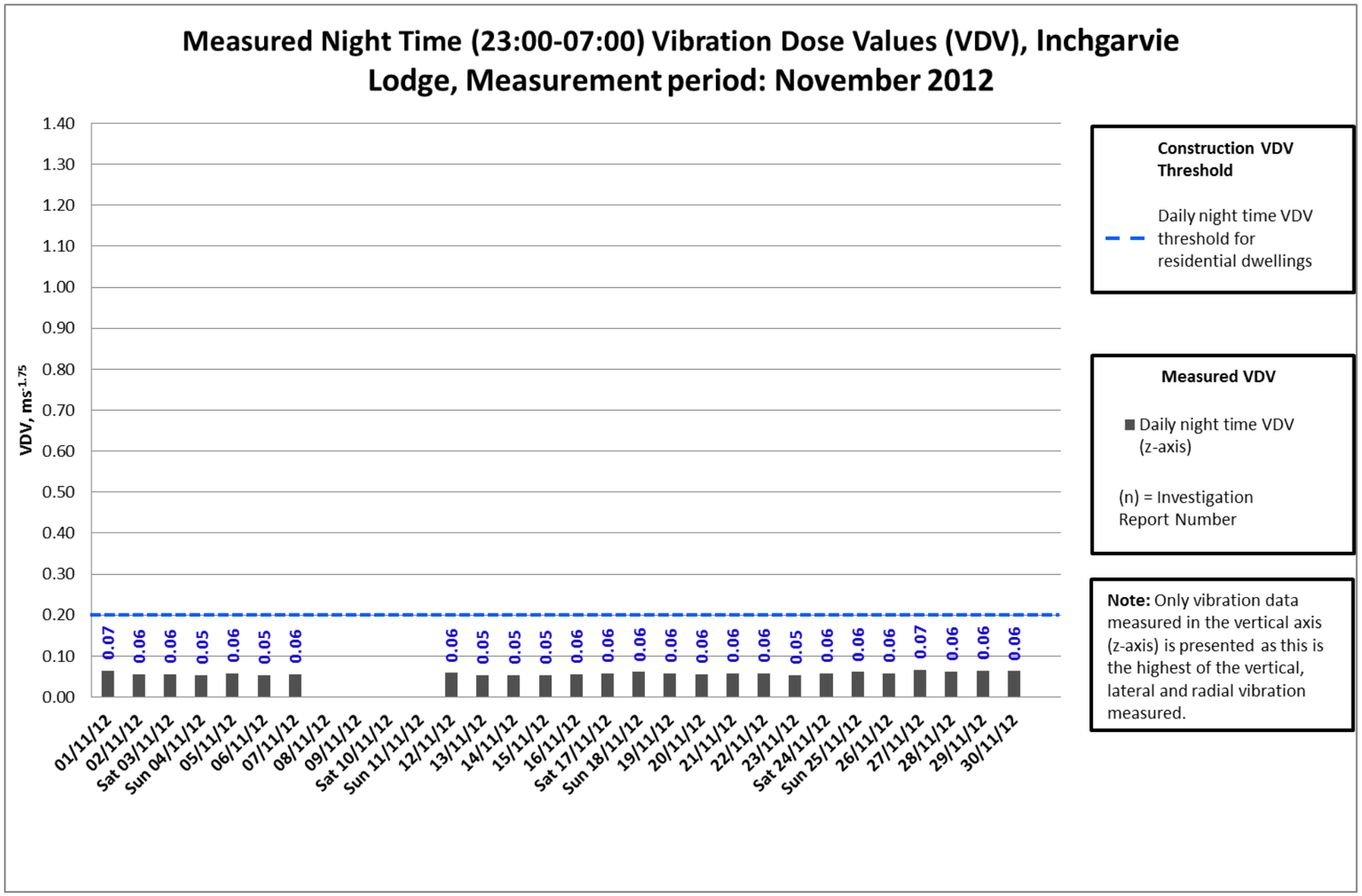


- The exceedance on 23/11/12 is due to the interference occurred during the device maintenance.



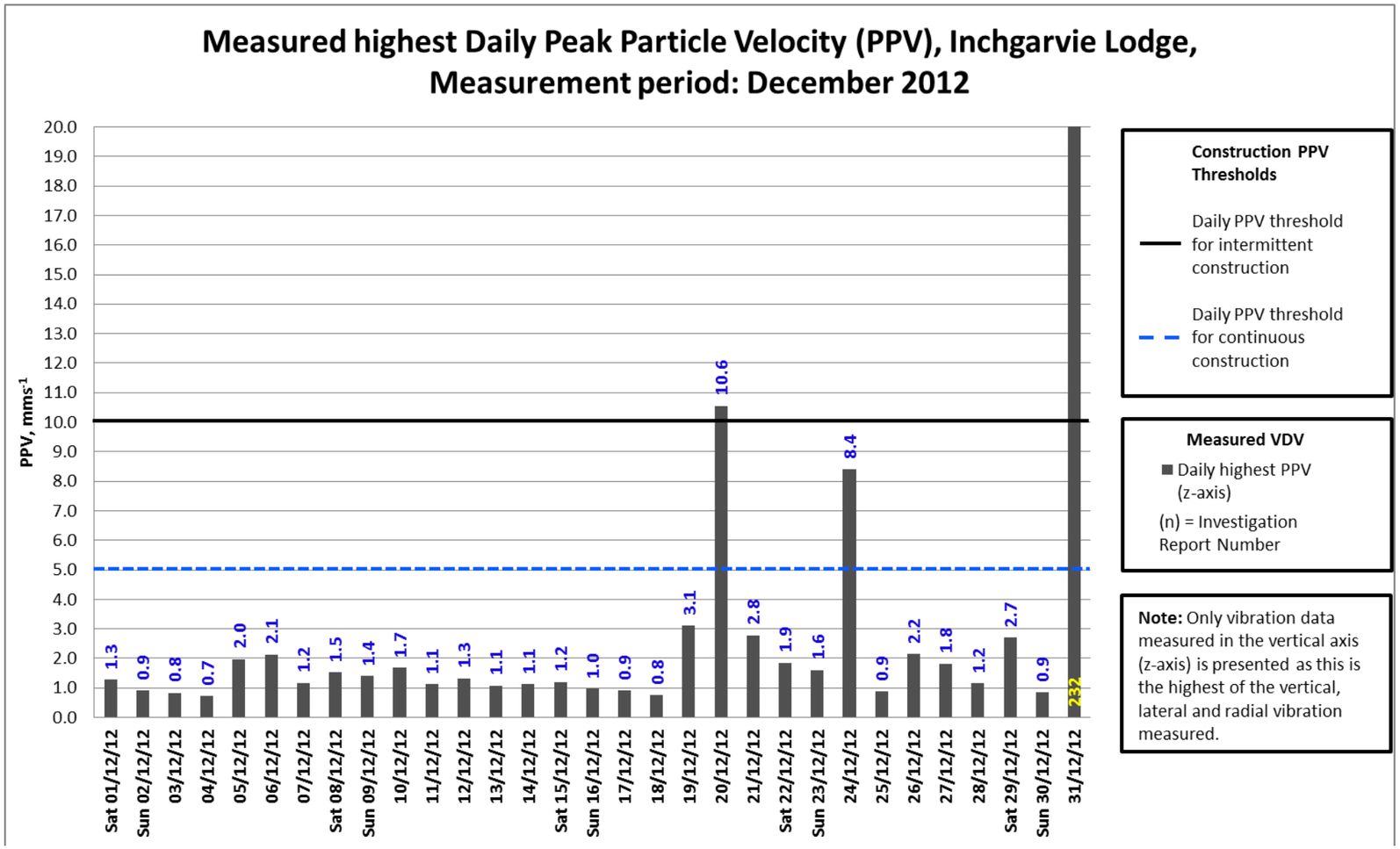
Note:

- Due to server issues at the site office some data, recorded for November 2012, was lost;



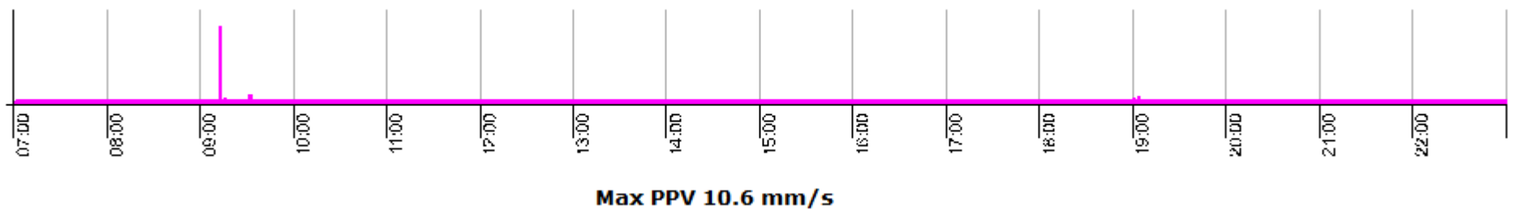
Note:

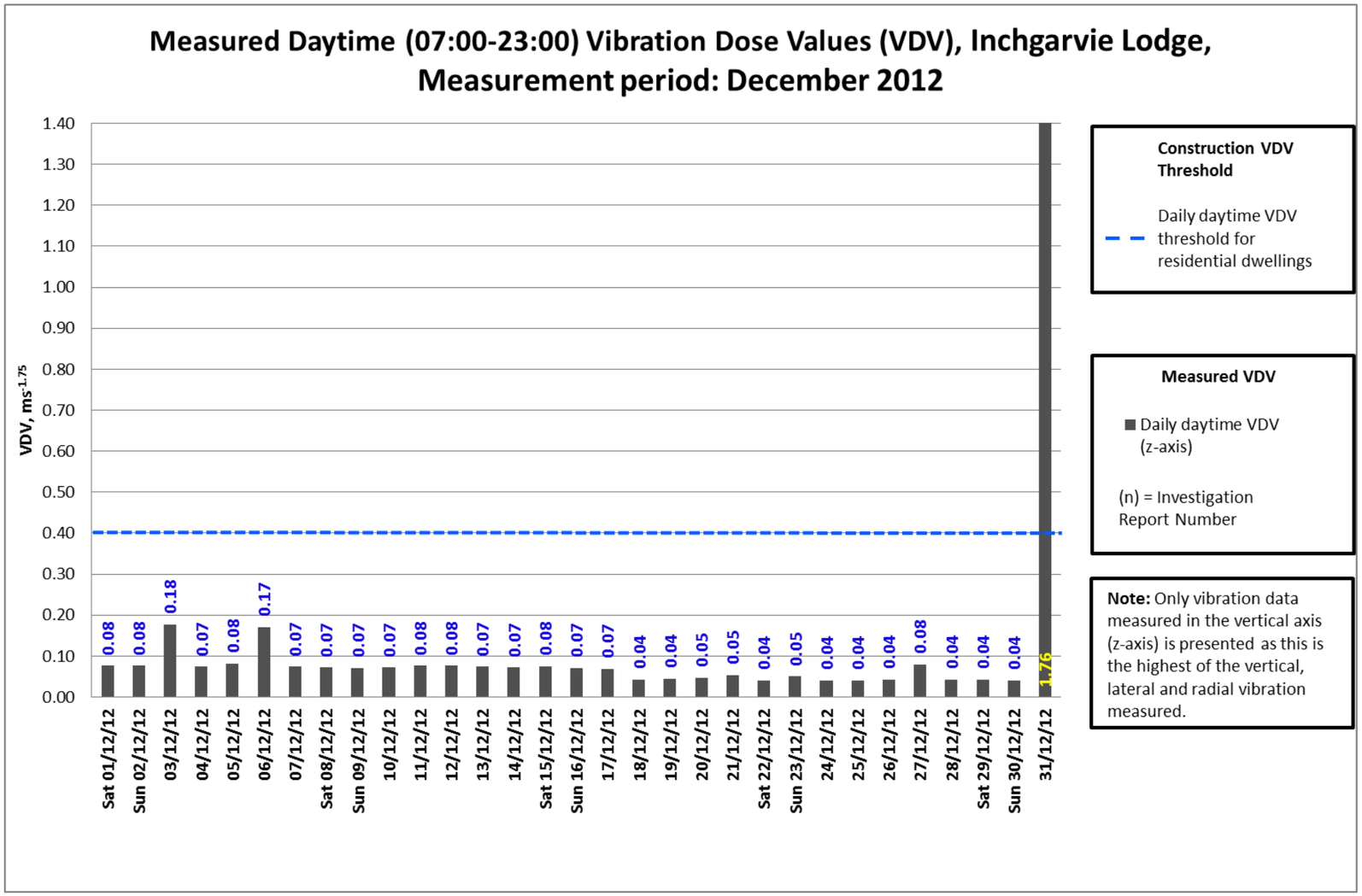
- Due to server issues at the site office some data, recorded for November 2012, was lost.



Notes:

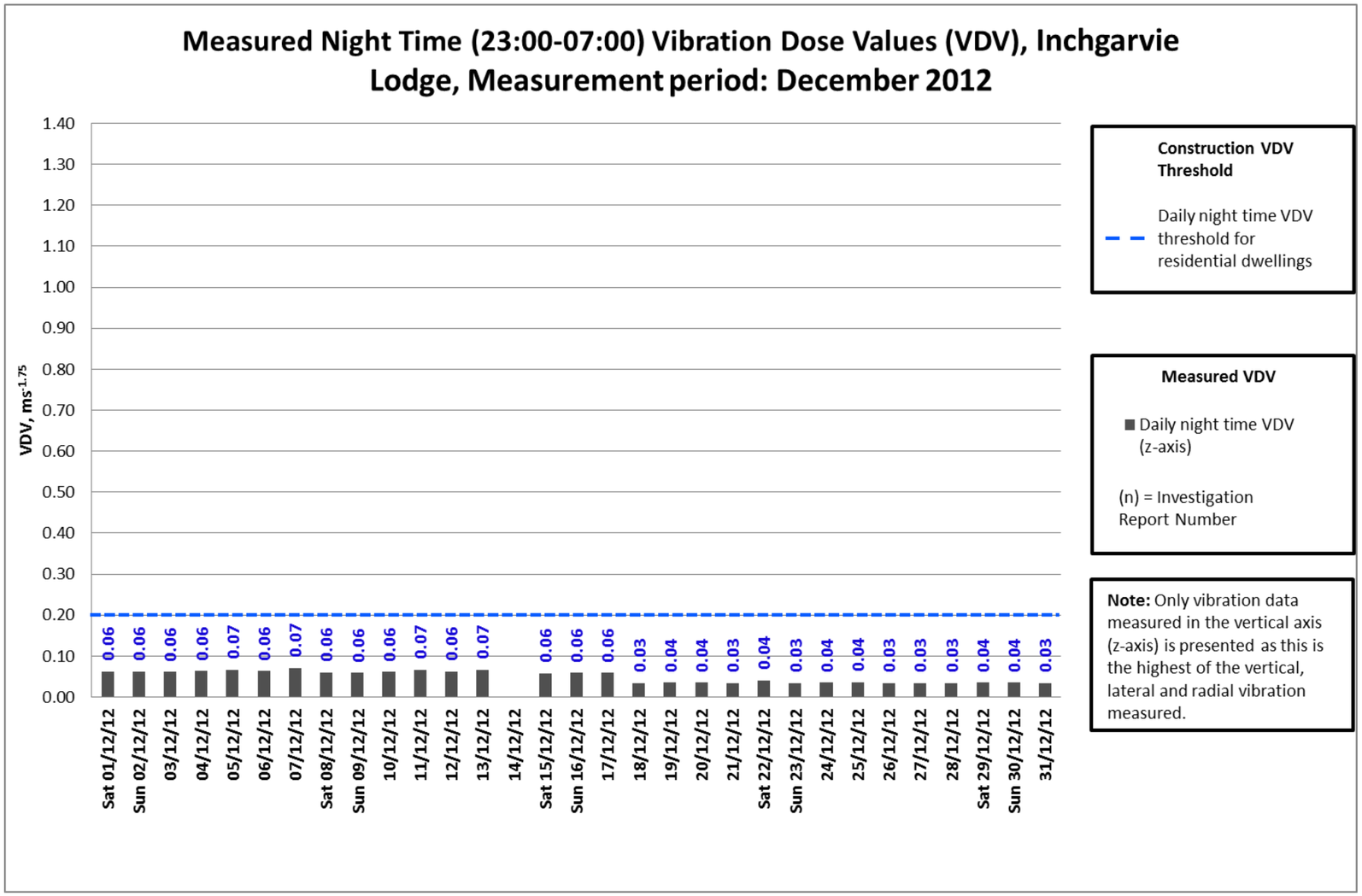
- The exceedance on 20/11/12 is due to the interference occurred during the device maintenance. This can be seen in the graph below;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards;





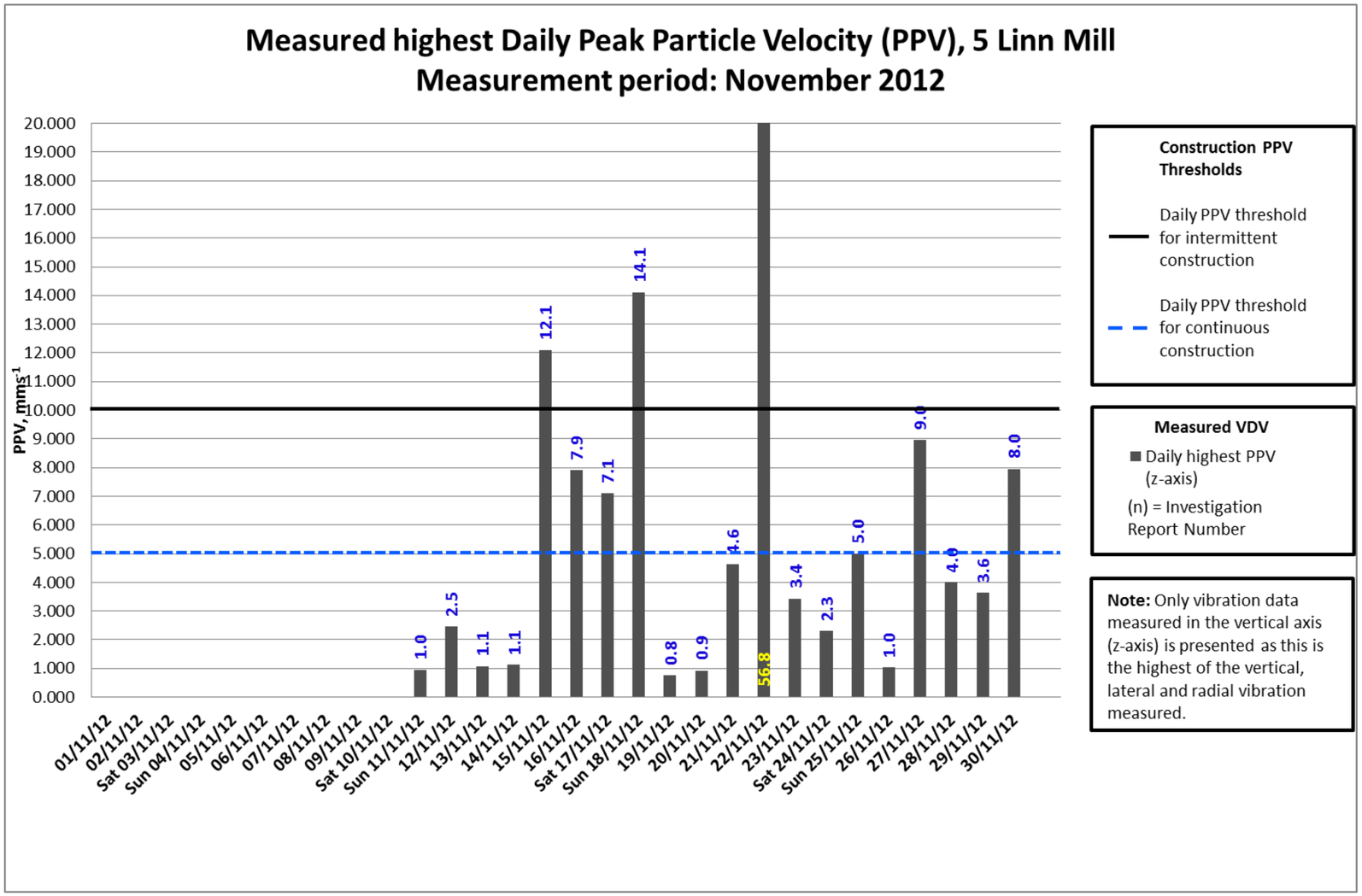
Notes:

- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



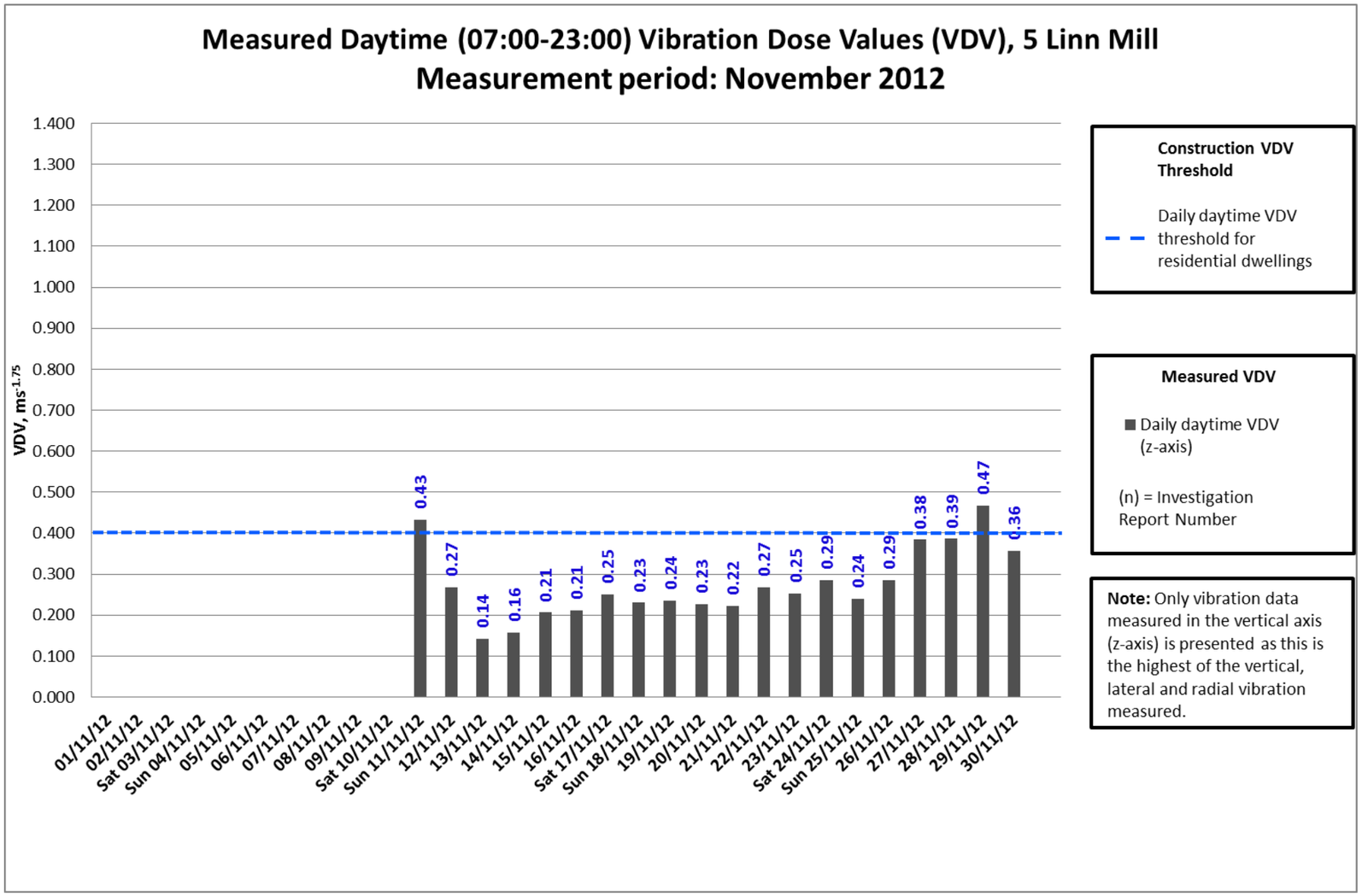
Notes:

- Corrupted daytime data was logged by the device for 14/12/12;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



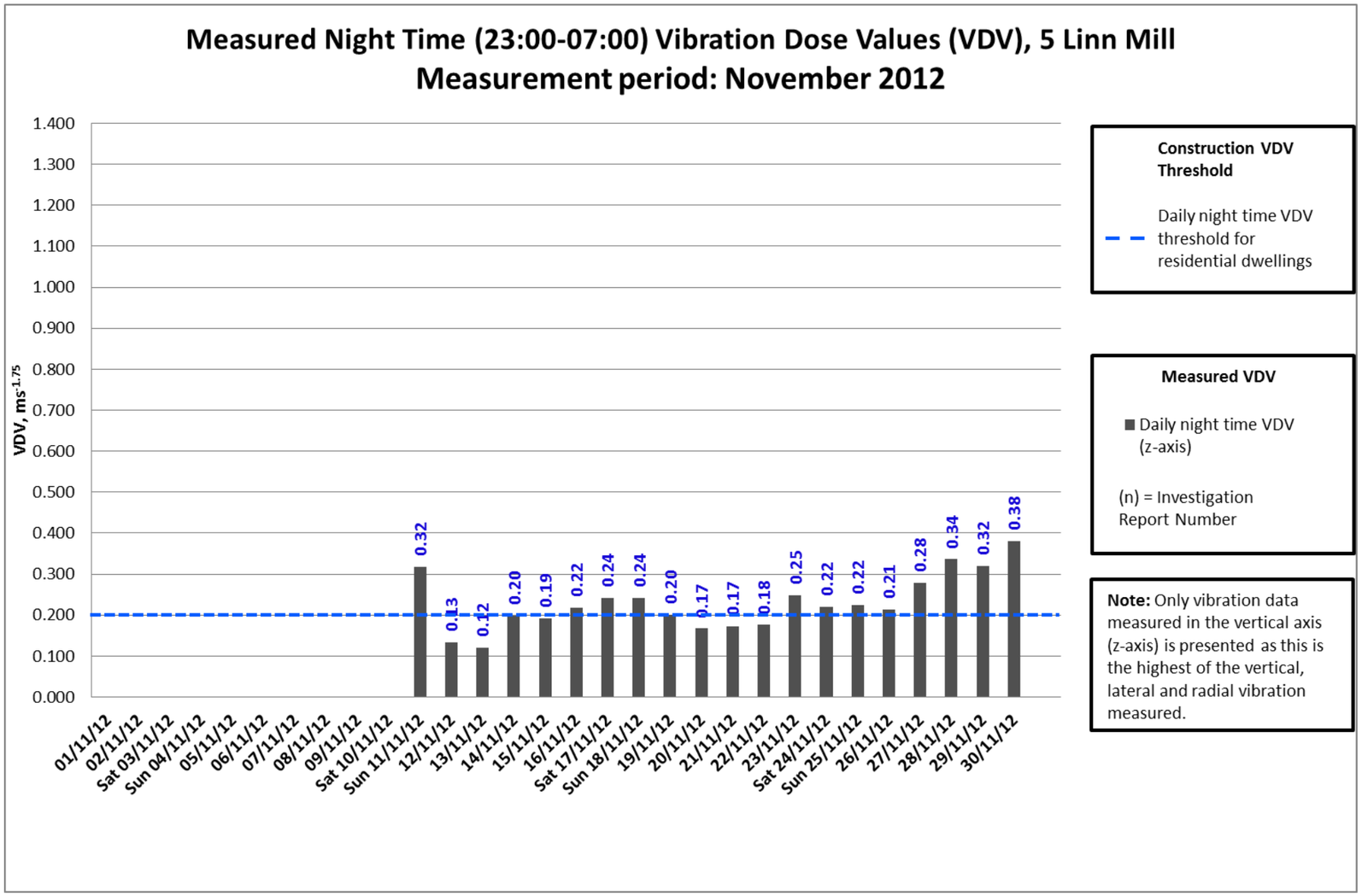
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activities. As can be seen from the above graph, exceedances also occur on Sundays. This shows that occurrences of exceedances are not due to construction activities because there are no construction on Sundays;
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



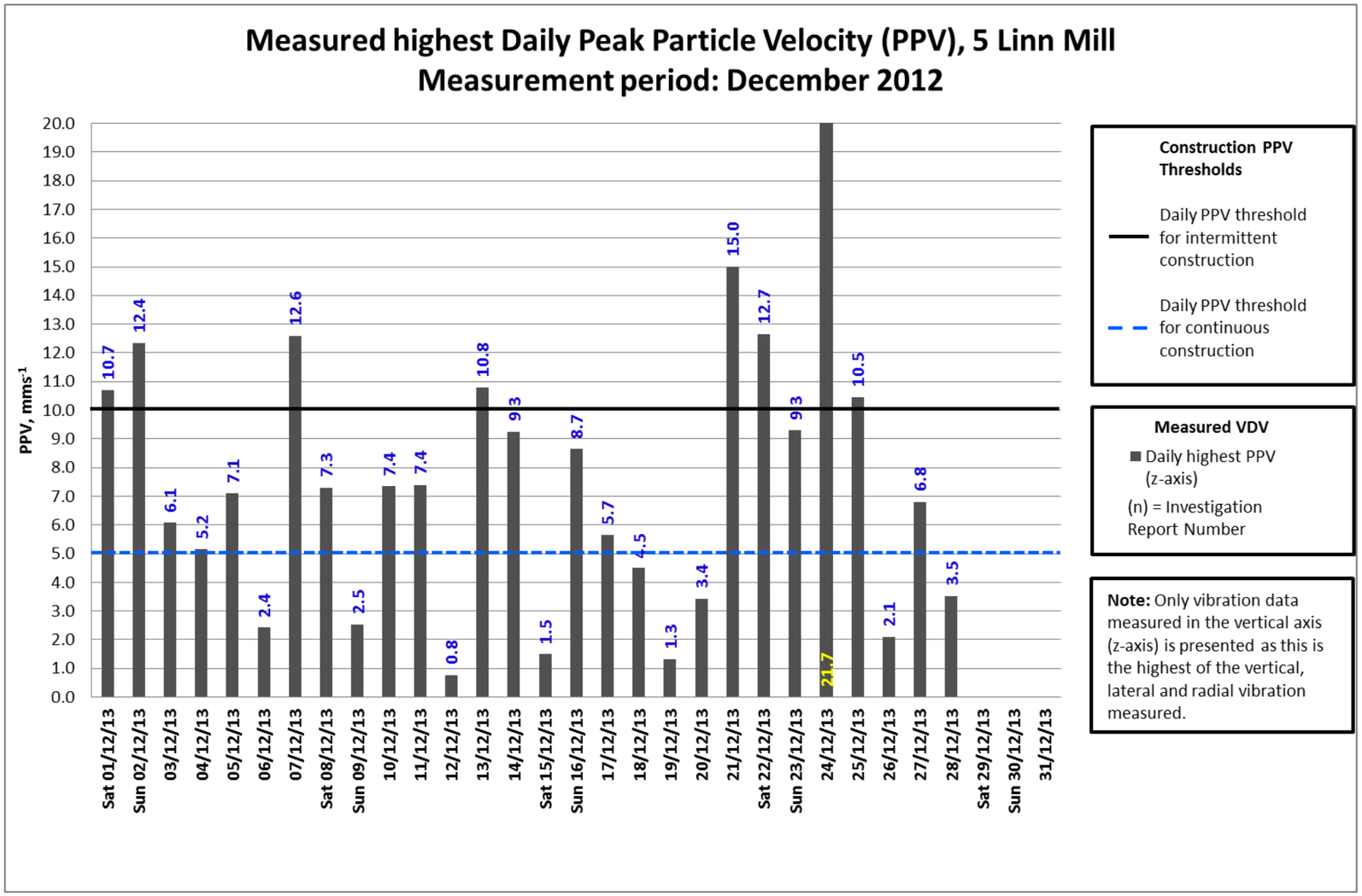
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activities.
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



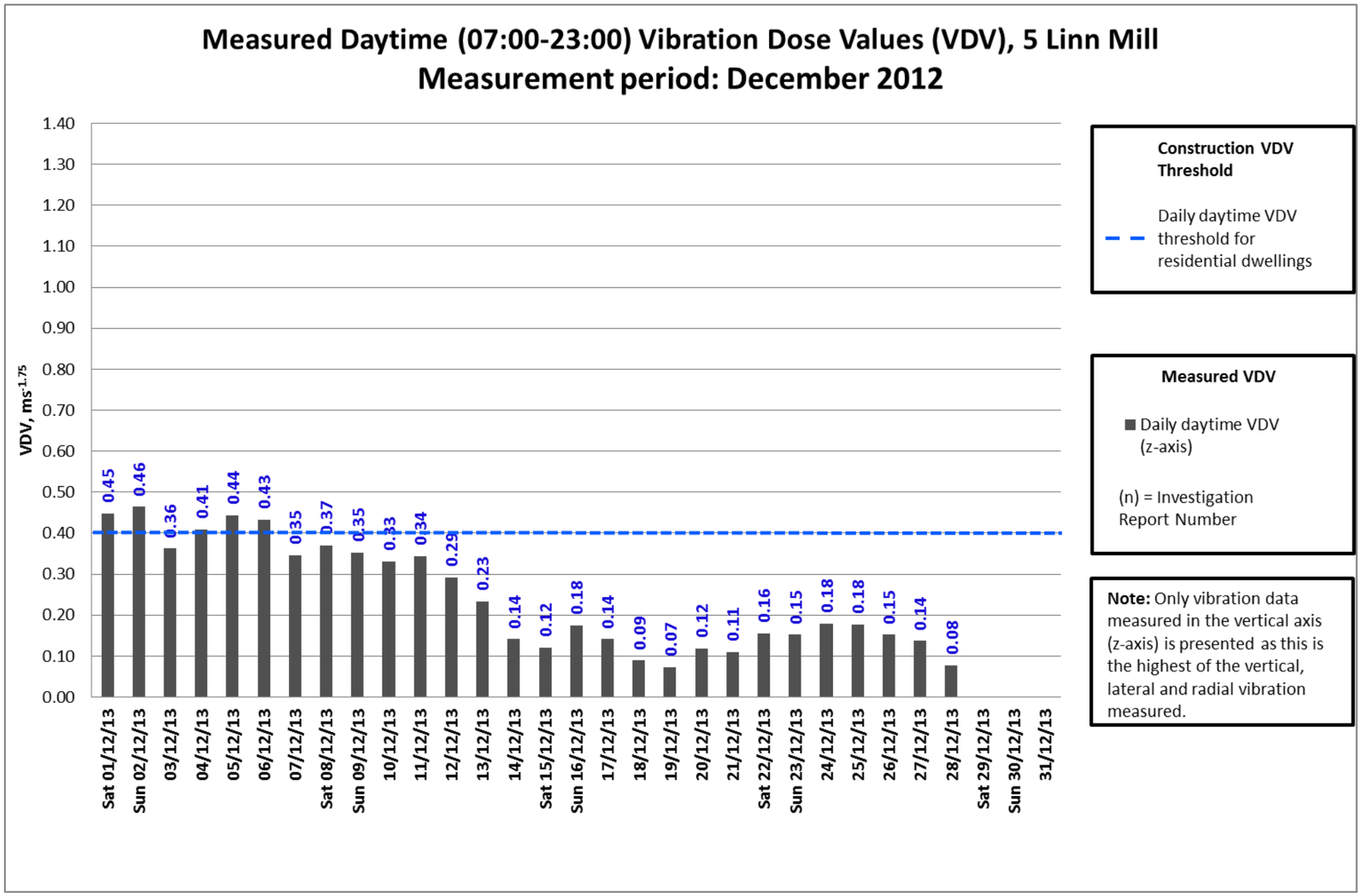
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activities. The closest night-time works to Linn Mill are more than 500m away;
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



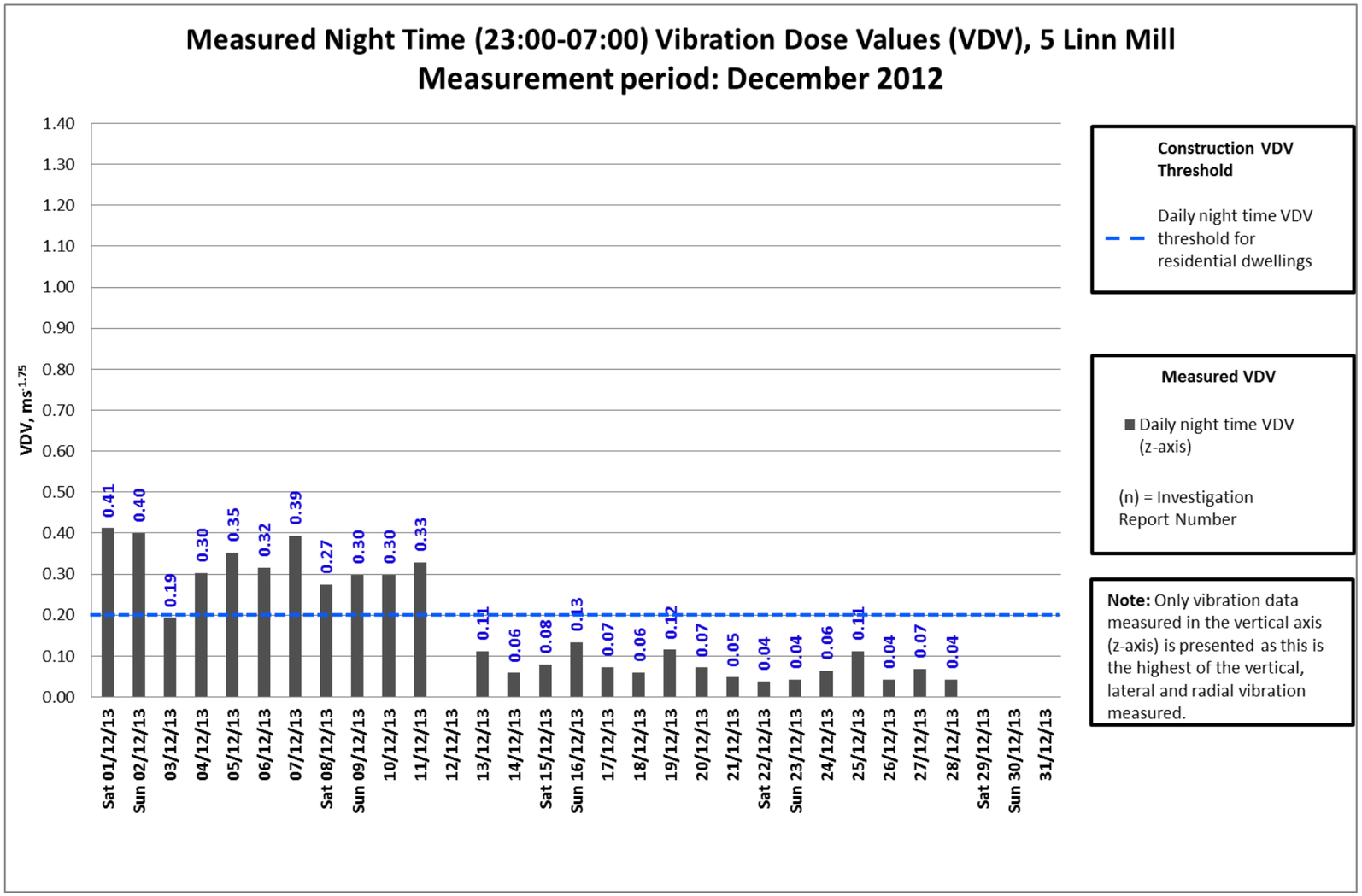
Notes:

- All the construction works (daytime and night-time) stopped from 22/12/12 onwards;
- Exceedances have been investigated and are all isolated events due to local interferences. As can be seen from the above graph, exceedances continue to occur during the holiday period. This shows that occurrences of exceedances are not due to construction activities.
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



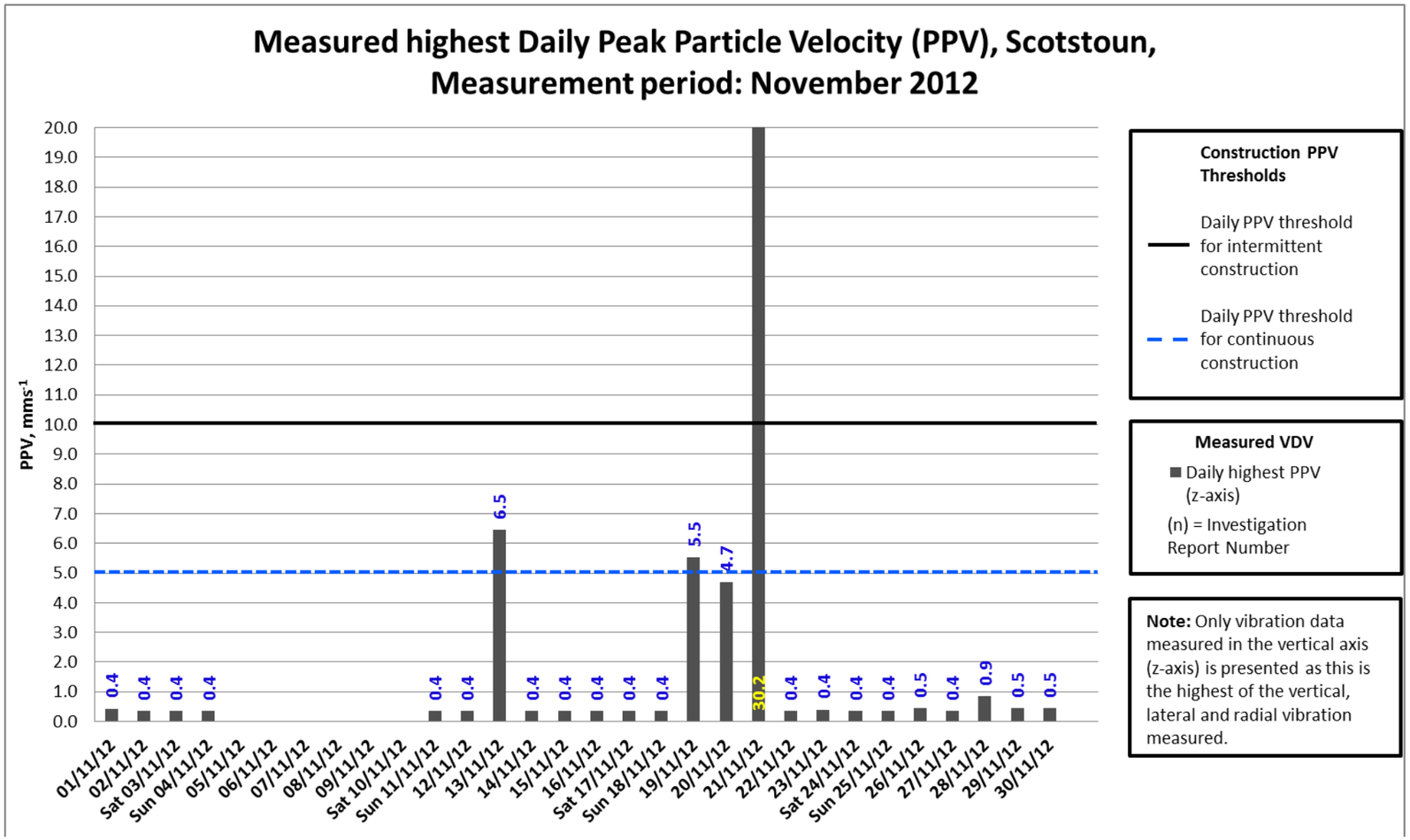
Notes:

- Exceedances have been investigated and are all isolated events due to local interferences;
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



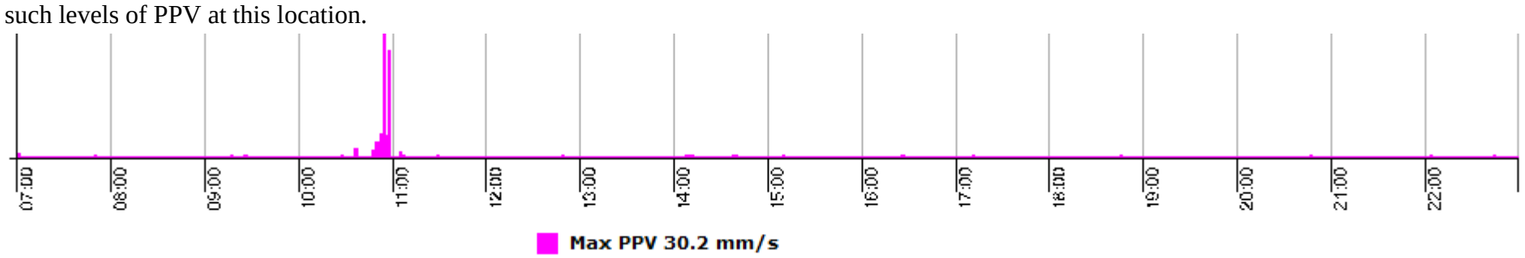
Notes:

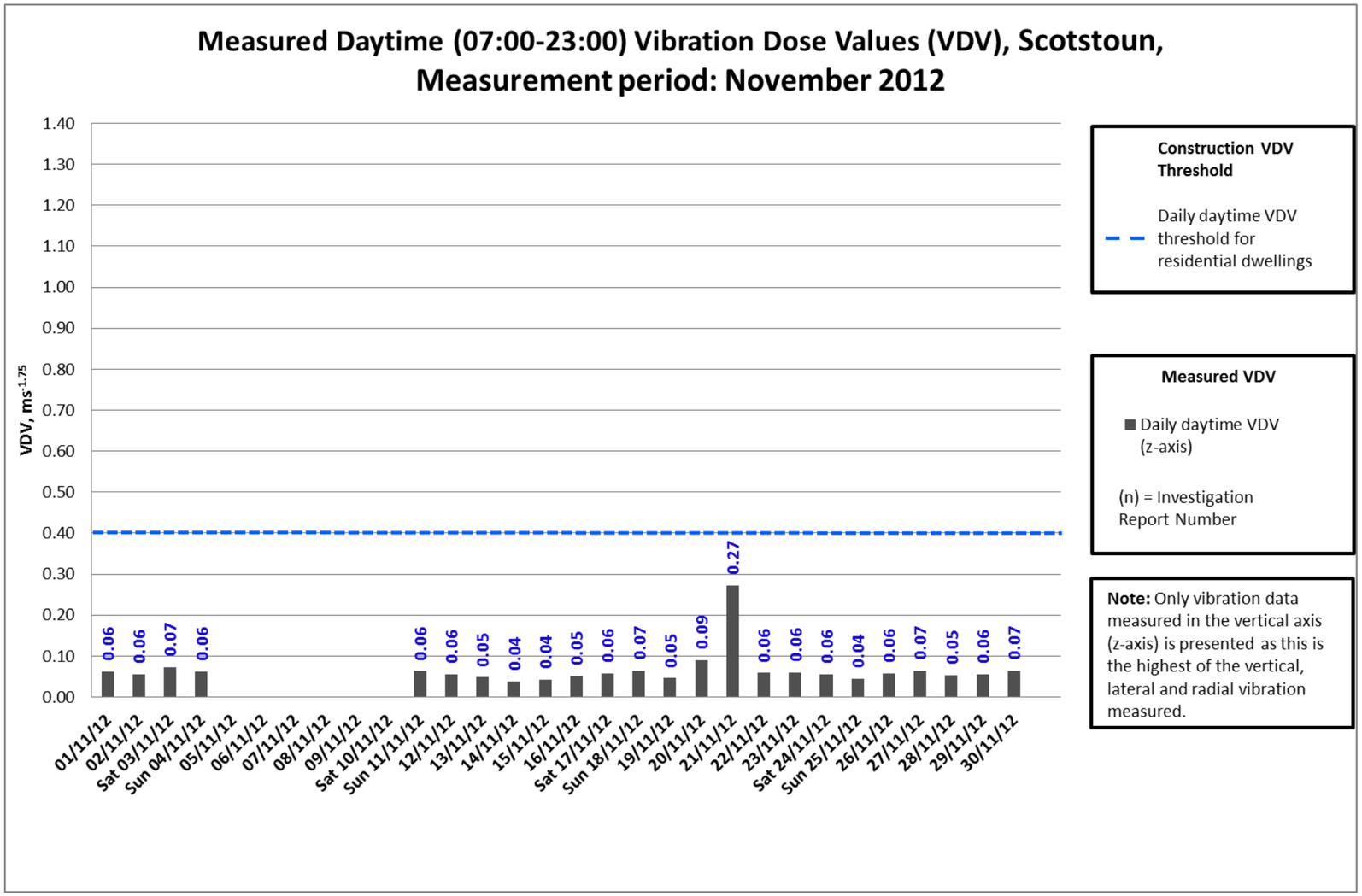
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activities. The closest night-time works to Linn Mill are more than 500m away;
- Arrangements are being made for this VIBROCK to be relocated to a representative location where less local interferences are likely.



Notes:

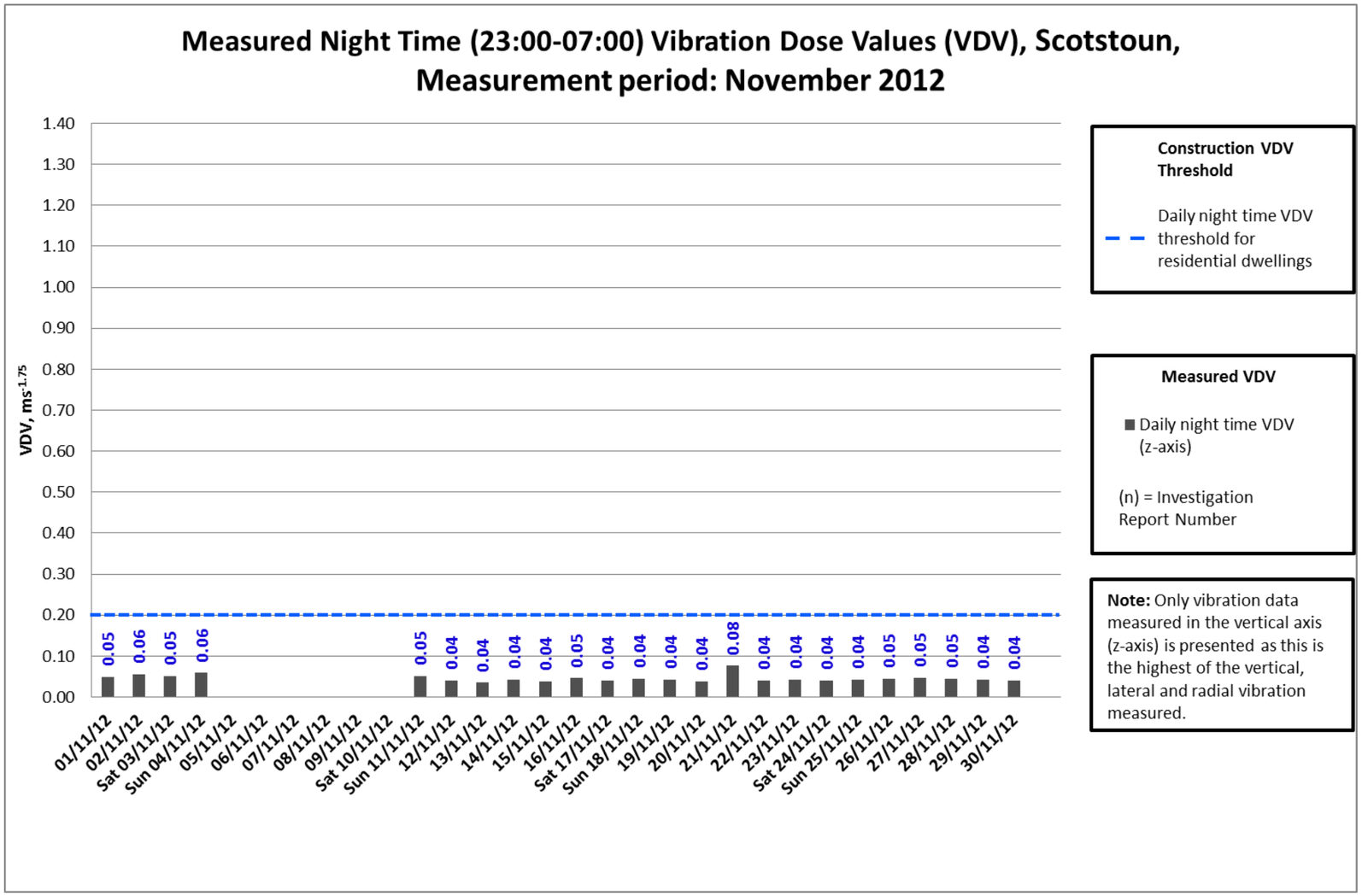
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are isolated events due to local interferences rather than any continuous construction activities (example for 21/11/12). None of the construction activities could cause such levels of PPV at this location.





Note:

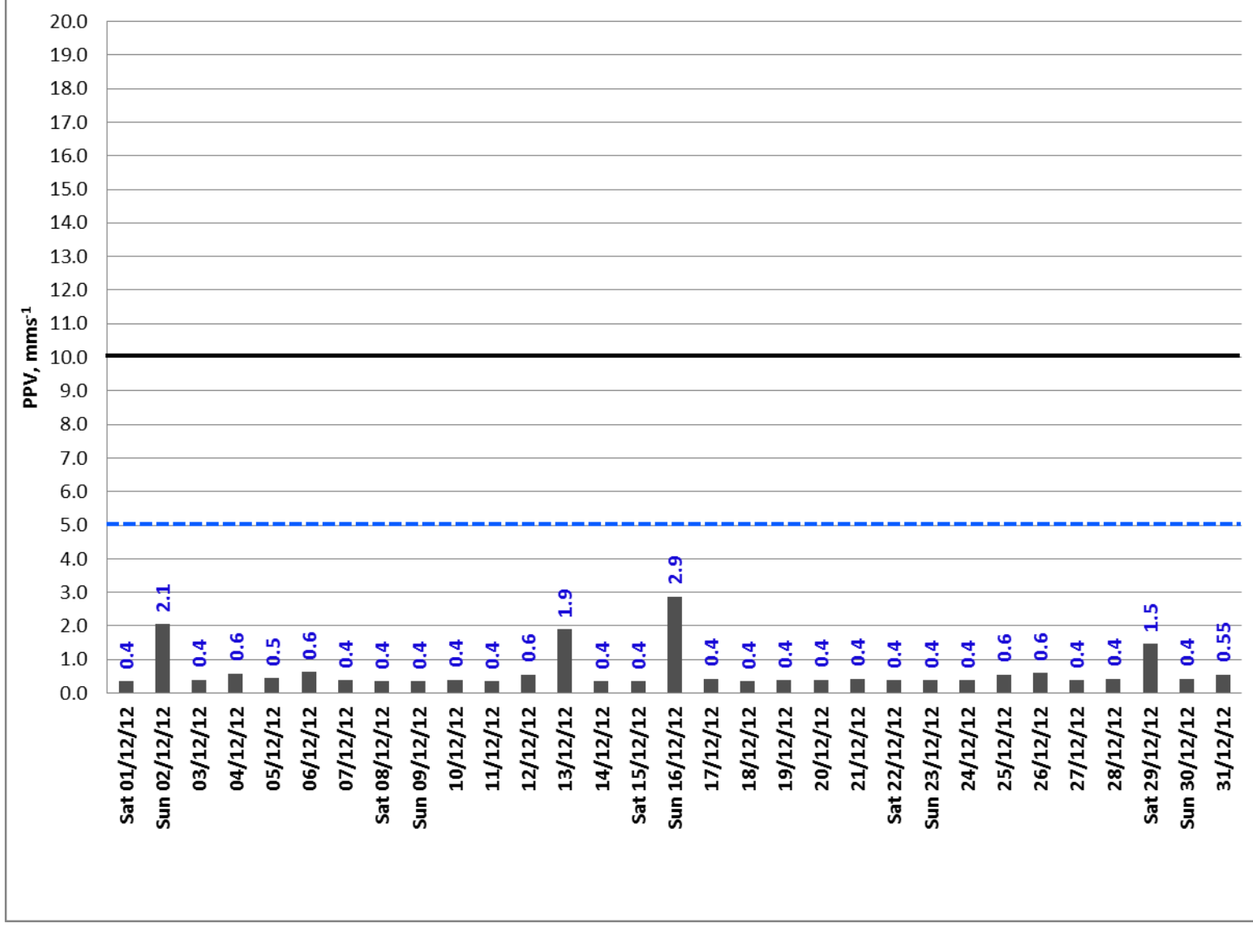
- Due to server issues at the site office some data, recorded for November 2012, was lost;



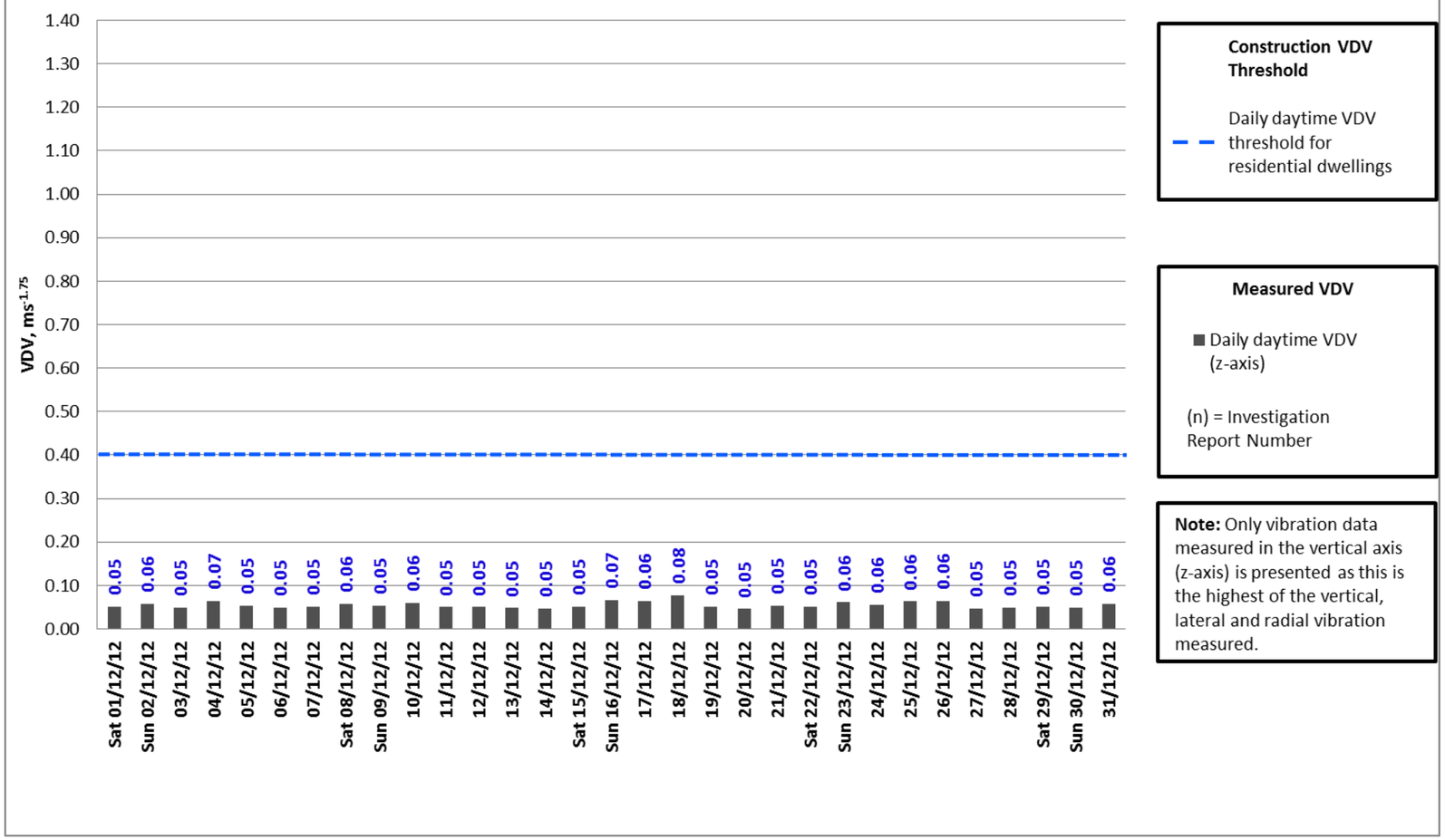
Note:

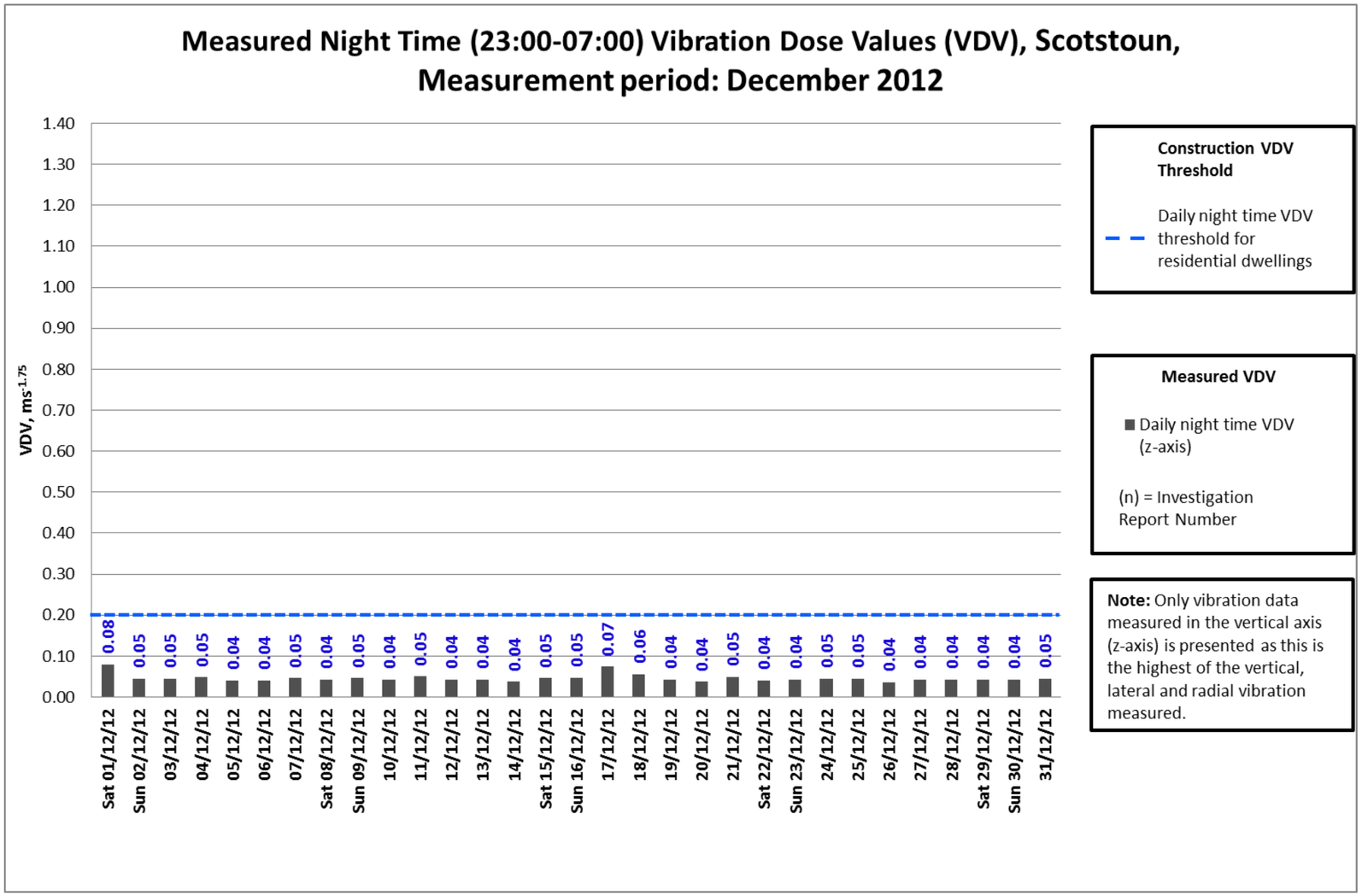
- Due to server issues at the site office some data, recorded for November 2012, was lost;

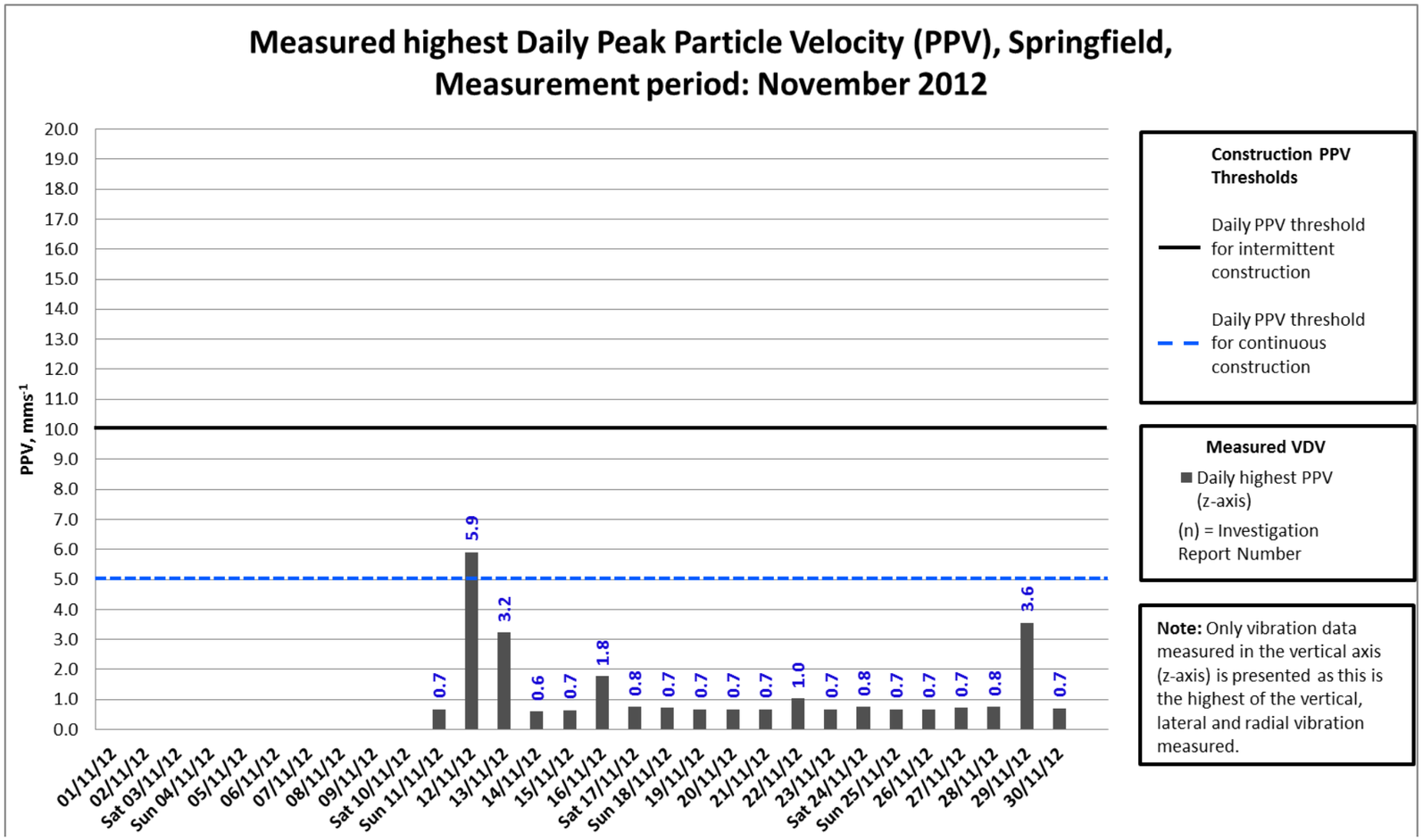
Measured highest Daily Peak Particle Velocity (PPV), Scotstoun, Measurement period: December 2012



Measured Daytime (07:00-23:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: December 2012

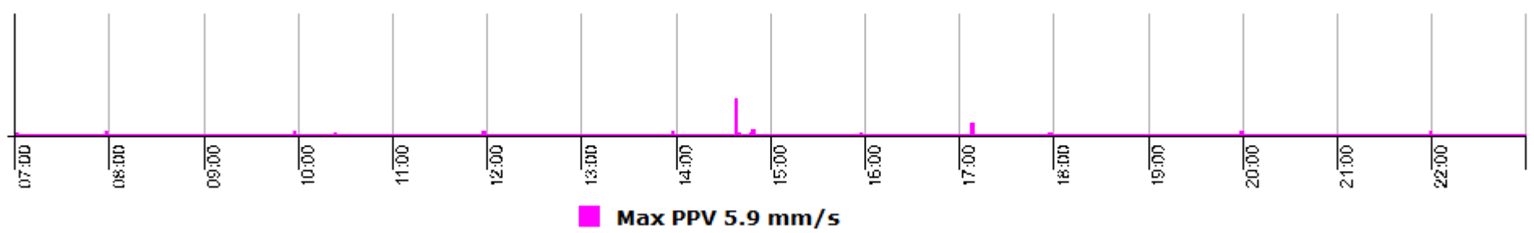


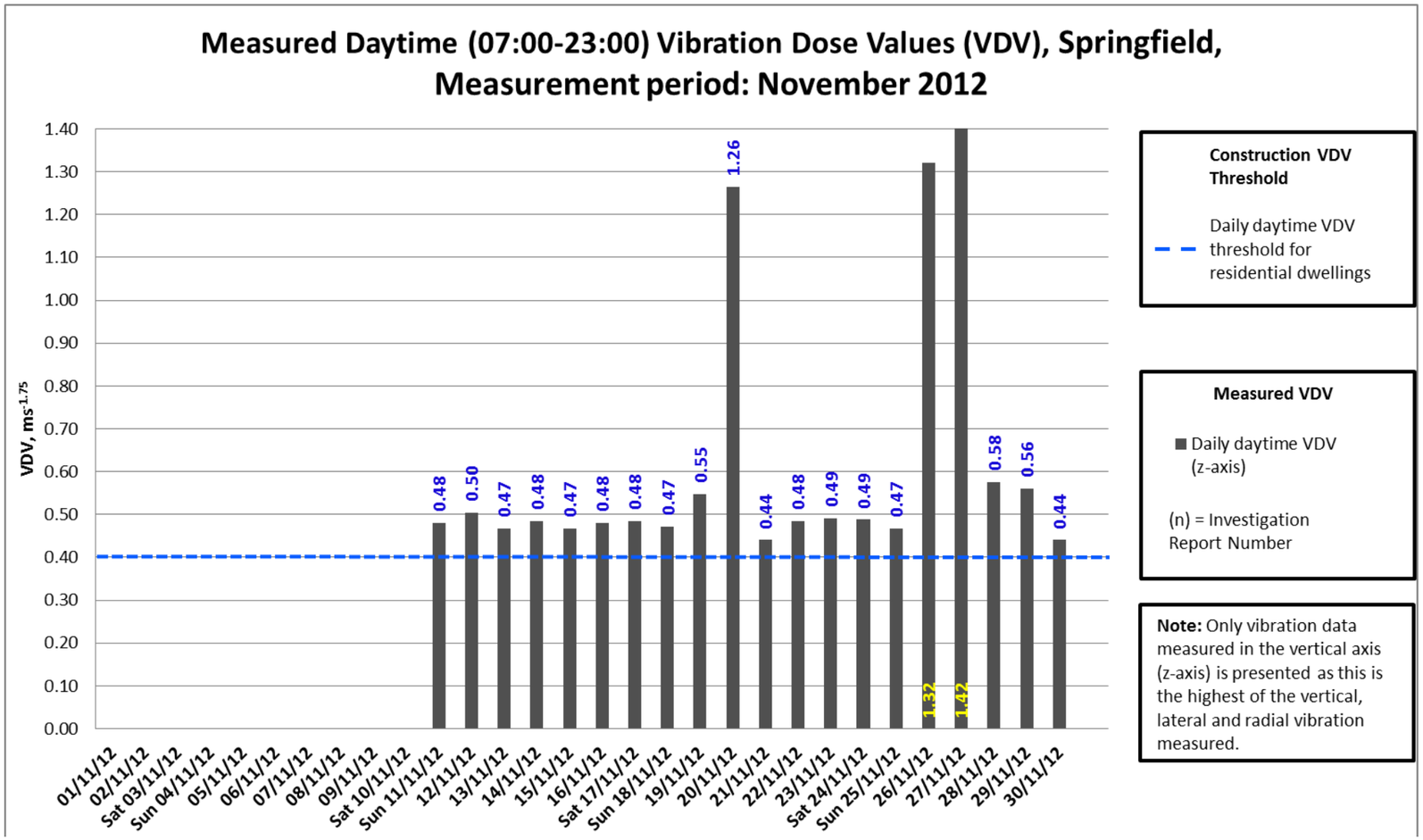

Measured Night Time (23:00-07:00) Vibration Dose Values (VDV), Scotstoun, Measurement period: December 2012
VDV, ms-1.75
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.08 0.05 0.05 0.05 0.04 0.04 0.05 0.04 0.05 0.04 0.05 0.04 0.04 0.04 0.05 0.05 0.07 0.06 0.04 0.04 0.05 0.04 0.04 0.05 0.05 0.04 0.04 0.04 0.04 0.05
Sat 01/12/12
Sun 02/12/12
03/12/12
04/12/12
05/12/12
06/12/12
07/12/12
Sat 08/12/12
Sun 09/12/12
10/12/12
11/12/12
12/12/12
13/12/12
14/12/12
Sat 15/12/12
Sun 16/12/12
17/12/12
18/12/12
19/12/12
20/12/12
21/12/12
Sat 22/12/12
Sun 23/12/12
24/12/12
25/12/12
26/12/12
27/12/12
28/12/12
Sat 29/12/12
Sun 30/12/12
31/12/12
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:

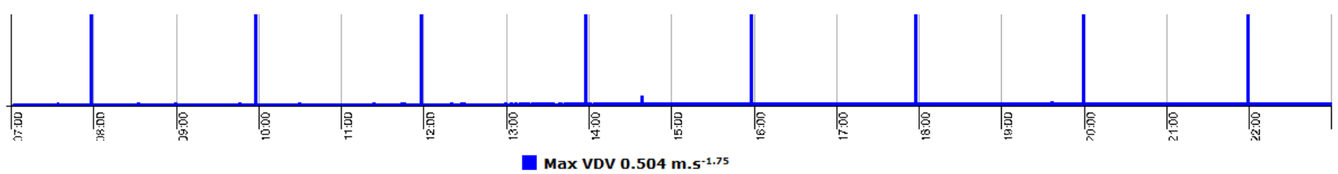
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The exceedance on 12/11/12 has been investigated. This is an isolated event due to local interferences rather than any continuous construction activities.

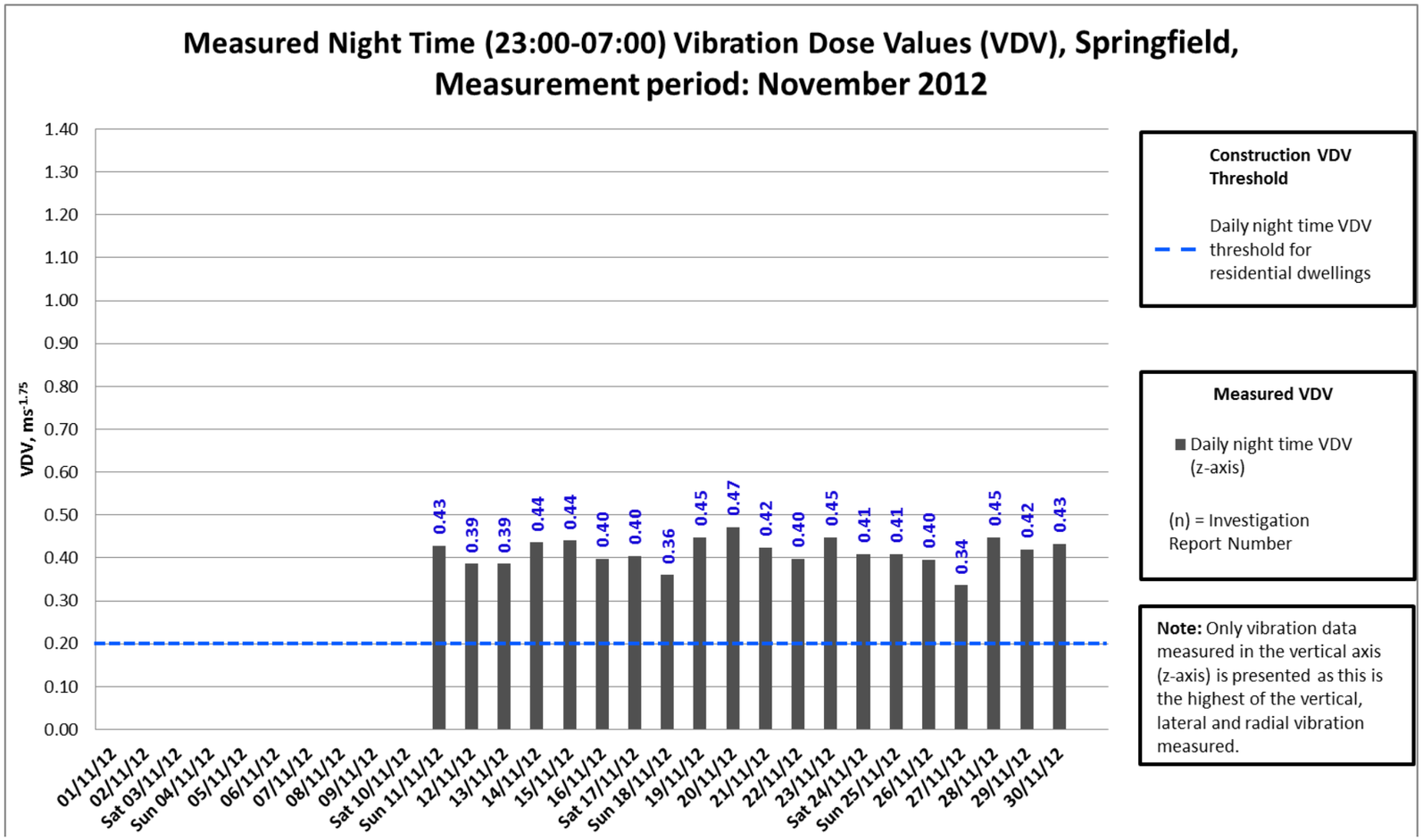




Notes:

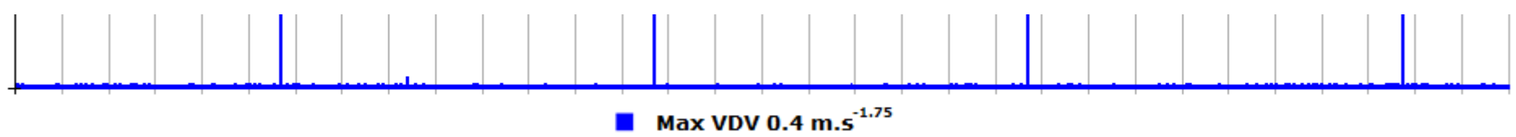
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these spikes as can be seen in the graph below. Other than these spikes the vibration levels are well below the limits (please see below for an example on 12/11/12).
- As can be seen from the graph above, exceedances occur over Sundays where no construction activity is going on.

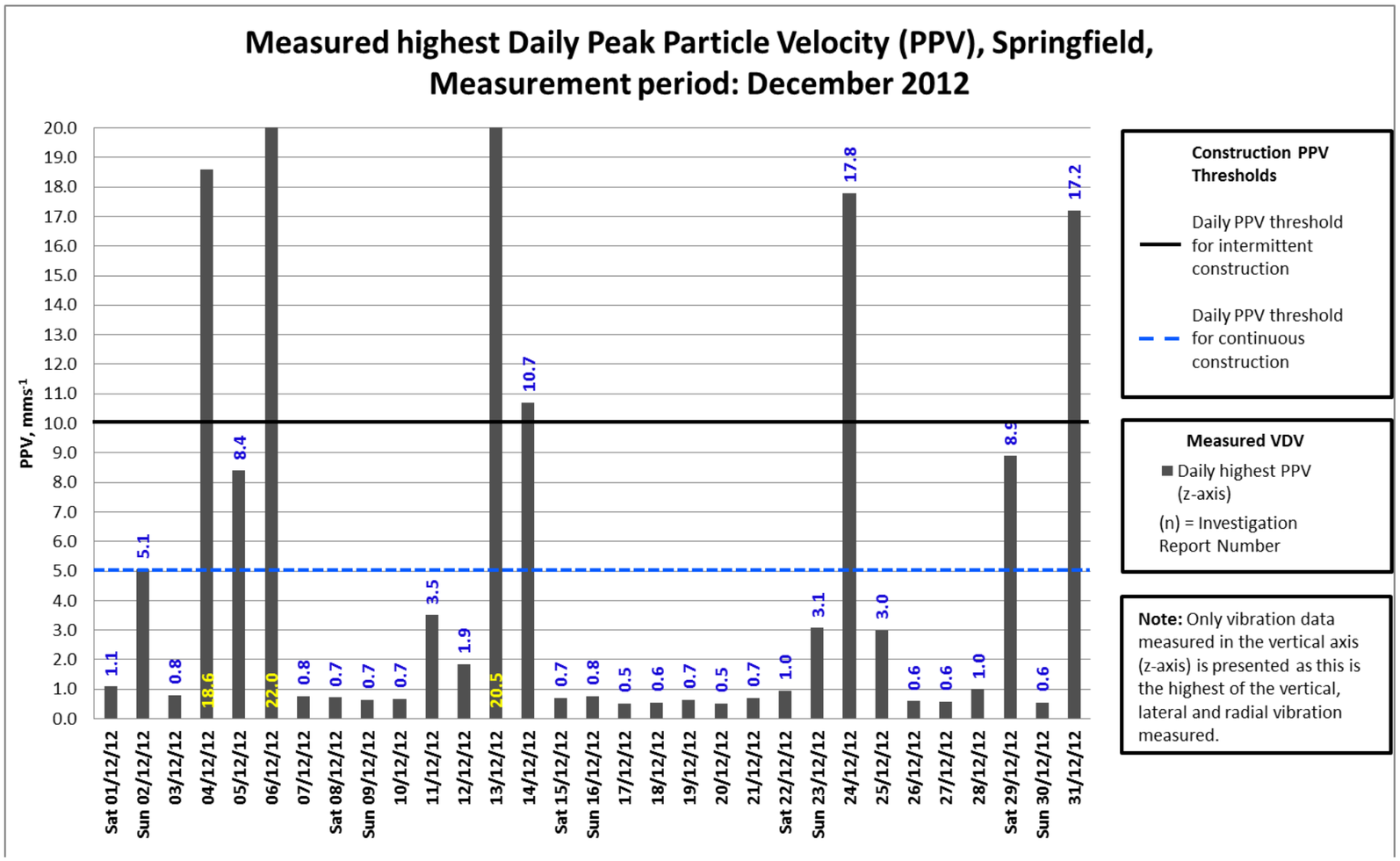




Notes:

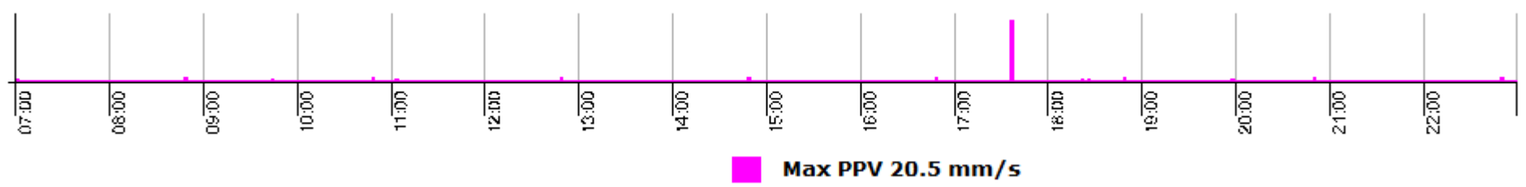
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these spikes as can be seen in the graph below. Other than these spikes the vibration levels are well below the limits (please see below for an example on 15/11/12).
- The closest night-time works to Springfiled are more than 600m away (which is not vibration inducing).

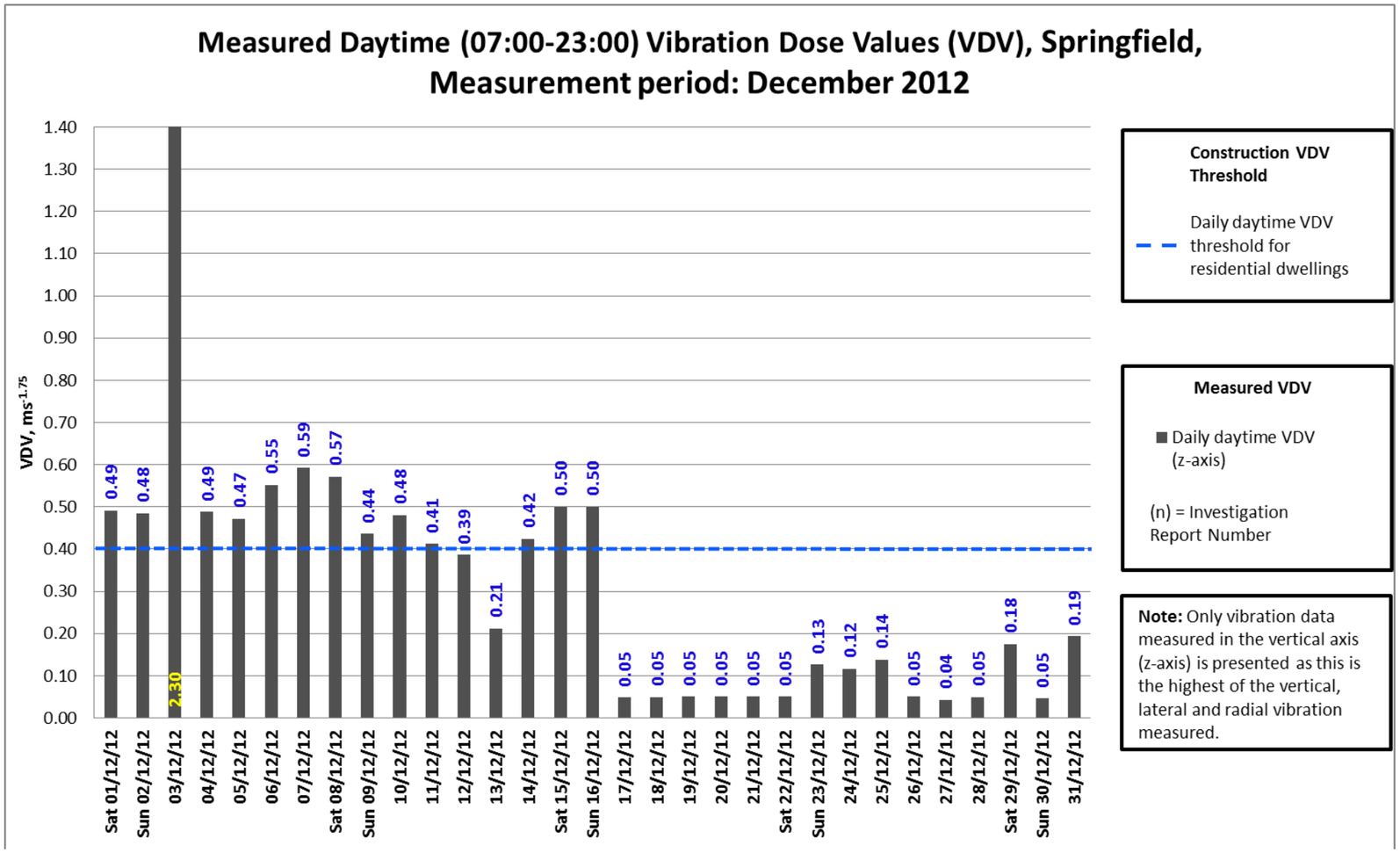




Notes:

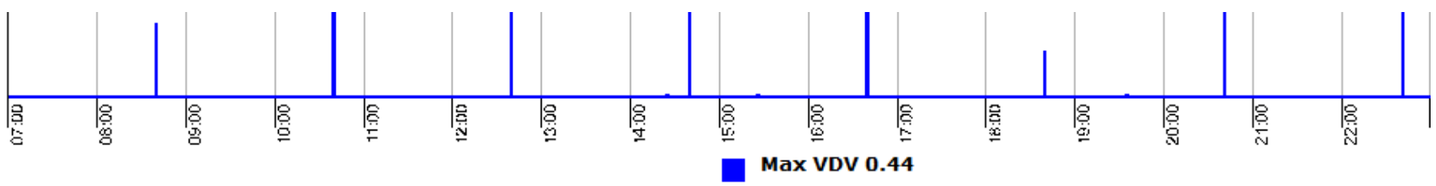
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activities (please see an example below for (13/12/12).

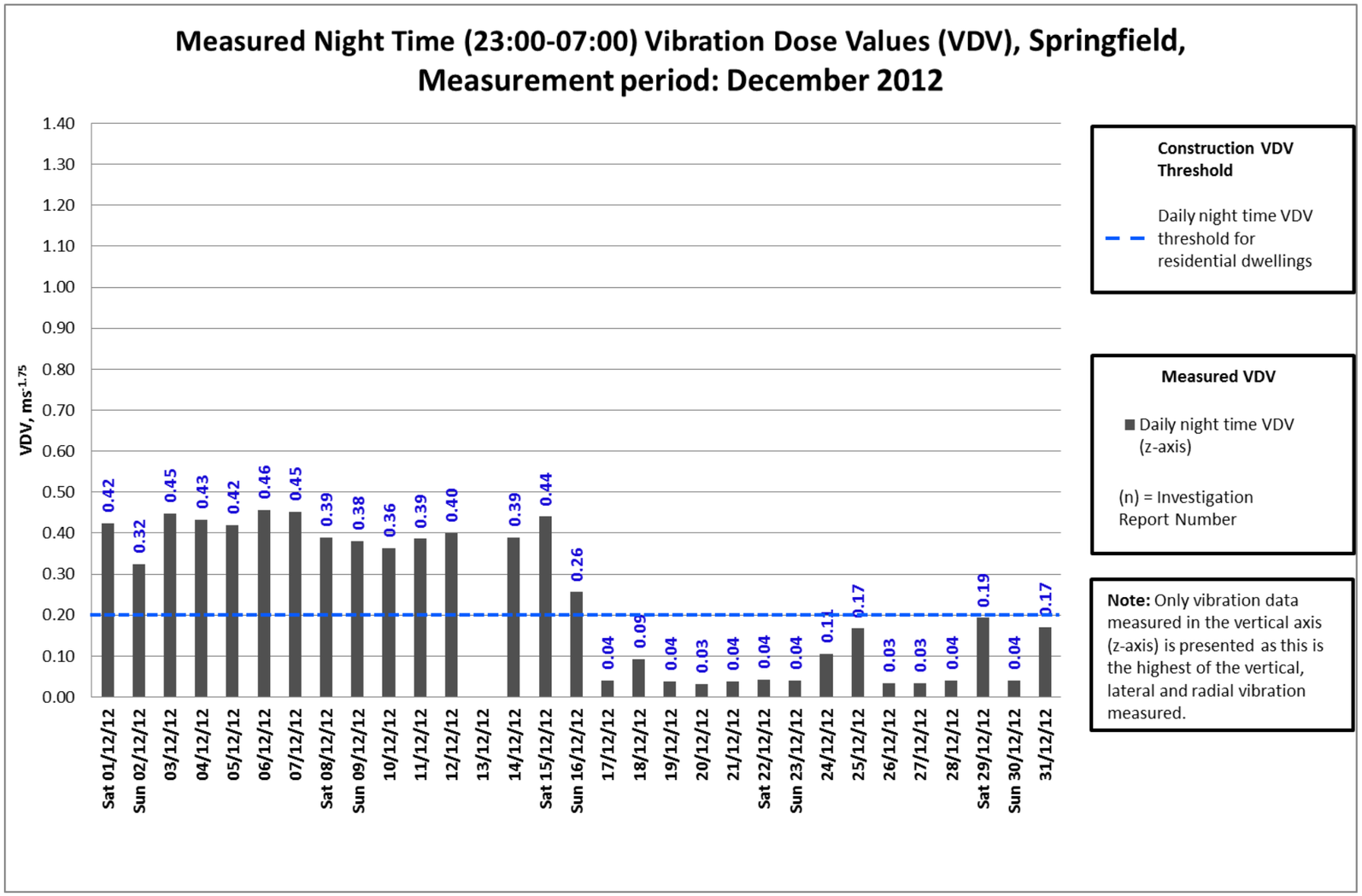




Notes:

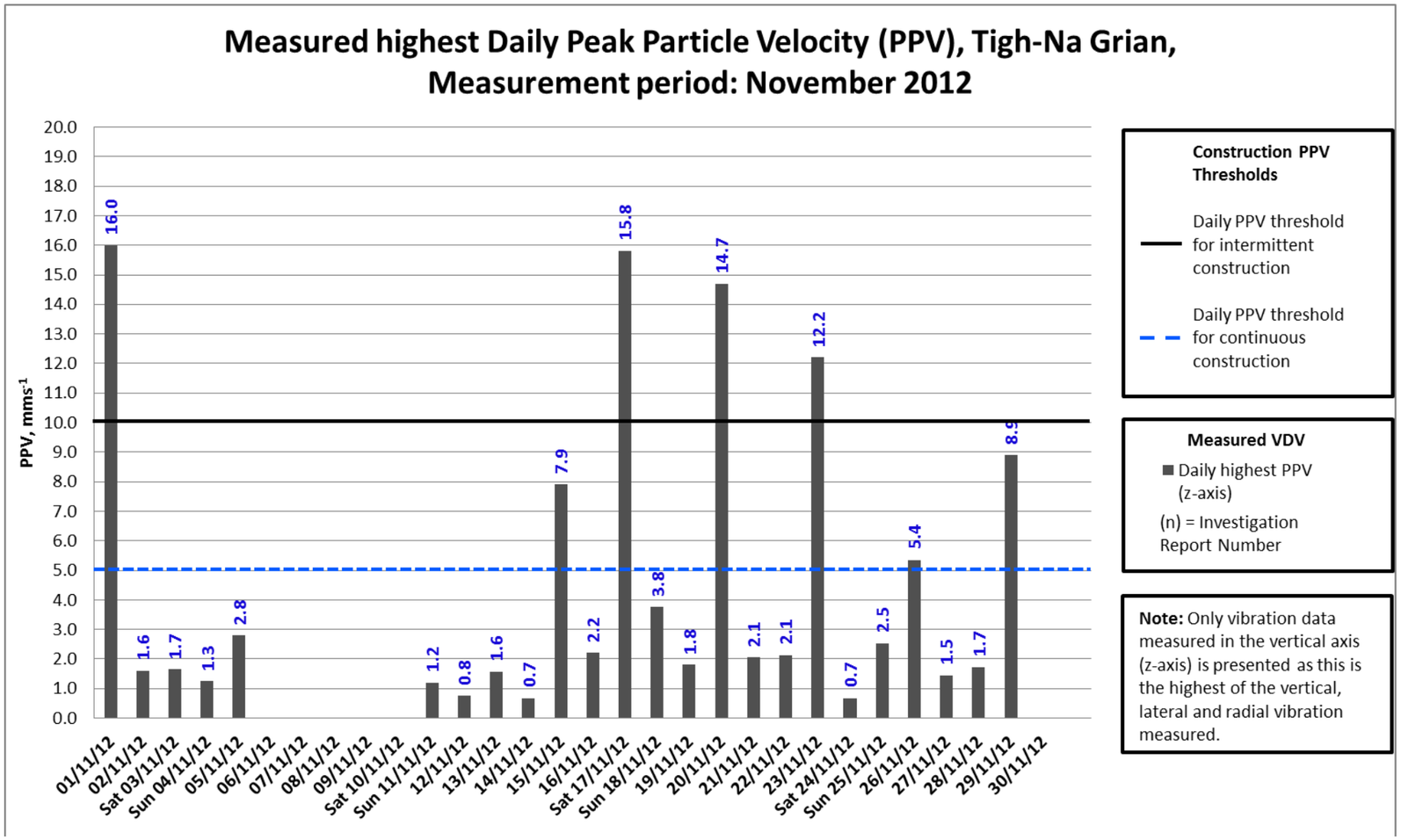
- Exceedances have been investigated and are all isolated events due to a problem with the device;
- The exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these spikes as can be seen in the graph below. Other than these spikes the vibration levels are well below the limits (please see below for an example on 09/12/12). However, following a reboot of the device on 17/12/12 this problem was temporarily resolved.





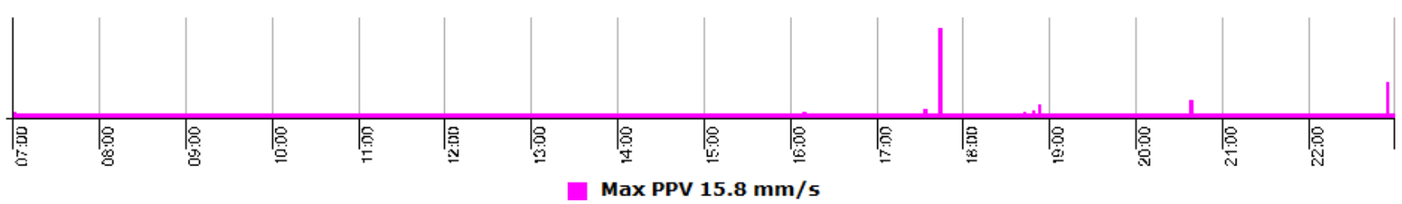
Notes:

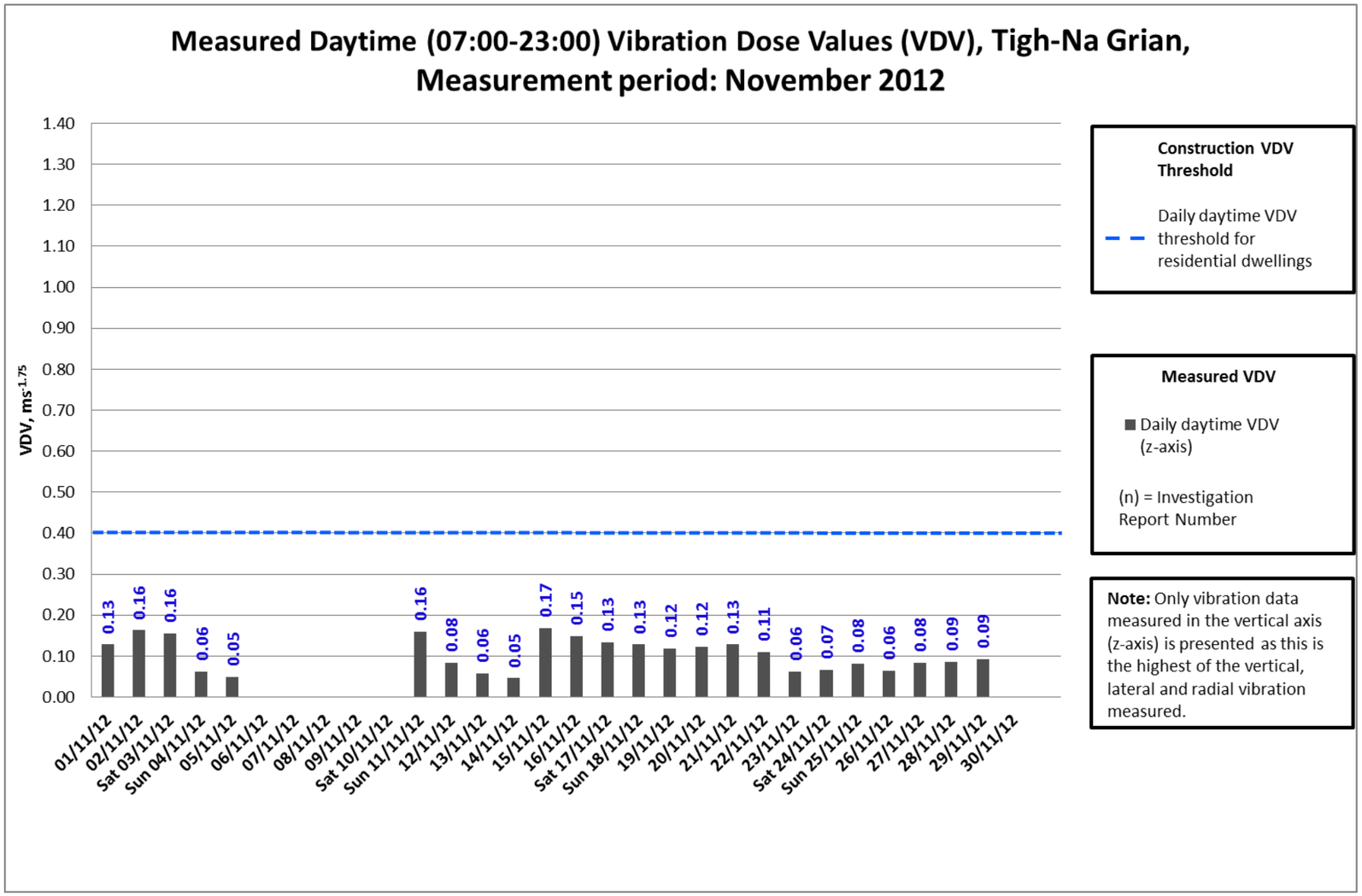
- Exceedances have been investigated and are all isolated events due to a problem with the device;
- The exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these spikes as can be seen in the graph below. Other than these spikes the vibration levels are well below the limits. However, following a reboot of the device on 17/12/12 this problem was temporarily resolved.
- The closest night-time works to Springfiled are more than 600m away (which is not vibration inducing anyway).
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



Notes:

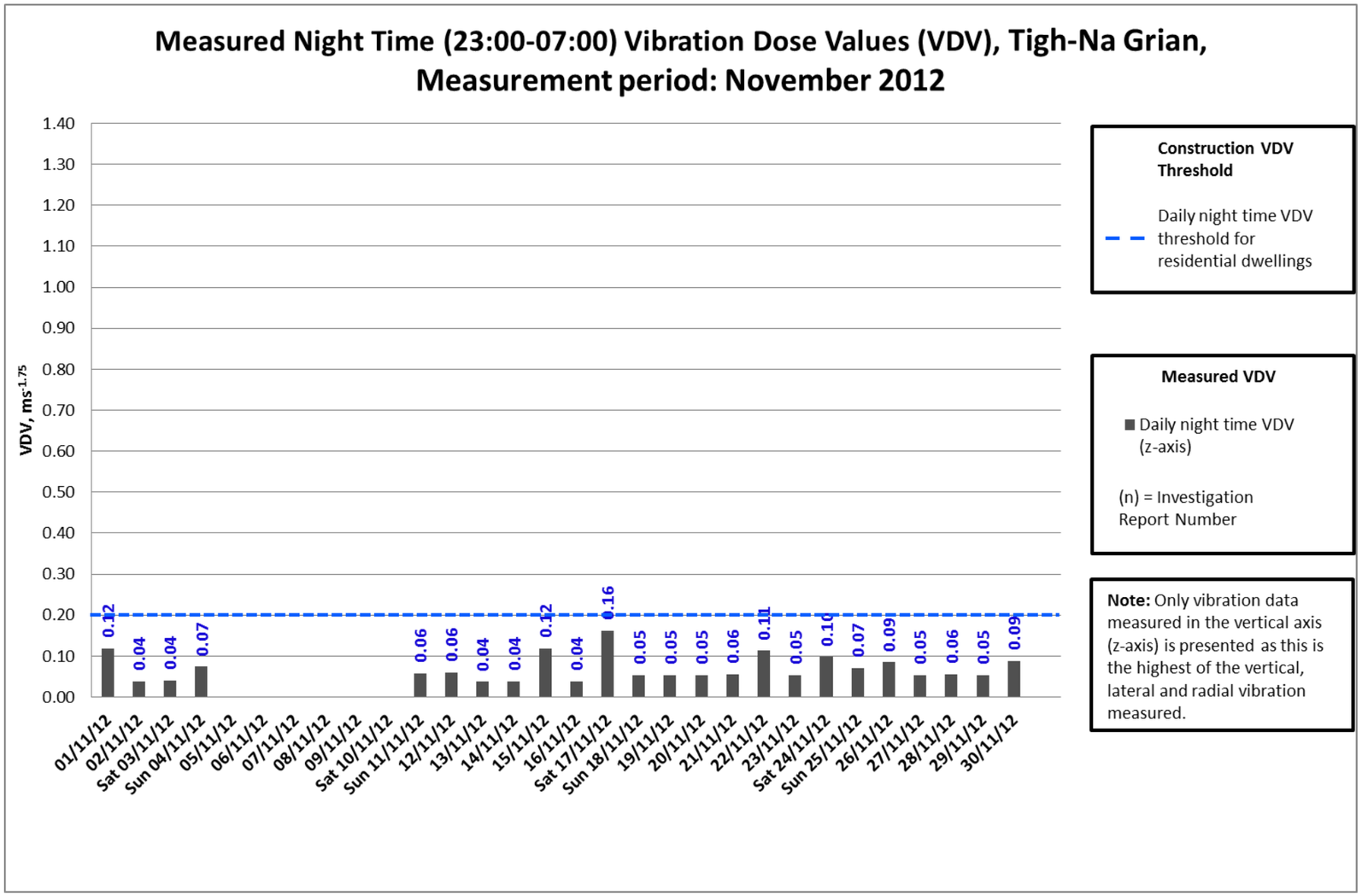
- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events due to local interferences rather than continuous construction work (an example presented below for 17/11/12);
- The closest construction activity to this location was more than 200m from this meter.





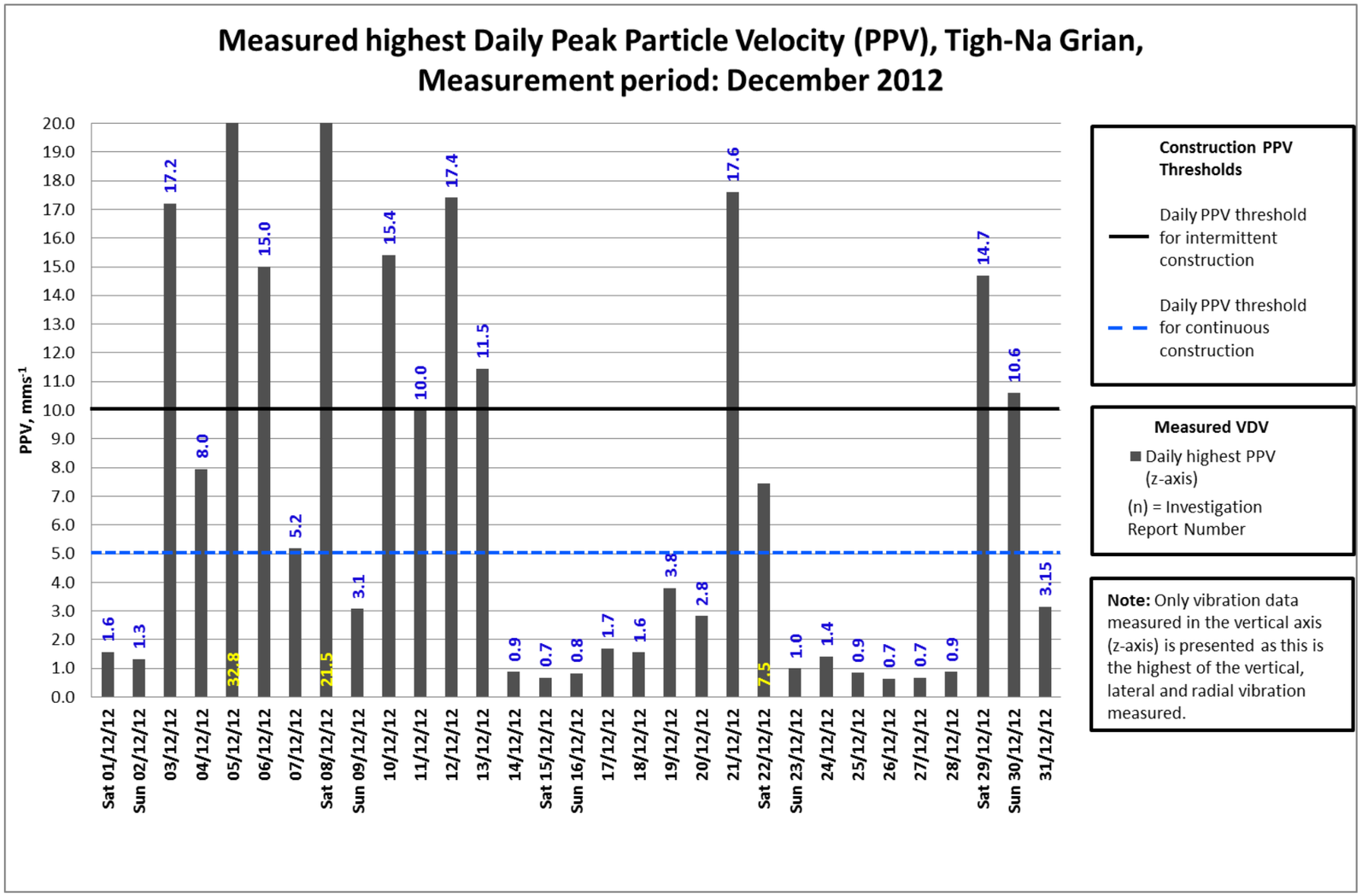
Note:

- Due to server issues at the site office some data, recorded for November 2012, was lost.



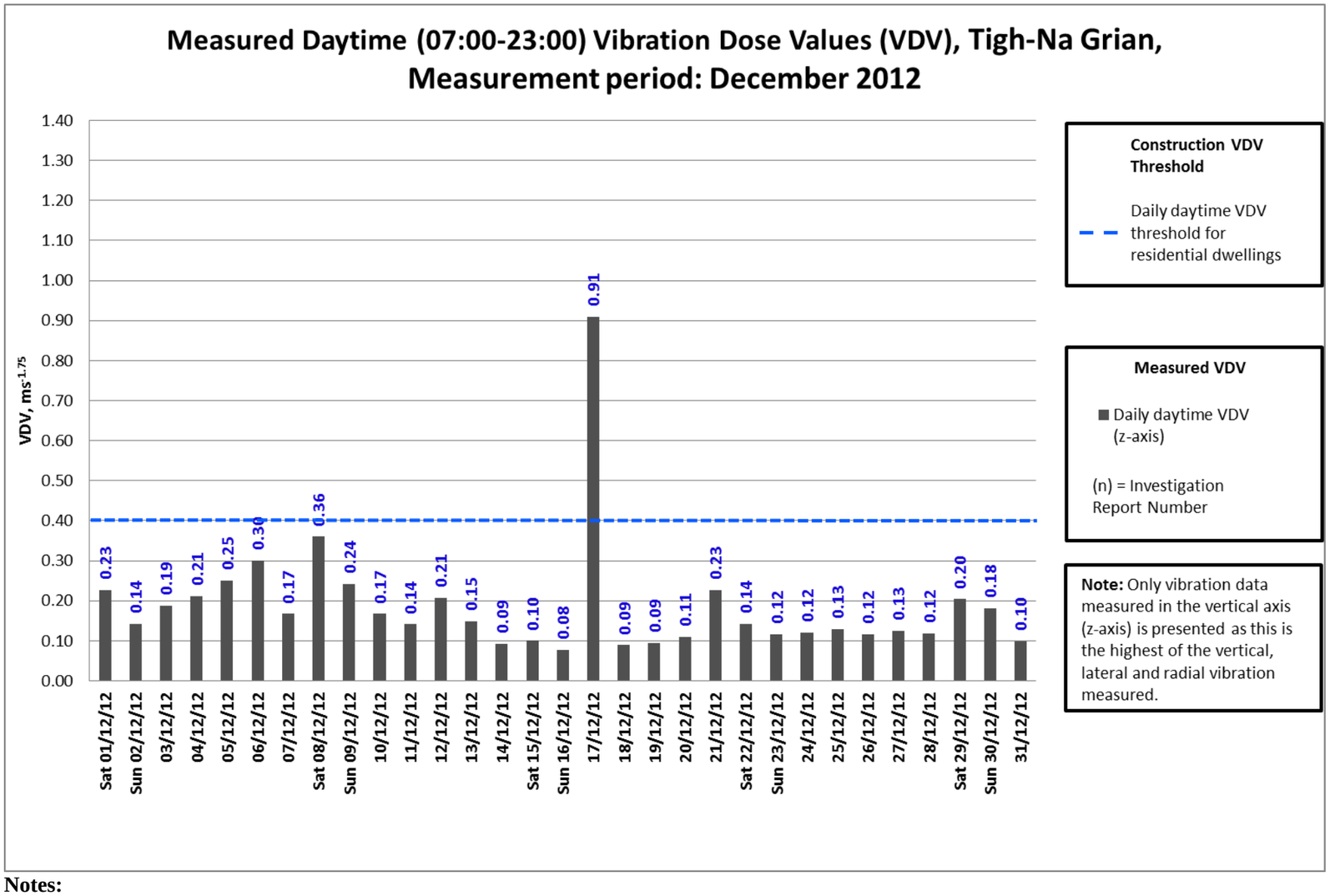
Note:

- Due to server issues at the site office some data, recorded for November 2012, was lost.



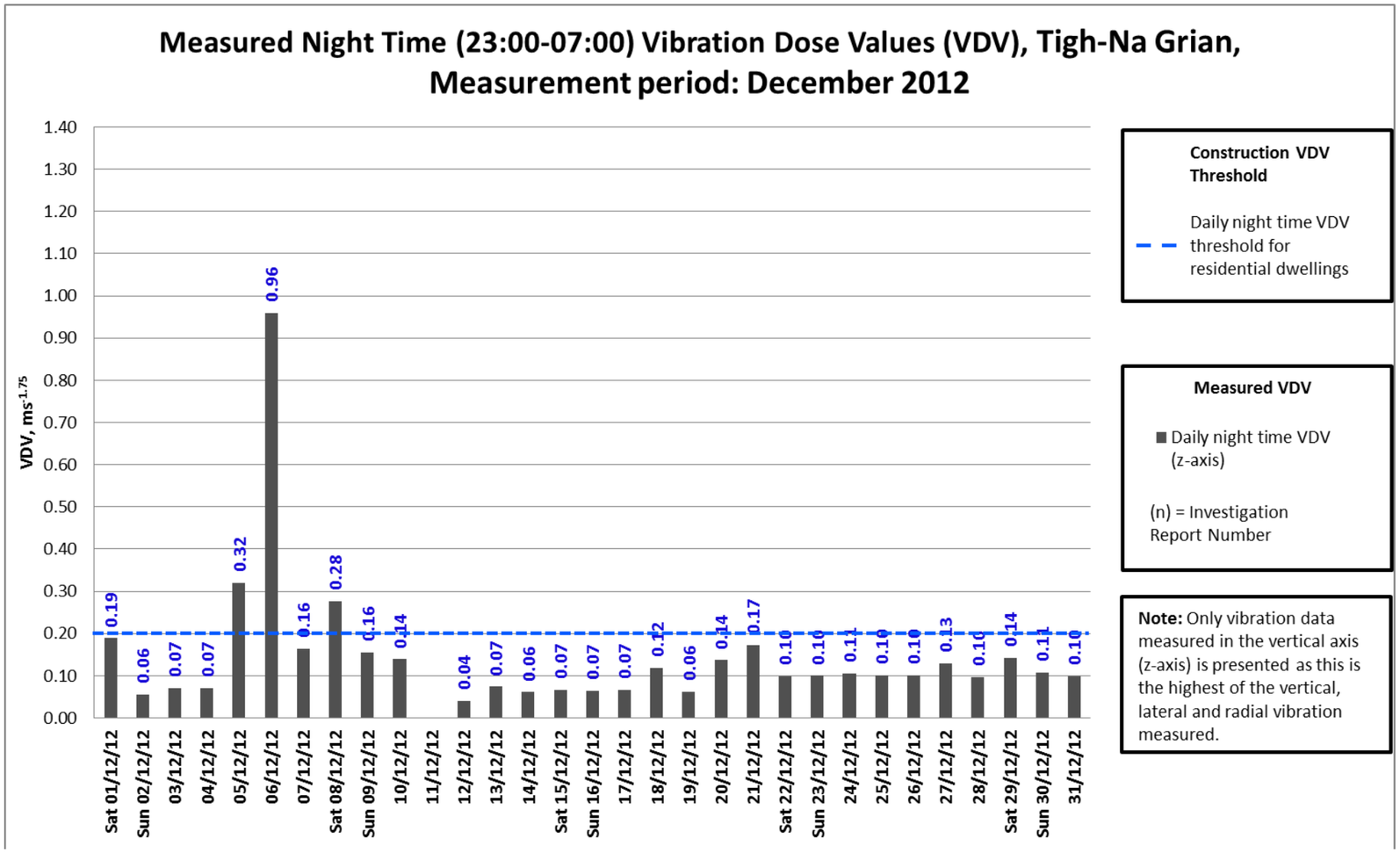
Notes:

- Exceedances have been investigated and are all isolated events due to local interferences. As can be seen from the above graph, exceedances continue to occur during the holiday period. This shows that occurrences of exceedances are not due to construction activities;
- The closest construction activity to this location was more than 200m from this meter;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



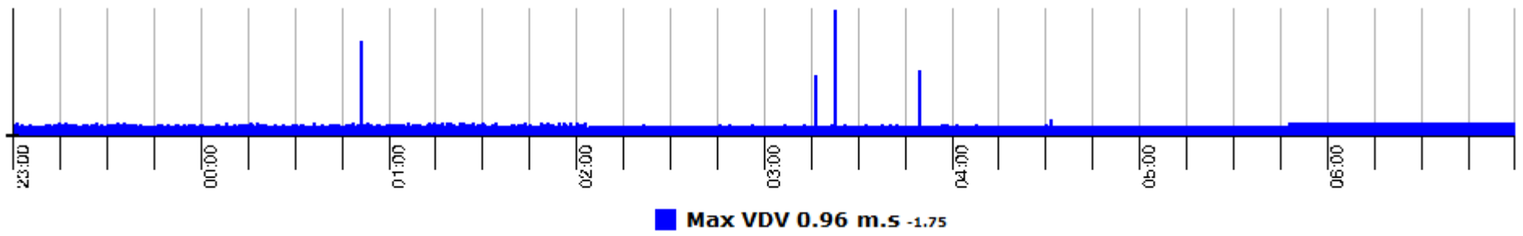
Notes:

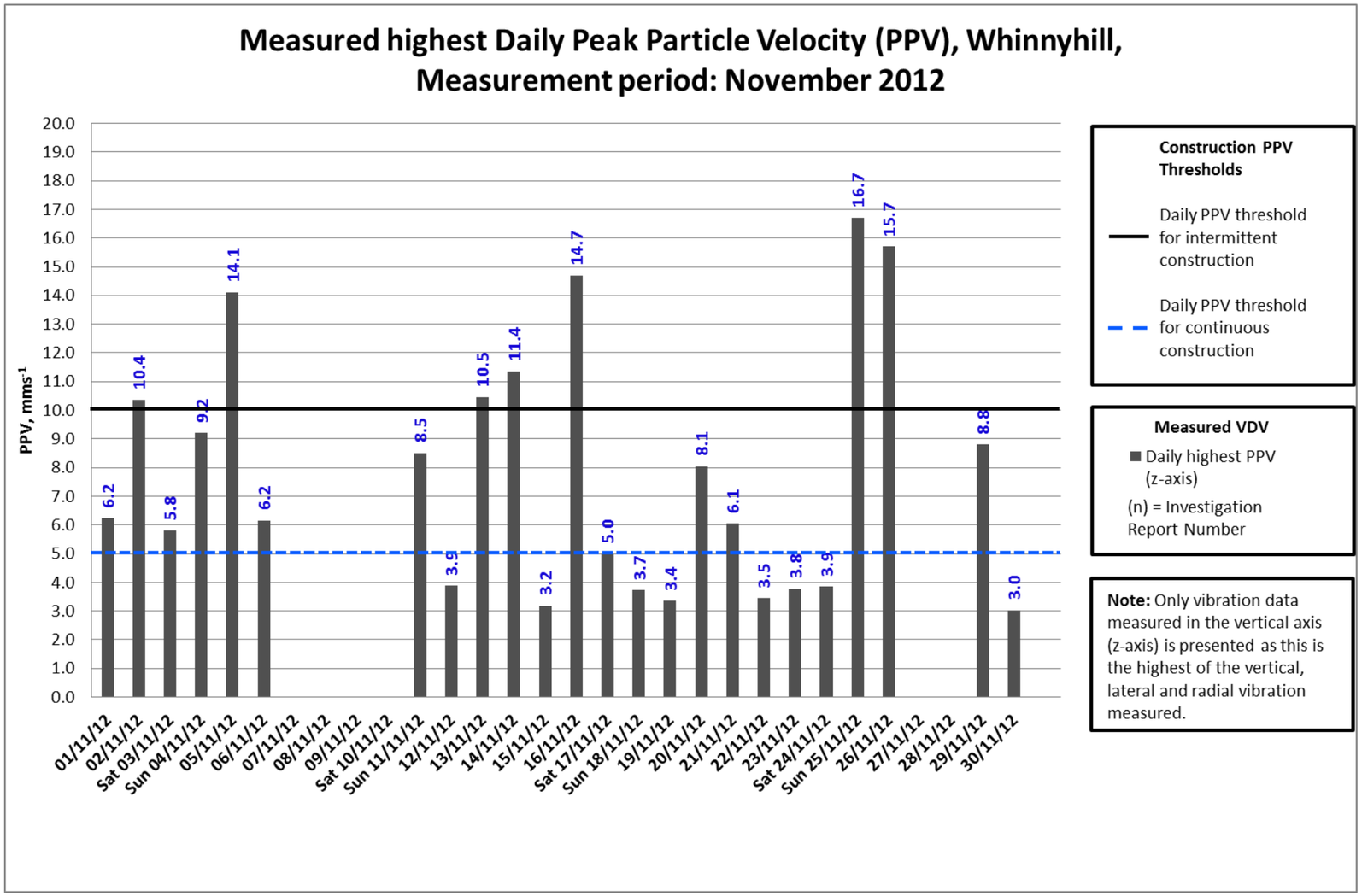
- The single exceedance on 17/12/12 was due to the interference occurred during the device maintenance;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



Notes:

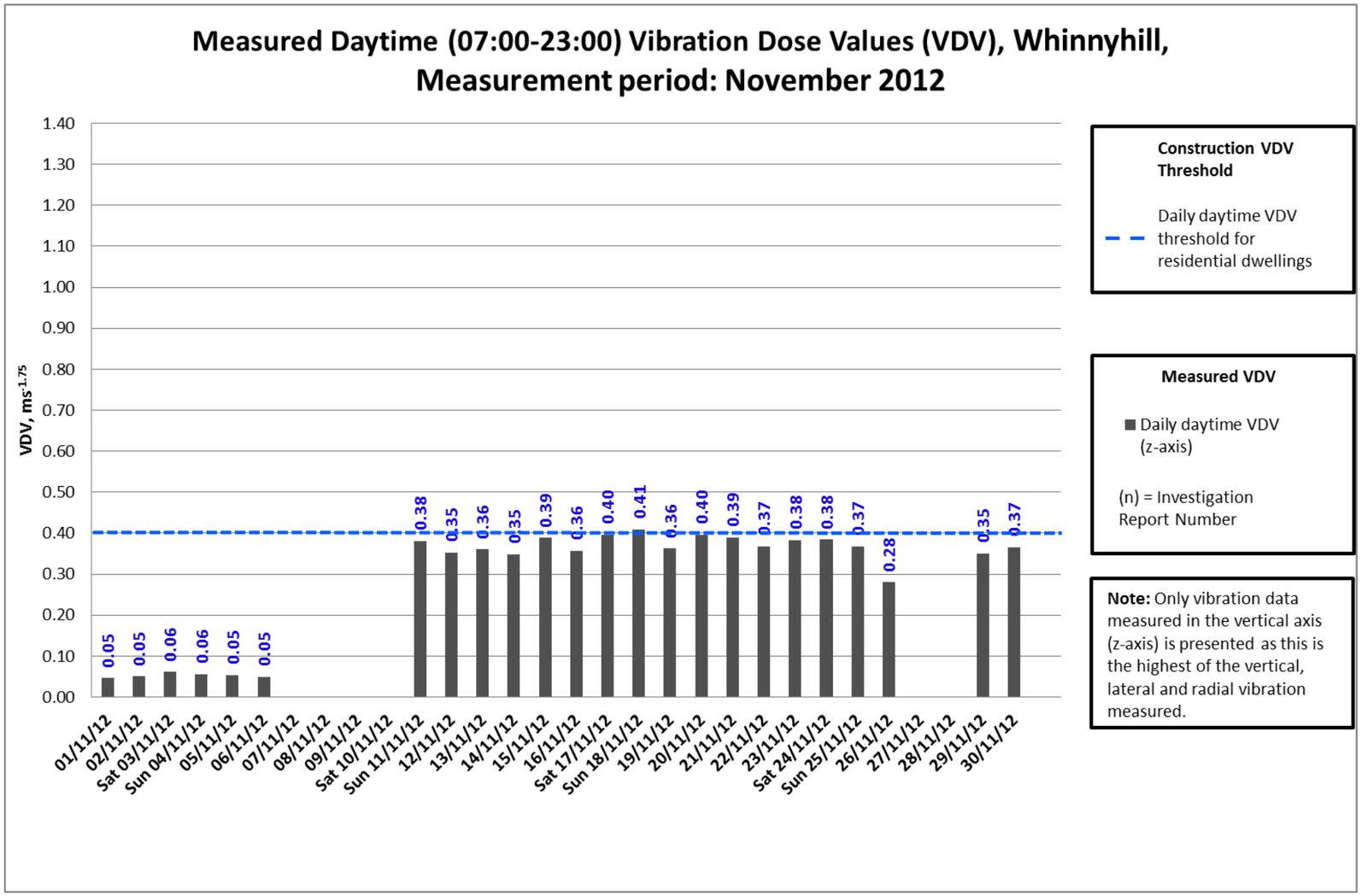
- Exceedances have been investigated and are all isolated events due to local interferences rather than any continuous construction activity (an example for 06/12/12 is presented below);
- The closest construction activity to this receptor is more than 200m away;





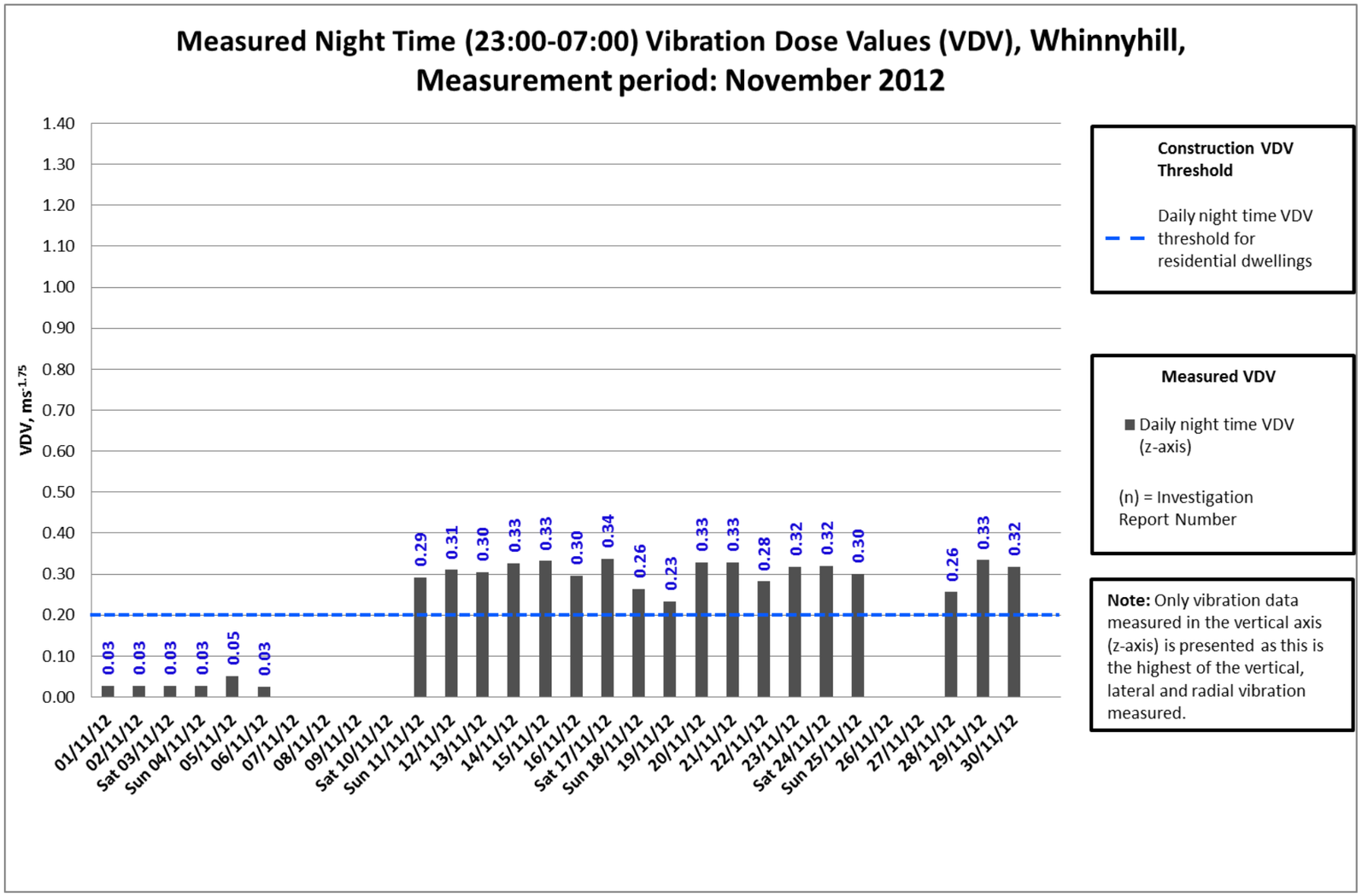
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- Exceedances have been investigated and are all isolated events. Such high level events cannot be due to continuous construction activities, around 300m away on the other side of the motorway.



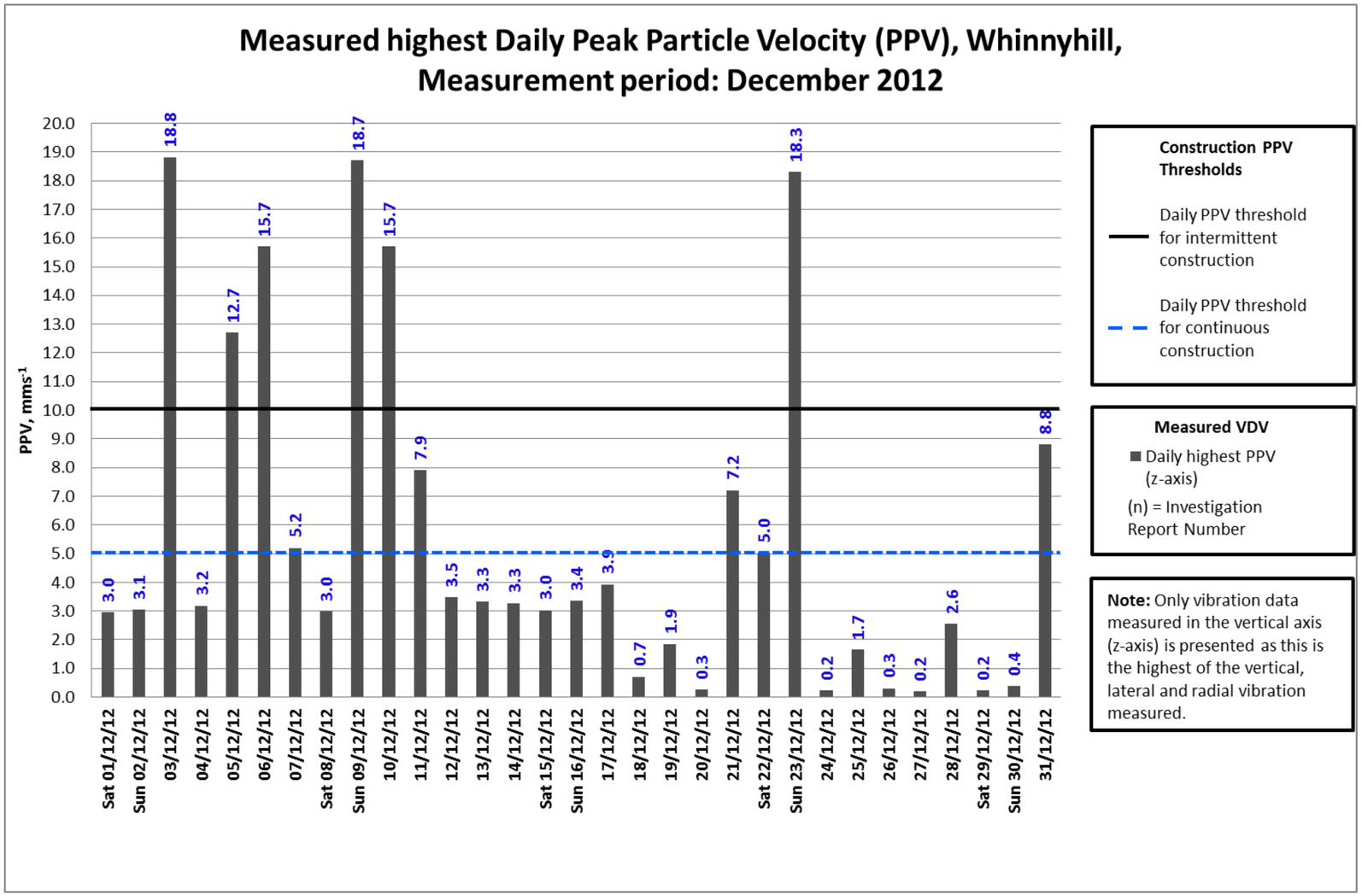
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The high VDV levels at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these instantaneous high levels. Other than these maximums, the VDV levels are well below the limits;
- As can be seen from the above graph the exceedance occurred on Sunday when no construction activity was going on. Also high levels occur during Sundays.



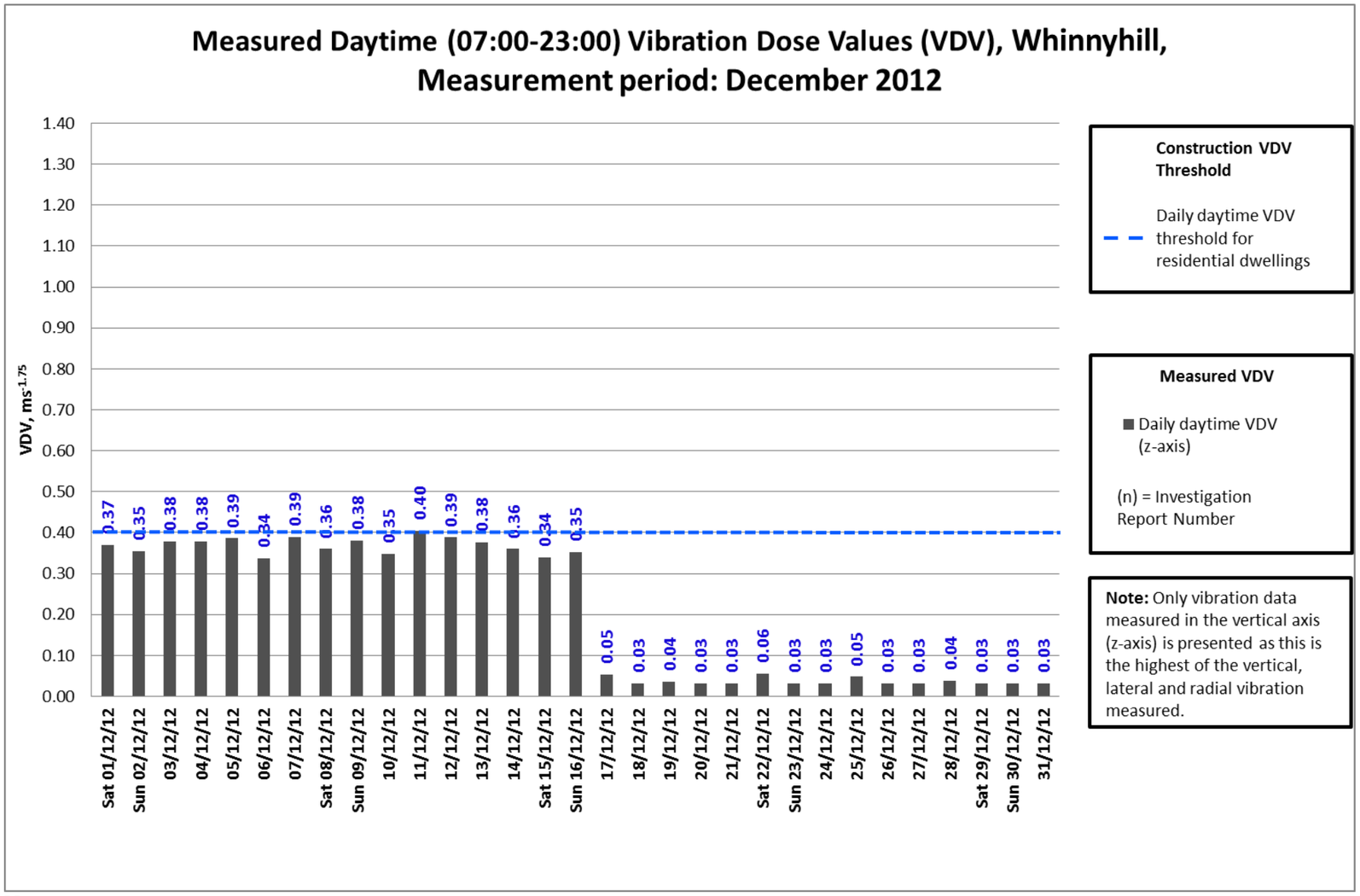
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost;
- The VDV exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in an equal hourly interval. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these instantaneous high levels. Other than these maximums, the VDV levels are well below the limits;
- As can be seen from the above graph exceedances also occurred on Sundays when no construction activity was going on.
- There is no night-time construction works within 1,800m of this receptor.



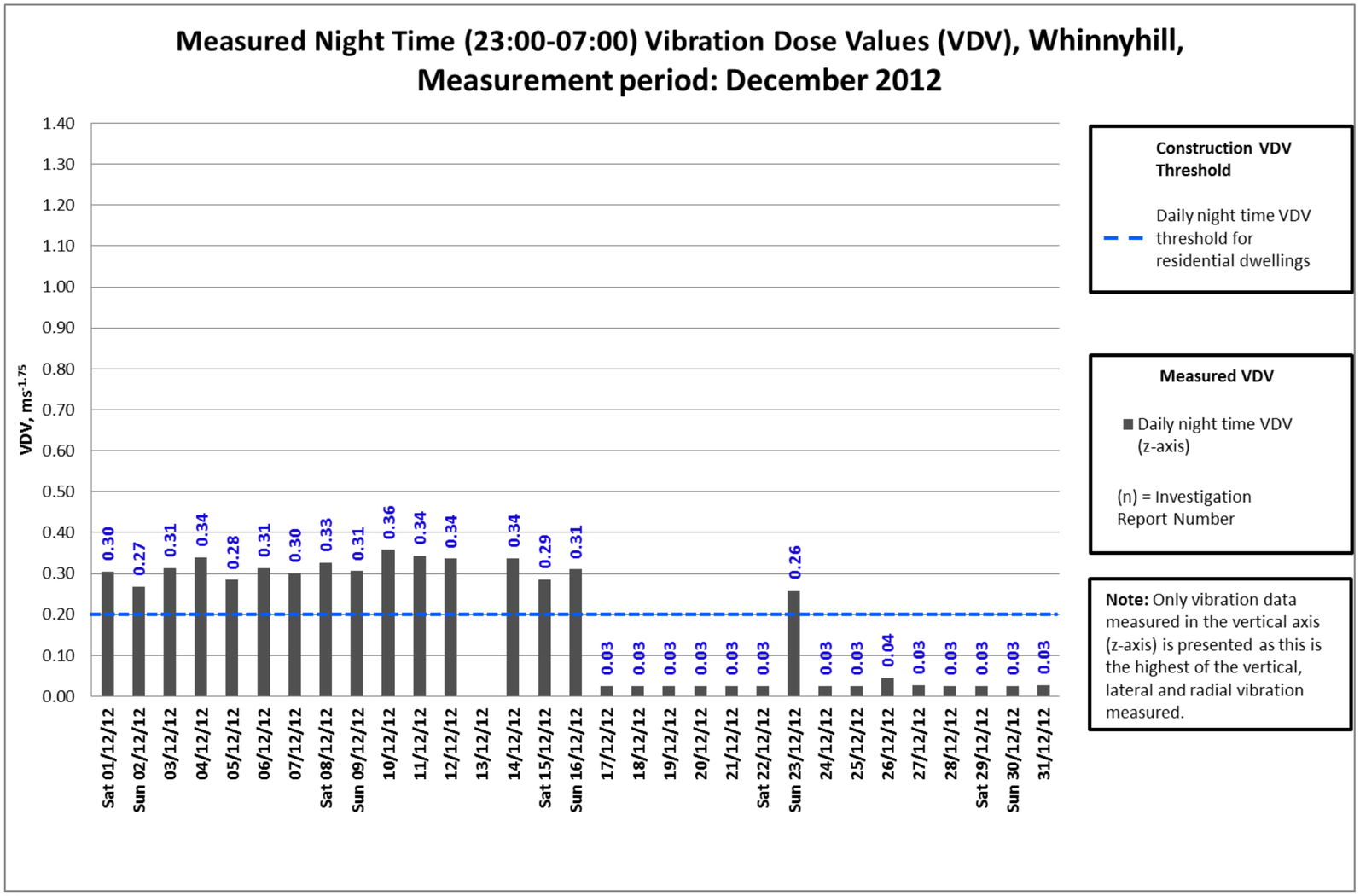
Notes:

- Exceedances have been investigated and are all isolated events. Such high level events cannot be due to continuous construction activities, around 300m away on the other side of the motorway;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



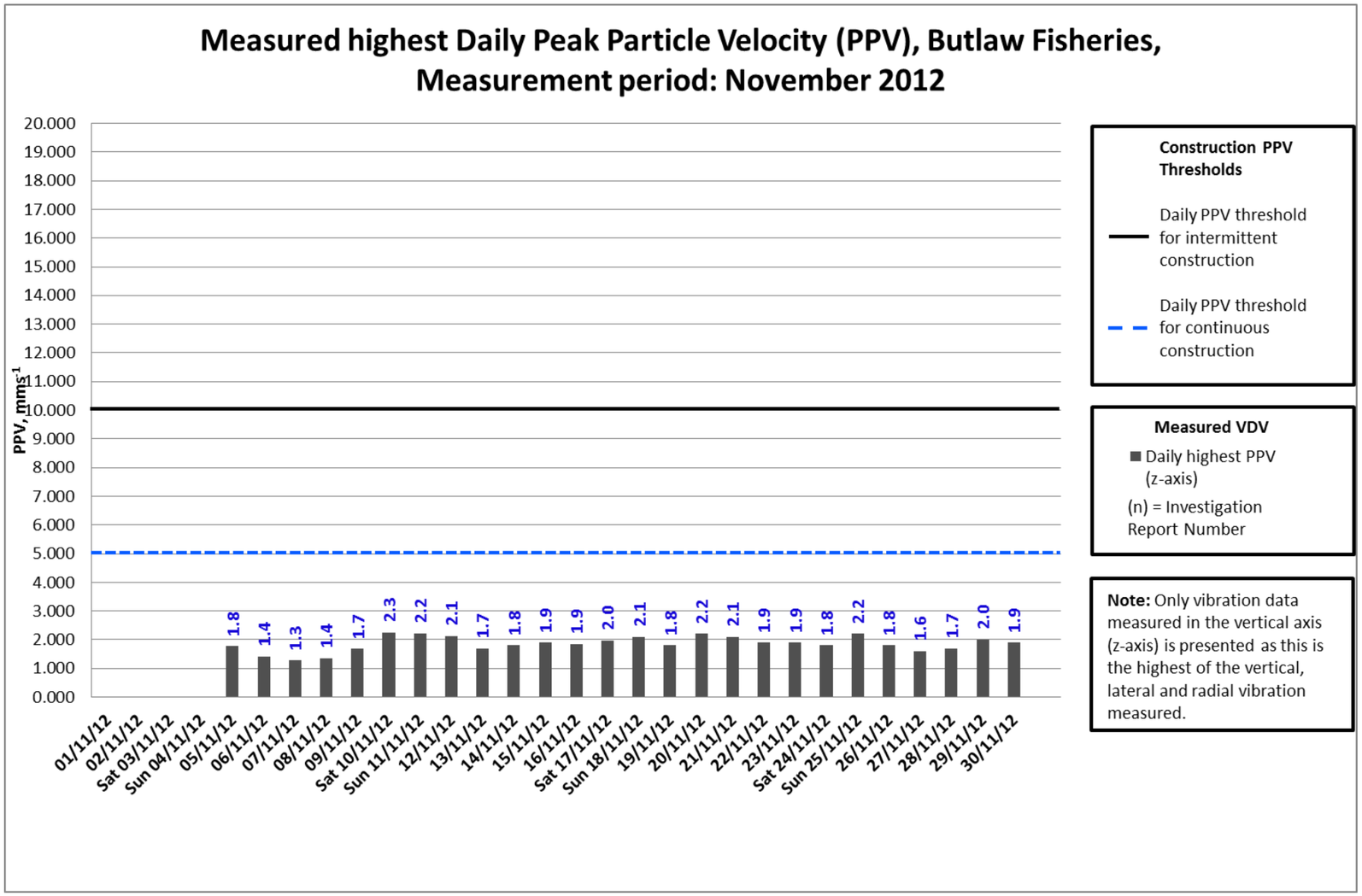
Notes:

- The high VDV levels at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in equal intervals. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these high levels. Other than these spikes the vibration levels are well below the limits. However, following a reboot of the device on 17/12/12 this problem was temporarily resolved.



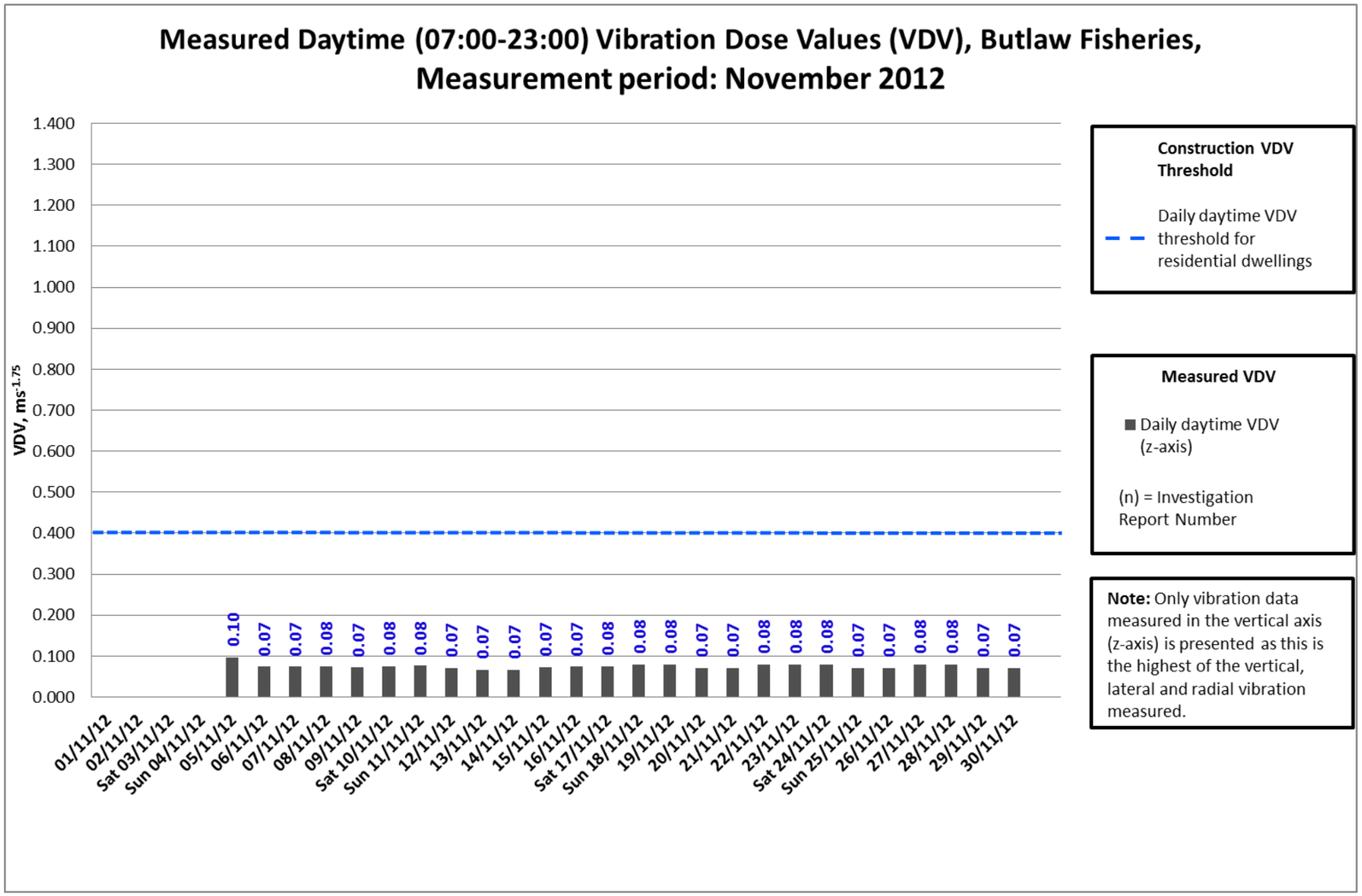
Notes:

- Exceedances have been investigated and are all isolated events due to a problem with the device;
- The exceedances at this VIBROCK have been thoroughly investigated. They are all instantaneous incidents happening in equal intervals. Following communication with the manufacturer, this is apparently due to the Vodafone modem being rebooted every hour which causes these spikes as can be seen in the graph below. Other than these spikes the vibration levels are well below the limits. However, following a reboot of the device on 17/12/12 this problem was temporarily resolved.
- There is no night-time construction works within 1,800m of this receptor.
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards;



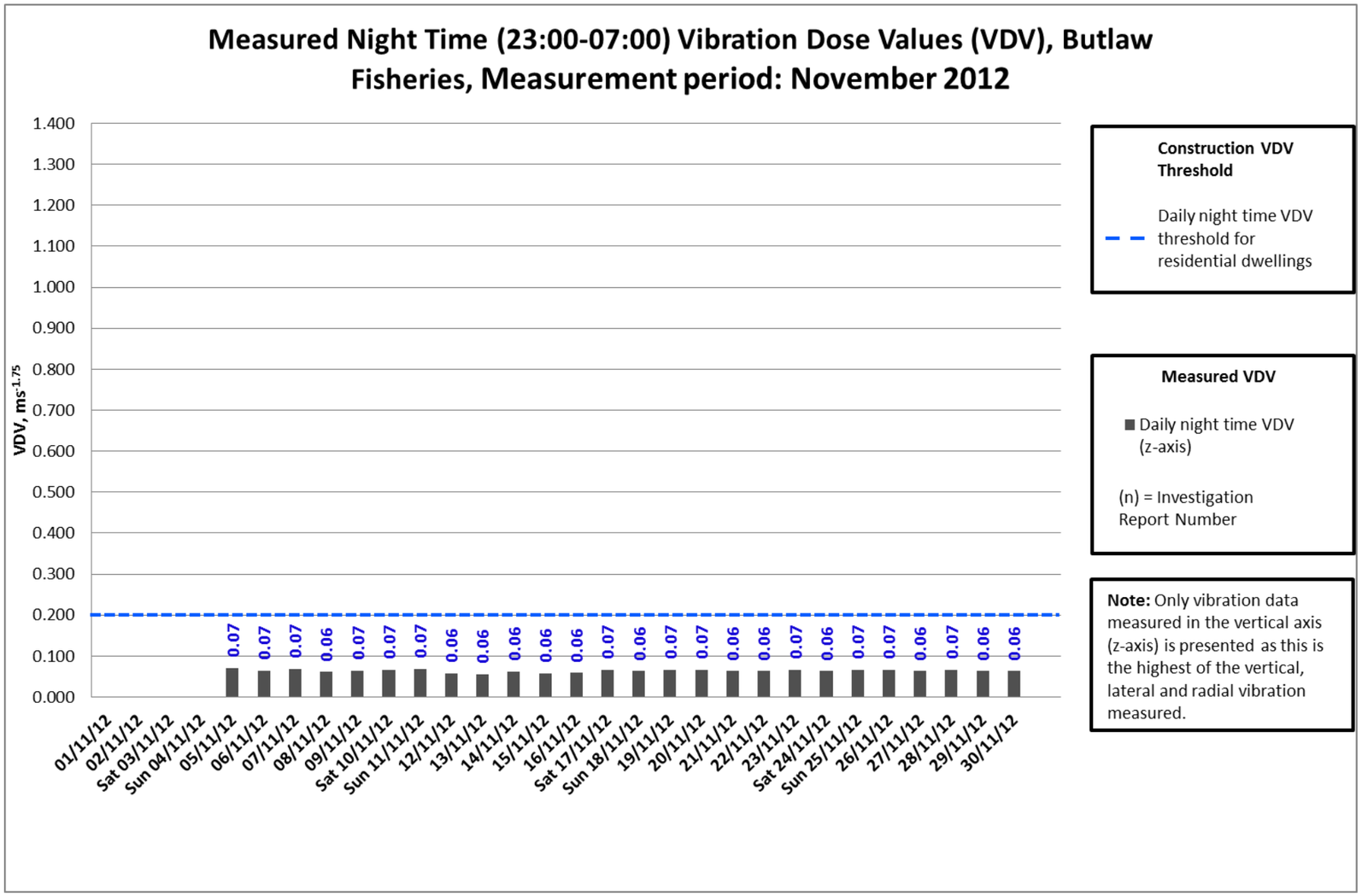
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost.



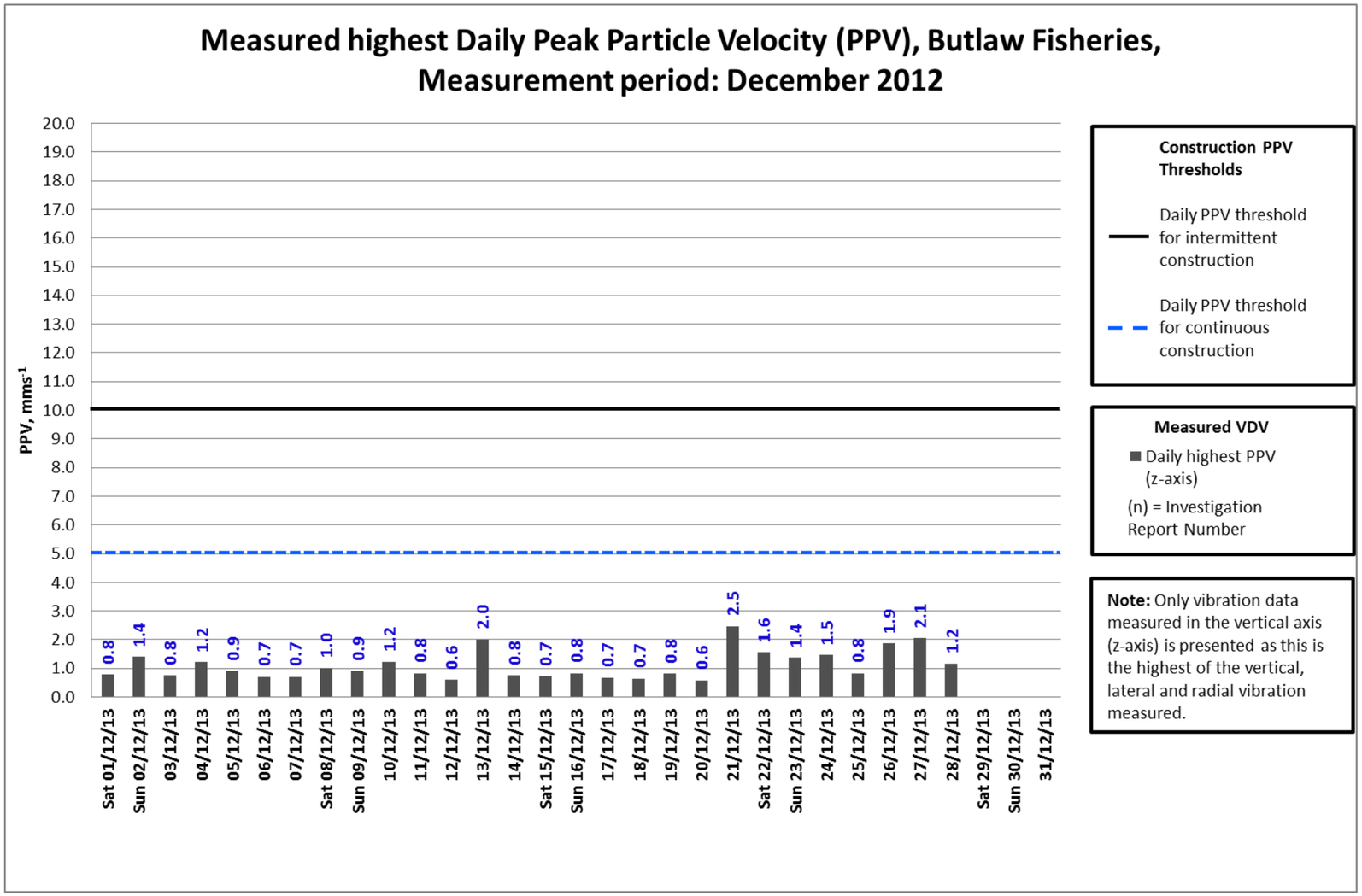
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost.



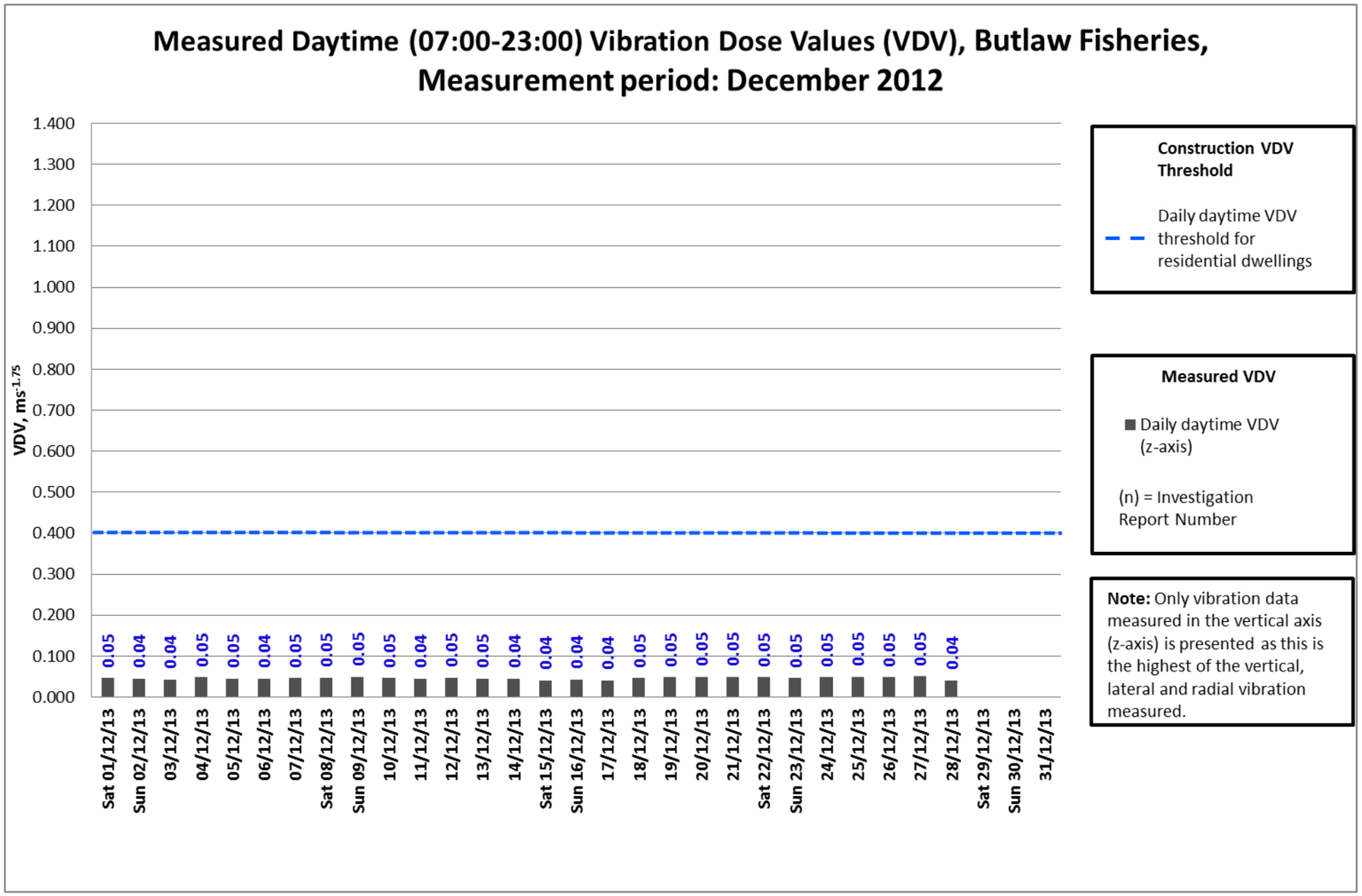
Notes:

- Due to server issues at the site office some data, recorded for November 2012, was lost.



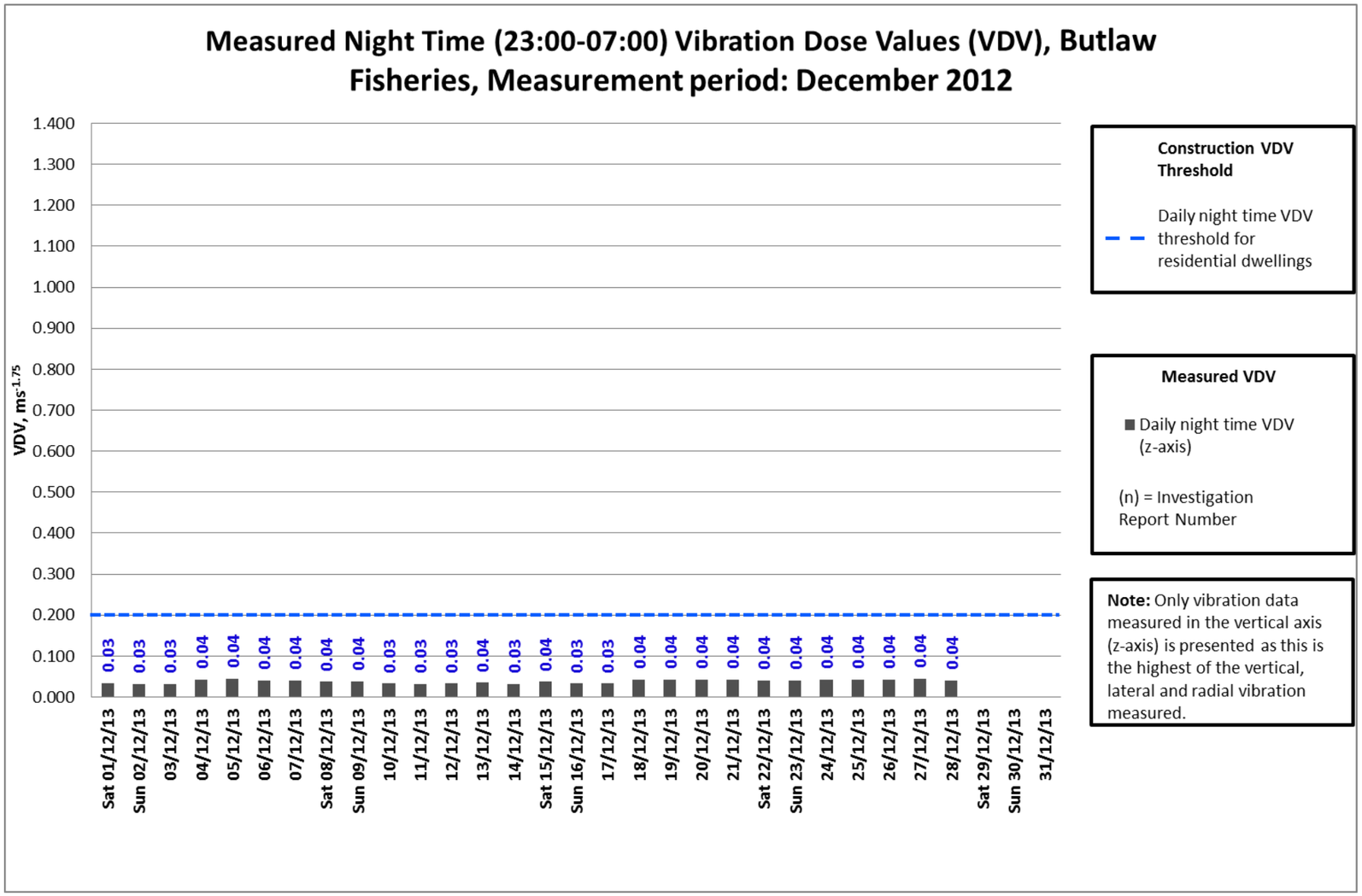
Notes:

- Corrupted daytime data was logged by the device for 29-31/12/12;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



Notes:

- Corrupted daytime data was logged by the device for 29-31/12/12;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.



Notes:

- Corrupted night-time data was logged by the device for 29-31/12/12;
- All the construction works (daytime and night-time) stopped from 22/12/12 onwards.