

WILSON IHRIG
ACOUSTICS, NOISE & VIBRATION

Derek Watry

Principal & President,
Wilson Ihrig



RAIL TRANSIT SEMINAR



August 26-28,
2025

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Katie Krainc

Associate Consultant,
Wilson Ihrig



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Results to Date of Continuous Rail Vibration Monitoring at University of Washington



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Master Implementation Agreement (MIA)



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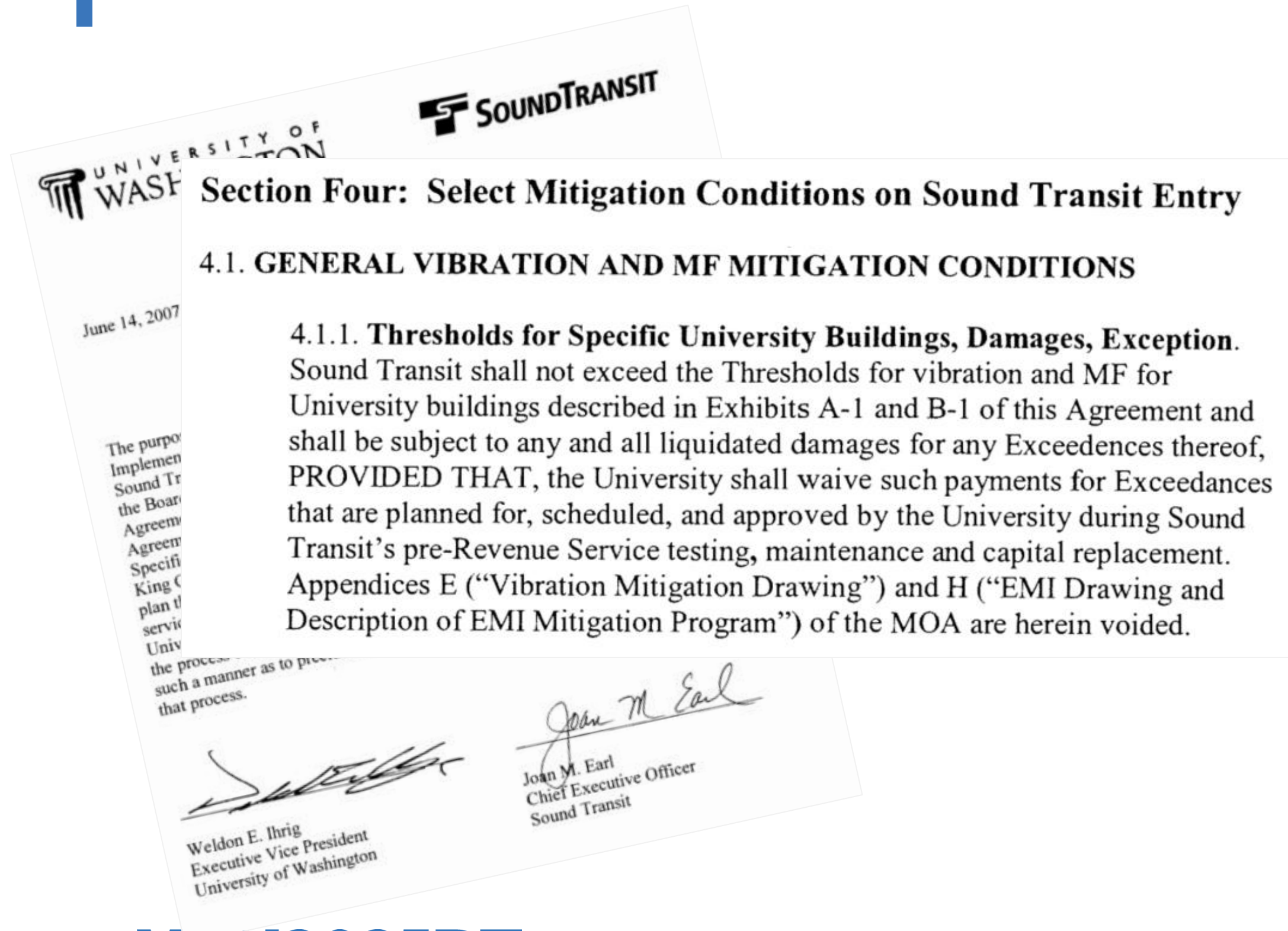
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SOUNDTRANSIT

Section Four: Select Mitigation Conditions

4.1. GENERAL VIBRATION AND MF MITIGATION

4.1.1. Thresholds for Specific University Buildings

Sound Transit shall not exceed the Threshold Vibration Levels for the University buildings described in Exhibit C. The University buildings shall be subject to any and all liquidated damages as set forth in Appendixes E ("Vibration Mitigation Measures") and Appendixes F ("Description of EMI Mitigation Measures").

PROVIDED THAT, the University shall not be liable for damages which are not caused by Sound Transit's pre-Revenue Service test runs.

Weldon E. Ihrig
Executive Vice President
University of Washington

Joan M. Earl
Chief Executive Officer
Sound Transit

Exhibit C
Preferred Alternative
Alignment Map

University of Washington Buildings

- A. Bagley Hall
- B. Benson Hall
- C. Bioengineering/Genomics
- D. Burke Museum
- E. Center on Human Development and Disability (CHDD)
- F. Chemistry
- G. Health Sciences Imaging Center
- H. Electrical Engineering/Computer Science
- I. Fisheries Center (CMBL)
- J. Fisheries Sciences
- K. Fisheries Teaching and Research Center
- L. Fluke Hall
- M. Henderson Hall
- N. Johnson Hall
- O. Marine Sciences (MMBL)
- P. Marine Studies
- Q. Mechanical Engineering and Annex
- R. Moore Hall
- S. Oceanography Research Building
- T. Ocean Sciences
- U. Physics/Astronomy
- V. Roberts Hall
- W. Surgery Pavilion
- X. UW Medical Center-Cyclotron
- Y. Wilcox Hall
- Z. Winkenwerder Hall

Stations

Crossover

Preferred Alternative



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4.1.4. Monitoring Program. Prior to construction of the Light Rail Transit System, the Parties shall jointly develop a detailed vibration and MF monitoring program to identify, measure and report on if and when a Threshold Exceedance occurs that is directly attributable to the Light Rail Transit System. The details of the monitoring program shall be memorialized in an Operating Agreement, PROVIDED THAT said Operating Agreement shall require that the monitoring program: be developed at Sound Transit expense; include early warning vibration detectors north and south of University Property; provide data that is auditable by the Parties in real time; is highly reliable; is acceptable to the University; is installed prior to Revenue Service for each segment of newly constructed Light Rail Transit System on University Properties; and is capable of identifying long term trends of increased average and peak vibration and MF levels over time attributable to the general degradation of the Light Rail Transit System.

Weldon E. Ihrig
Executive Vice President
University of Washington

Sound Transit

Crossover

Health Sciences Imaging Center
H. Electrical Engineering/Computer Science
J. Fisheries Center (CMBL)
K. Fisheries Sciences
L. Fluke Hall
M. Henderson Hall
N. Mechanical Engineering and
R. Annex
S. Moore Hall
T. Oceanography Research Building
U. Physics/Astronomy
V. Roberts Hall
W. Surgery Pavilion
X. UW Medical Center-Cyclotron
Y. Wilcox Hall
Z. Winkenwerder Hall

Preferred Alternative

Exhibit C
Preferred Alternative
Alignment Map

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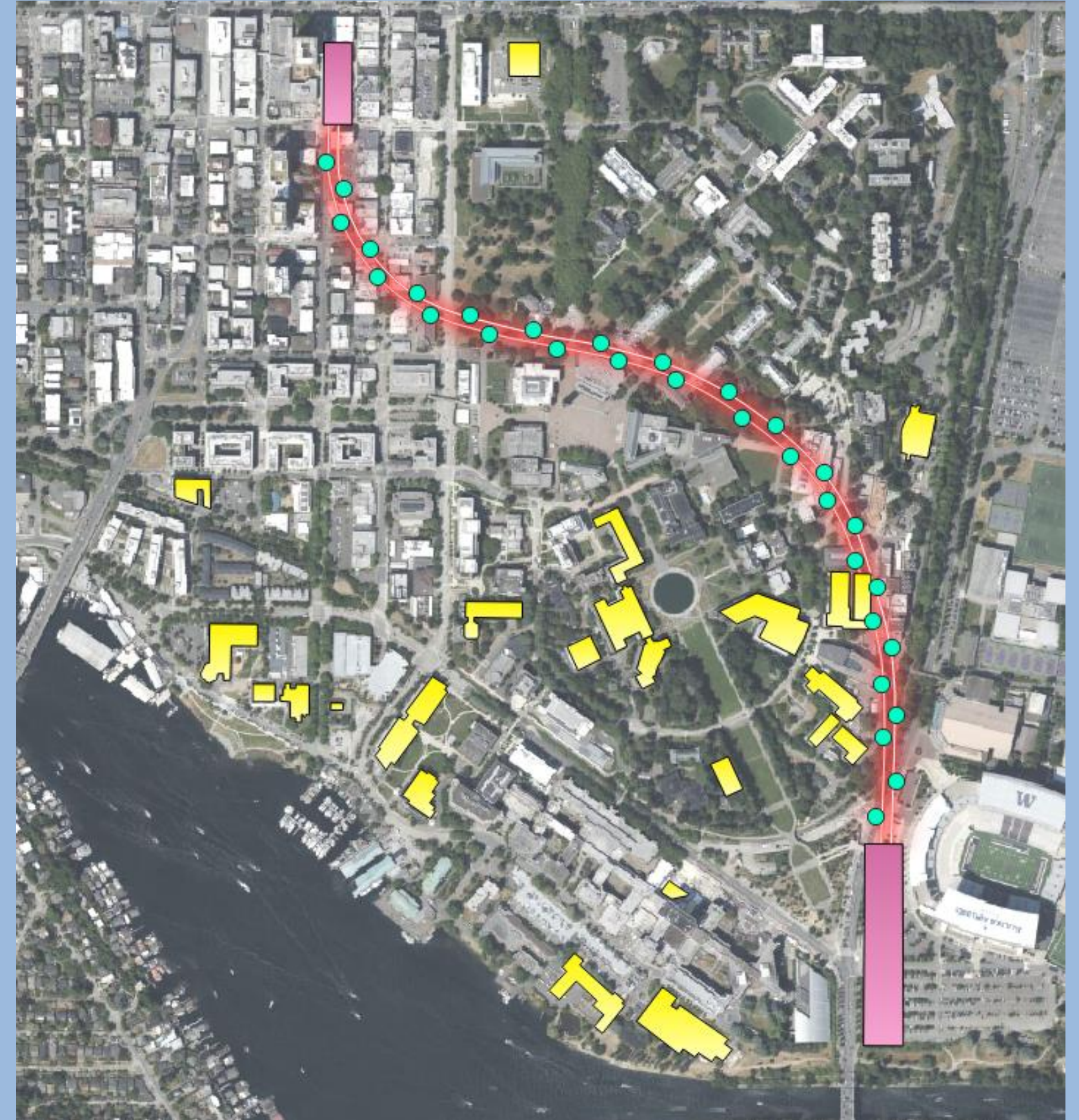


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Sensitive University Buildings

- University of Washington Station to U District Station
- 24 sensitive buildings
- 31 monitors



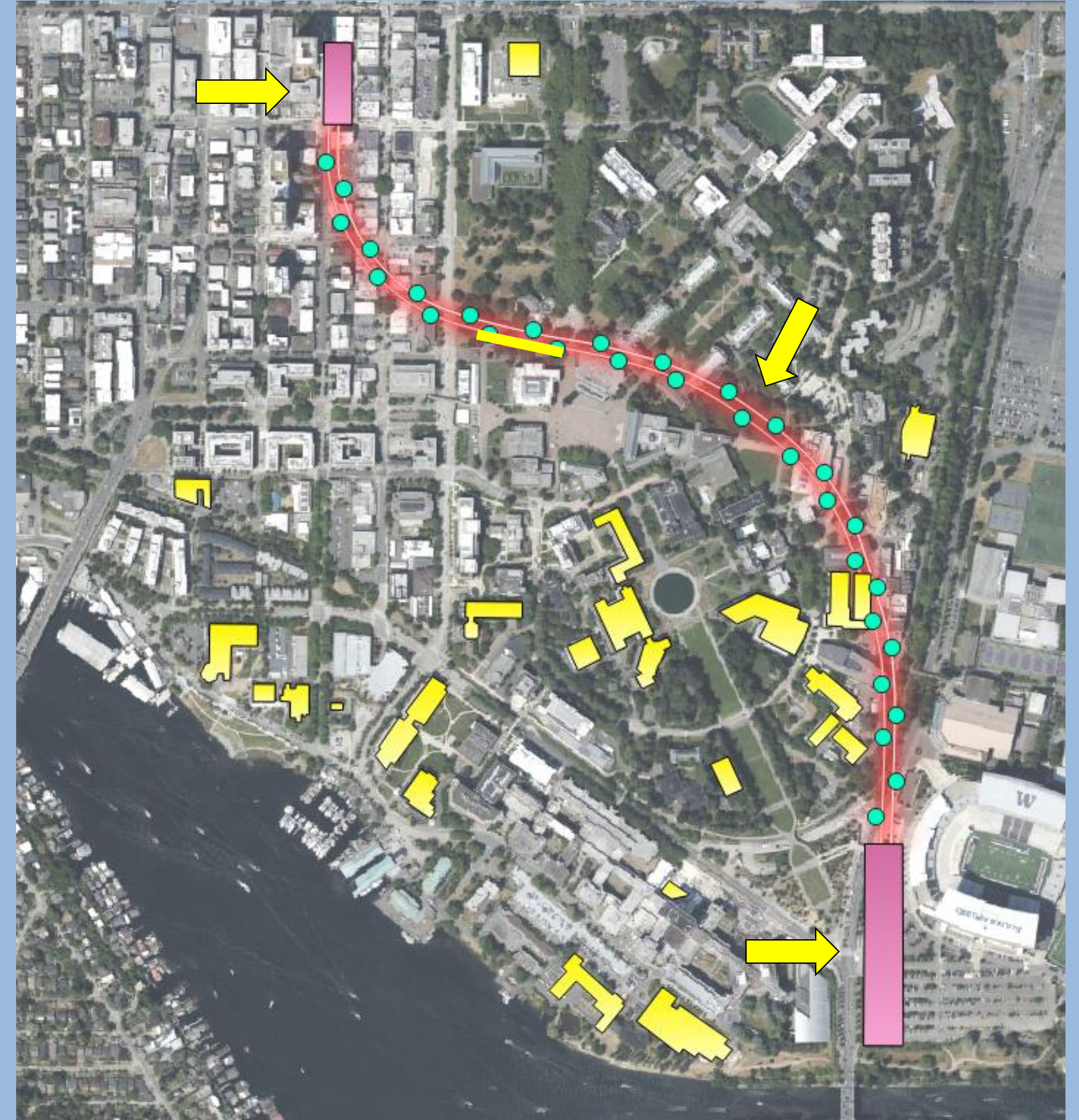


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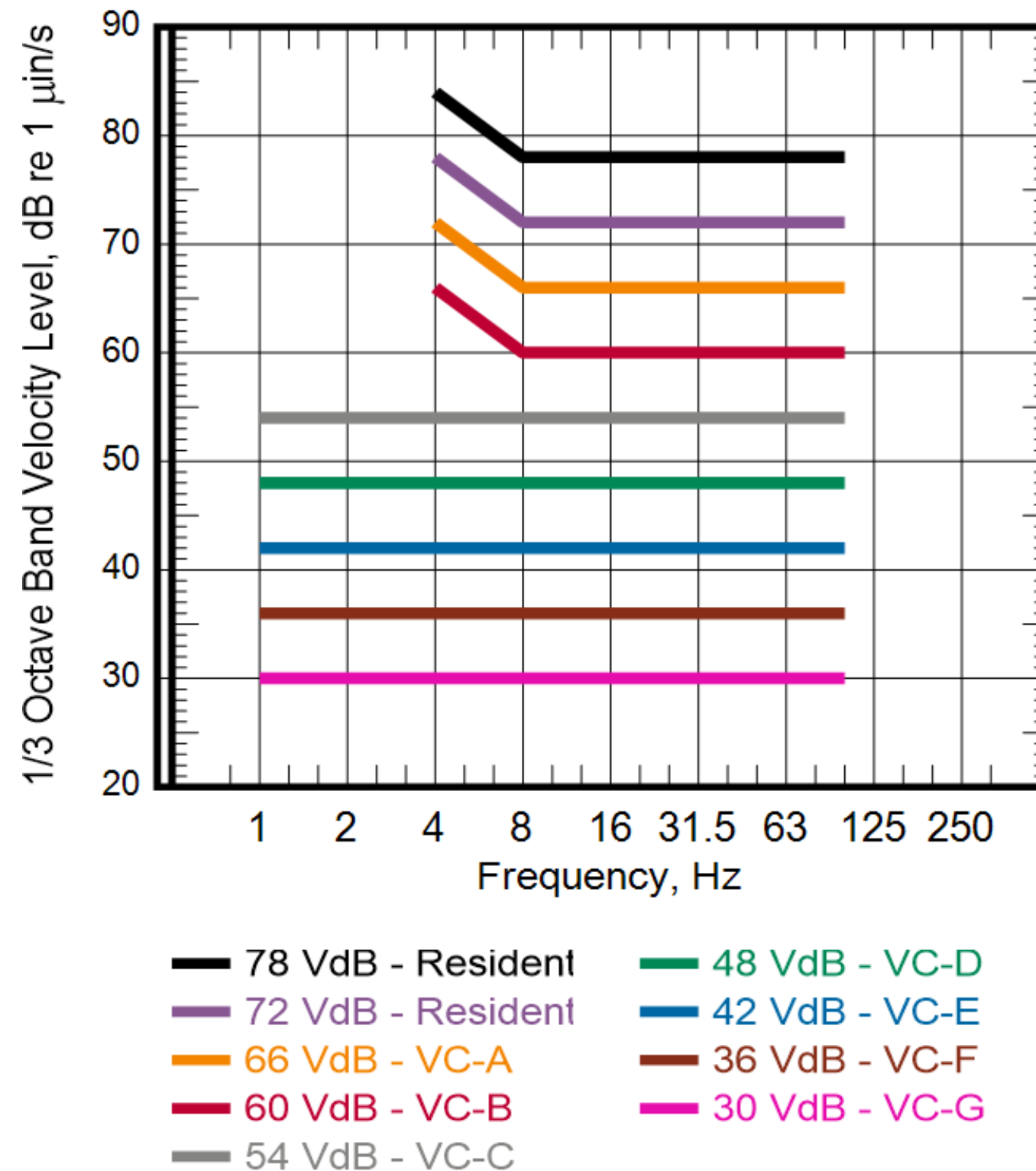
Sensitive University Buildings

- University of Washington Station to U District Station
- 24 sensitive buildings
- 31 monitors





Range of Vibration Criteria



VC-F & VC-G

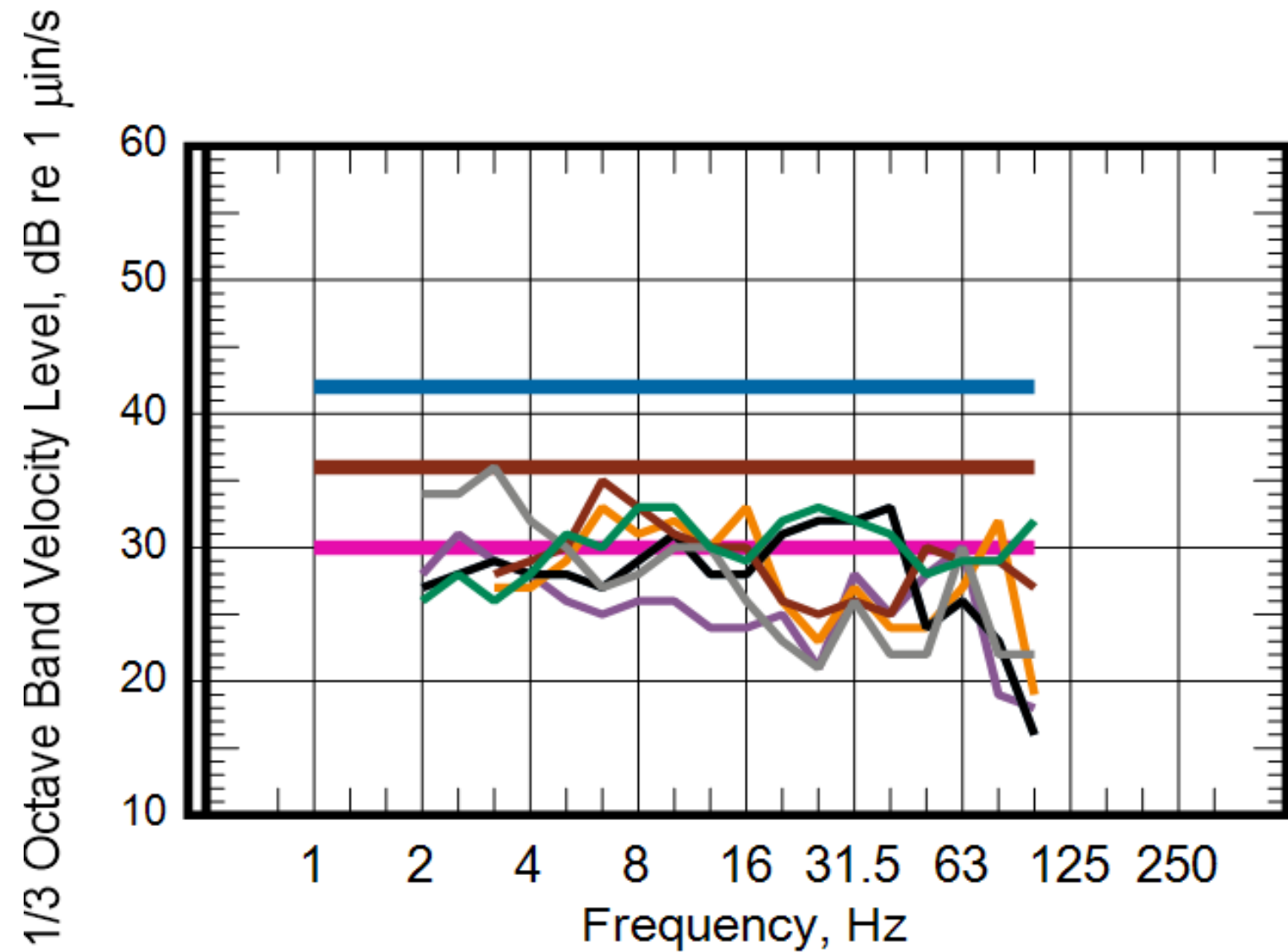
Extremely quiet research spaces; not recommended as a design criterion, only for evaluations





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MIA Thresholds



- | | |
|-----------------|---------------------|
| — 42 VdB - VC-E | — Bioengineering |
| — 36 VdB - VC-F | — Ocean. Res. Bldg. |
| — 30 VdB - VC-G | — Roberts Hall |
| — New Chemistry | — Physics/Astronomy |
| — EE/CS | — Winkenwerder Hall |

Most restrictive

Buildings with
lowest thresholds

Lower than VC-G

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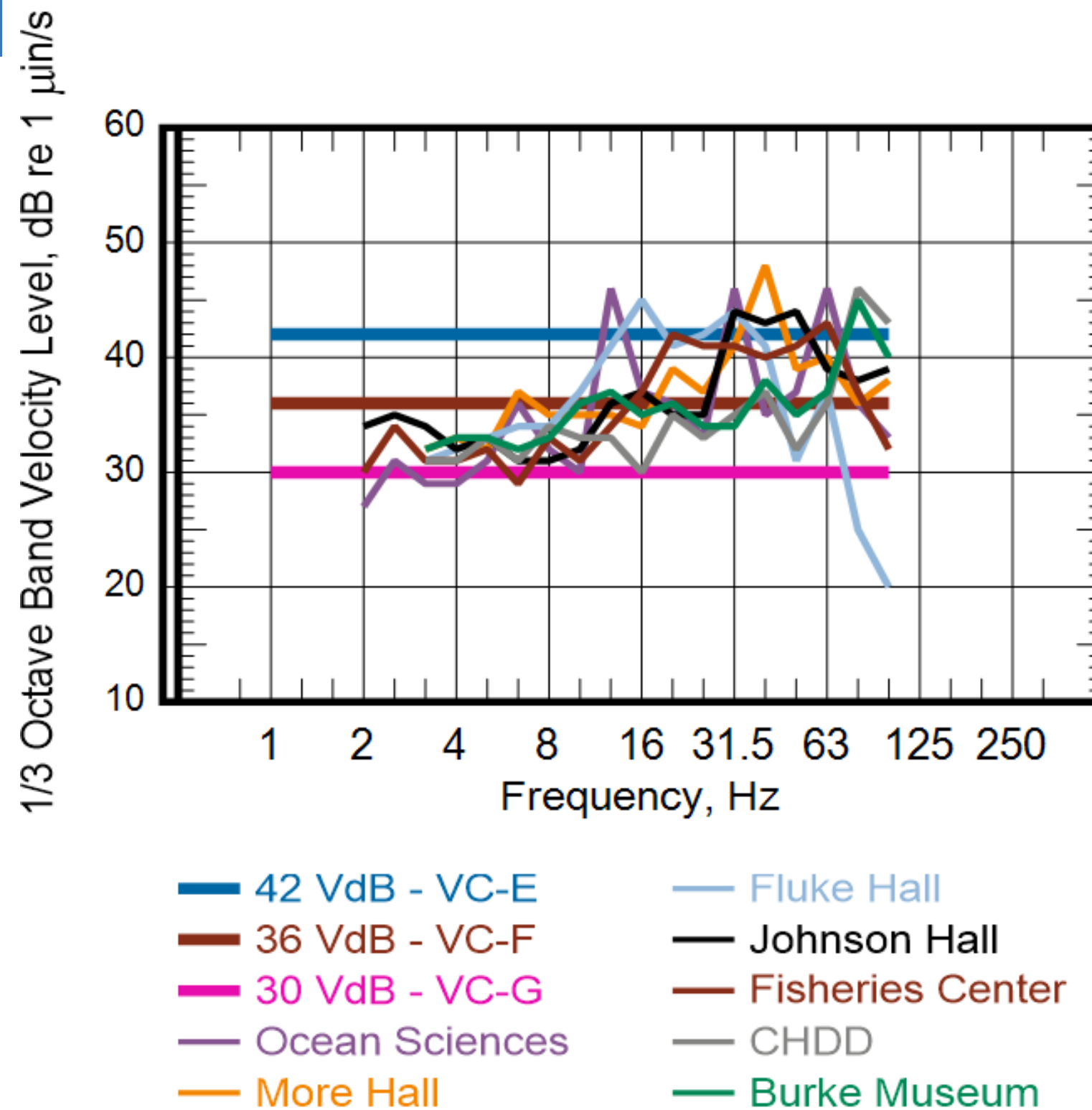
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MIA Thresholds



Least restrictive

Buildings with
highest
thresholds

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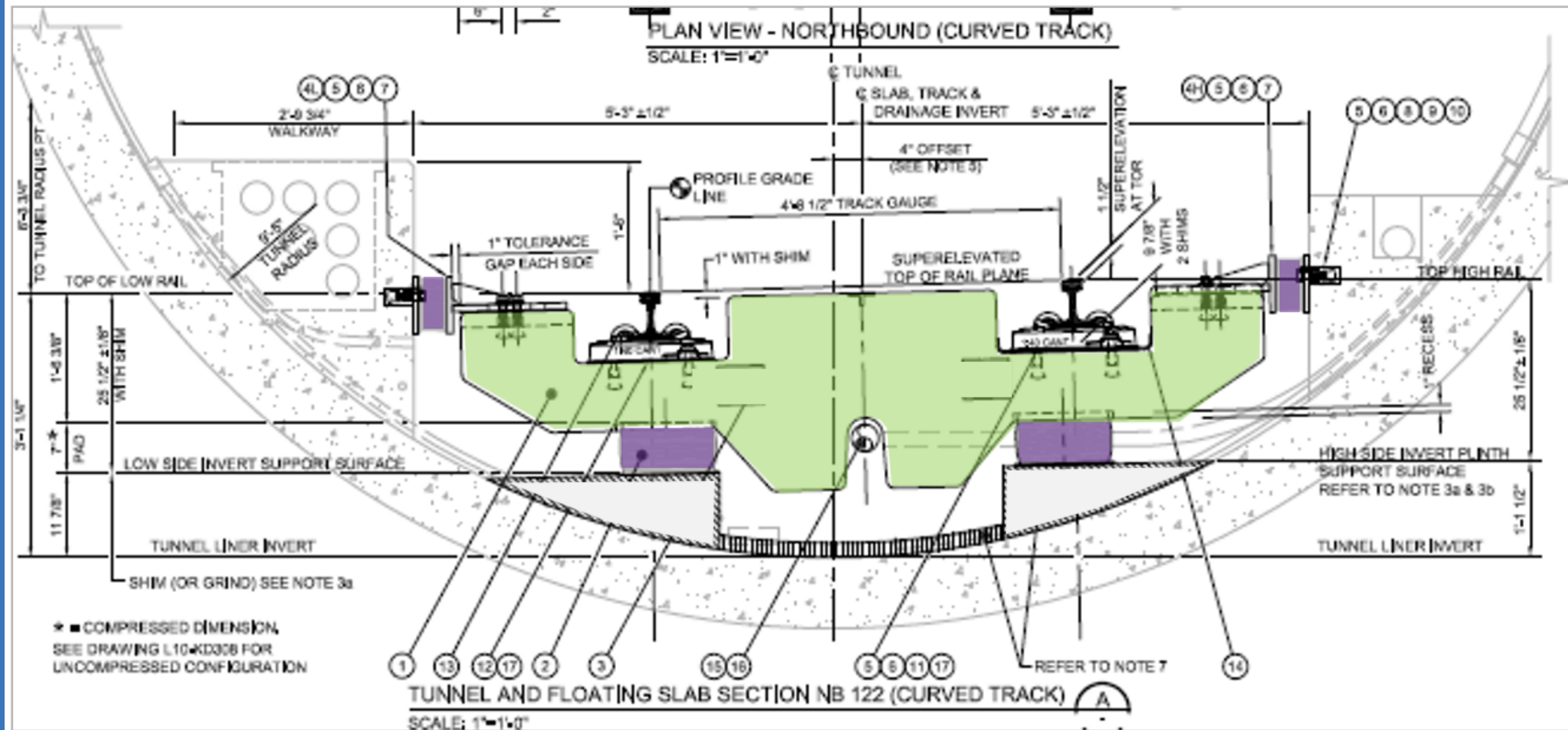
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5 Hz Floating Slab



Additional factors

Ultra-straight rail
Grinding program
Vehicle FDL
specifications



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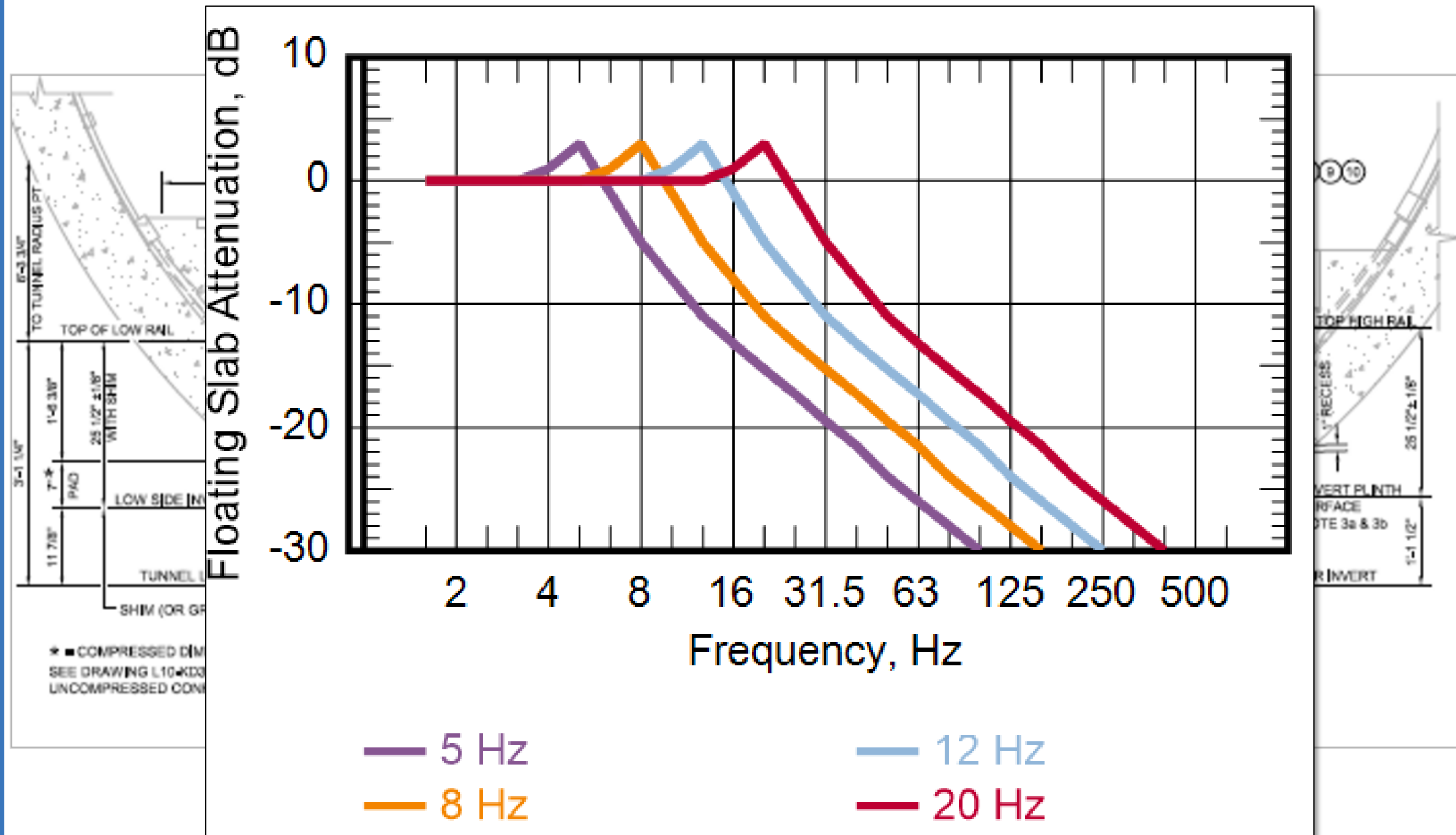
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5 Hz Floating Slab



Additional factors

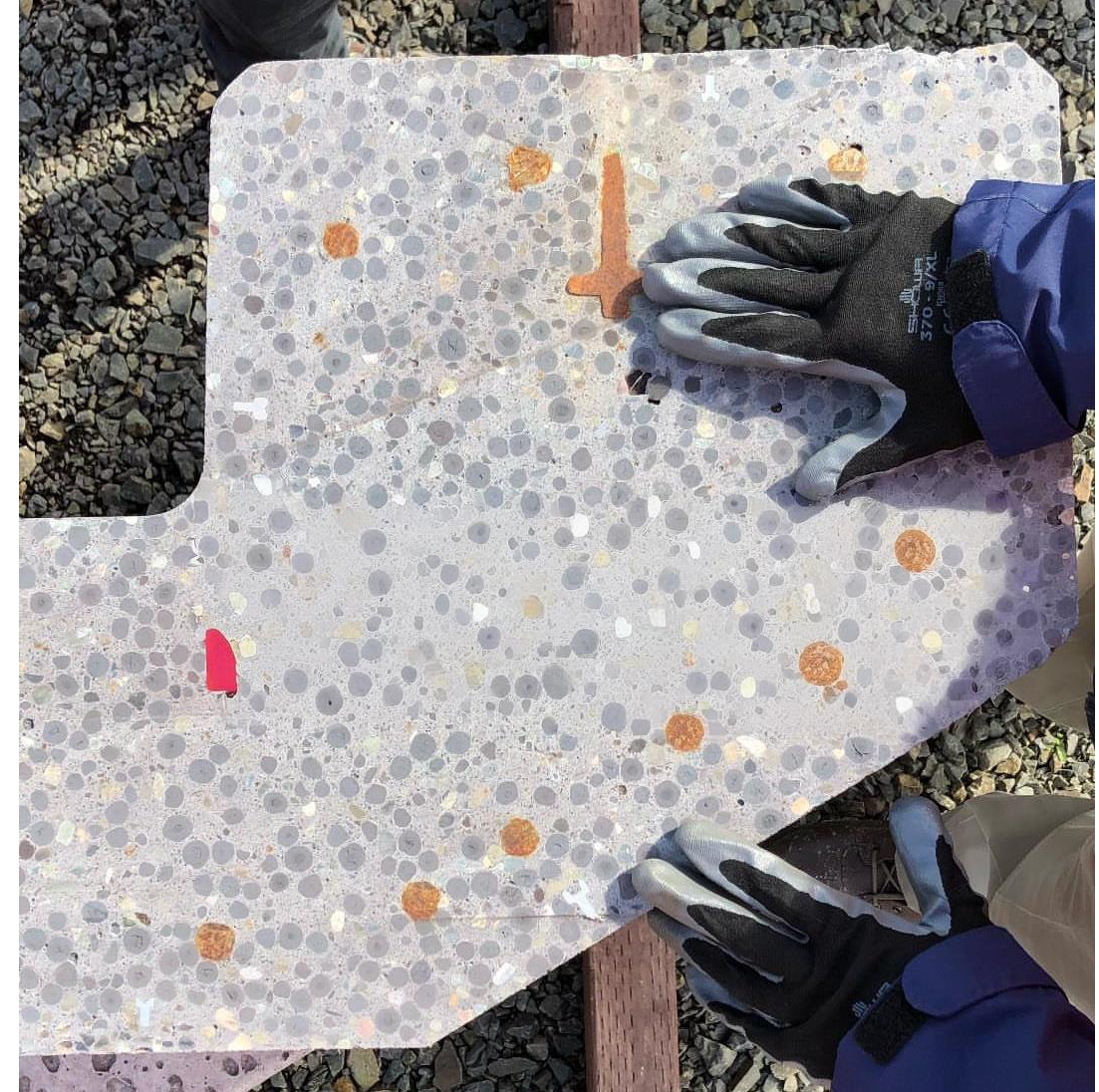
- Ultra-straight rail
- Grinding program
- Vehicle FDL specifications





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5 Hz Floating Slab



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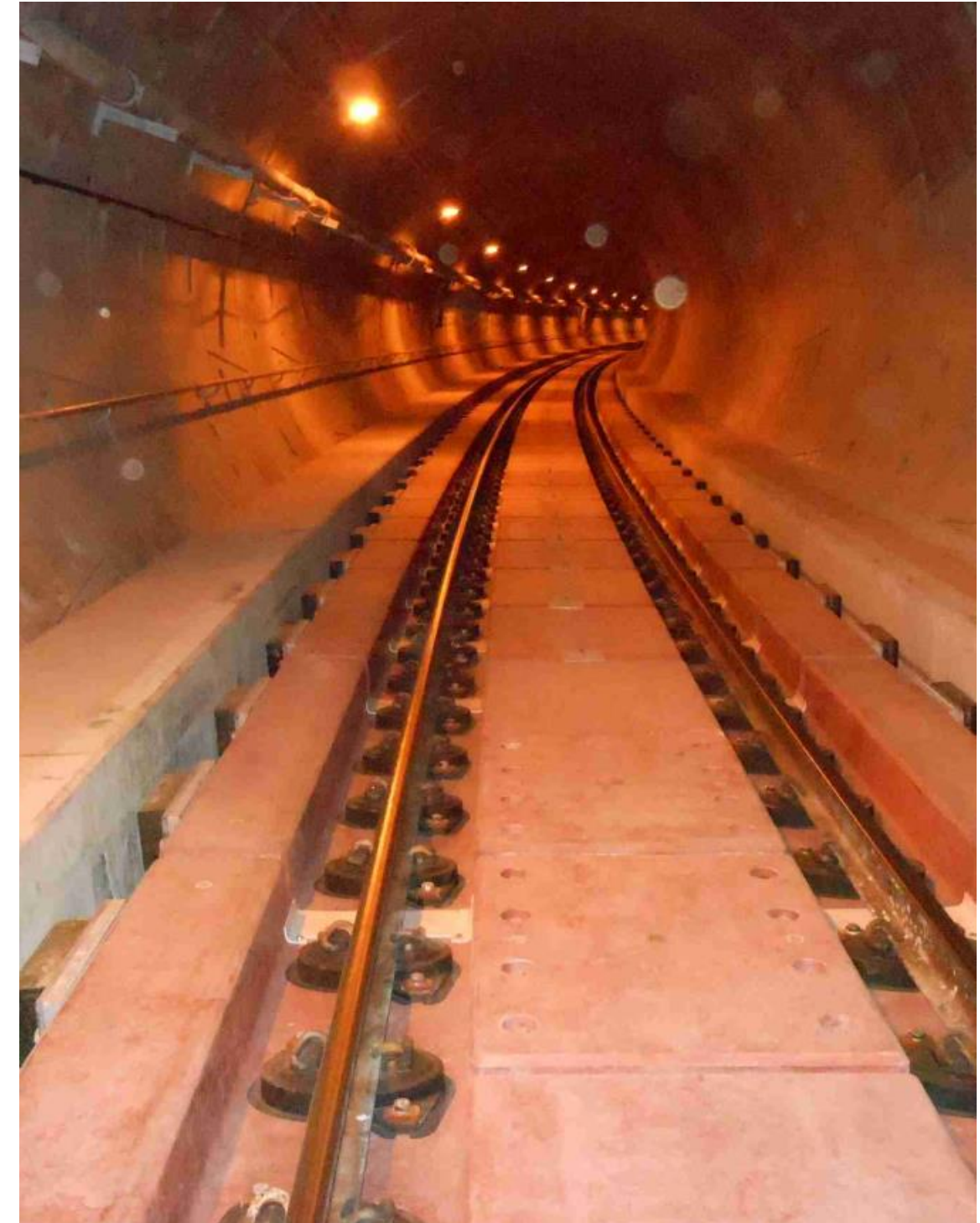
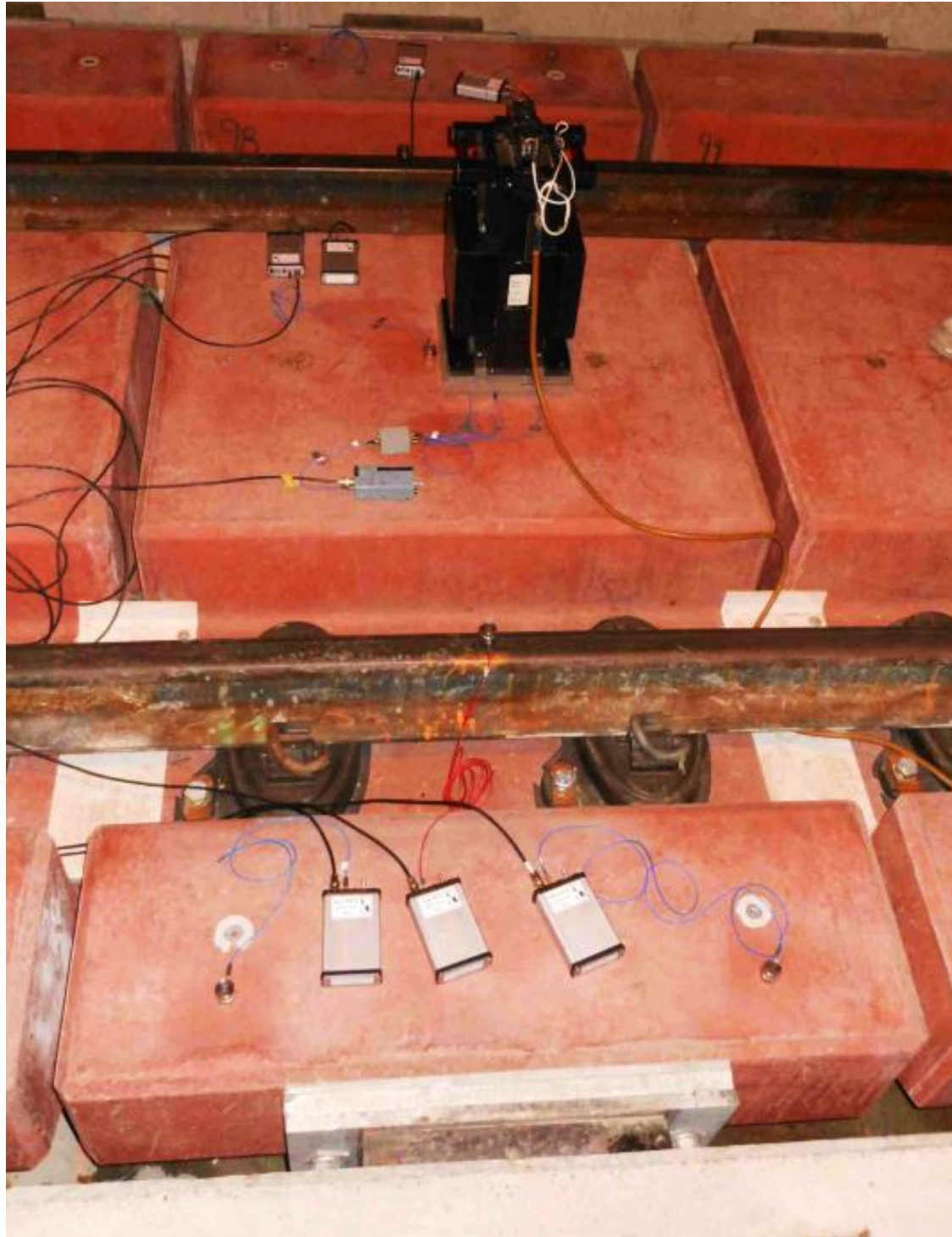
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5 Hz Floating Slab



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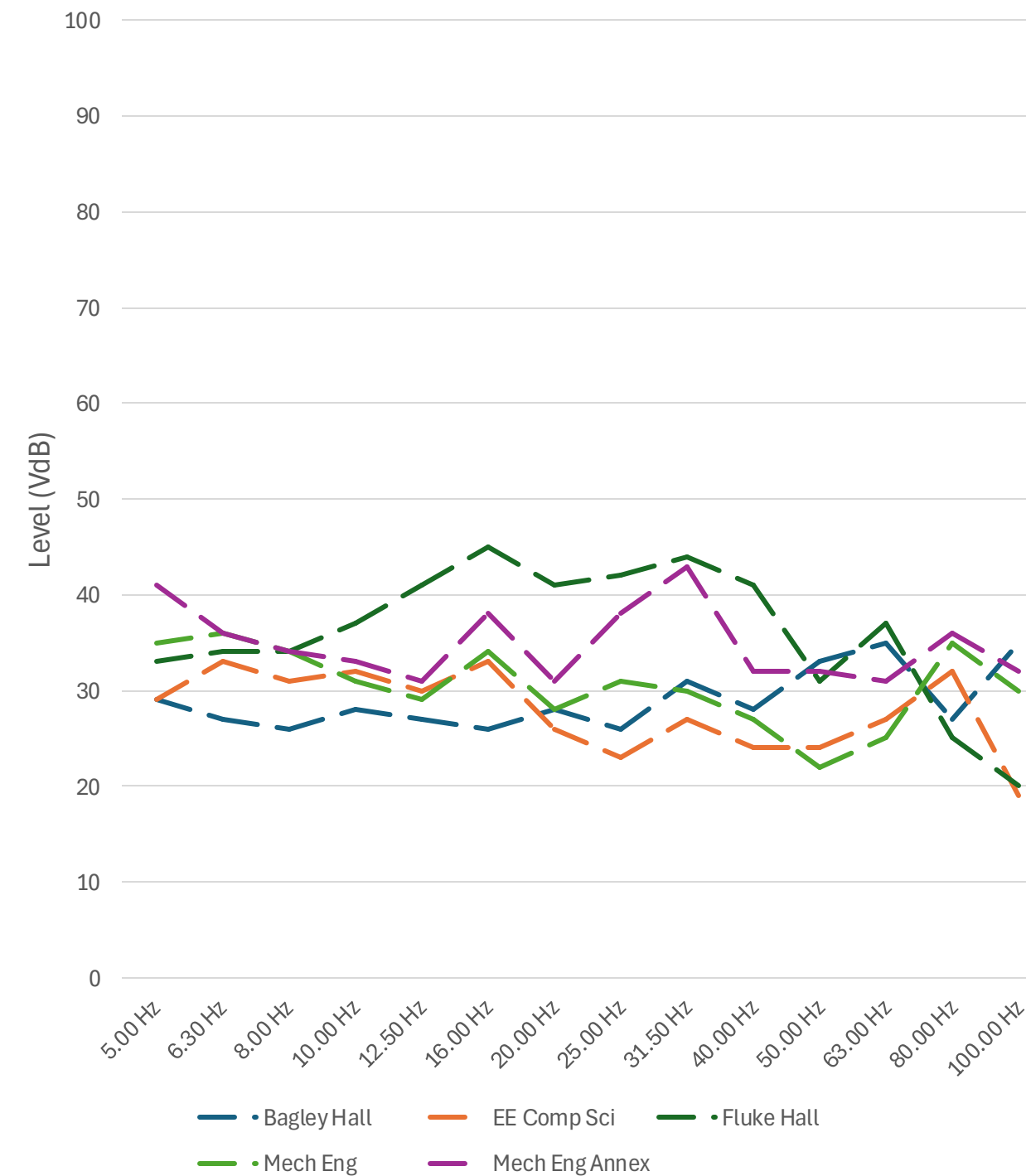




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Vibration Adjustment Estimate (VAE)

- Criteria at buildings



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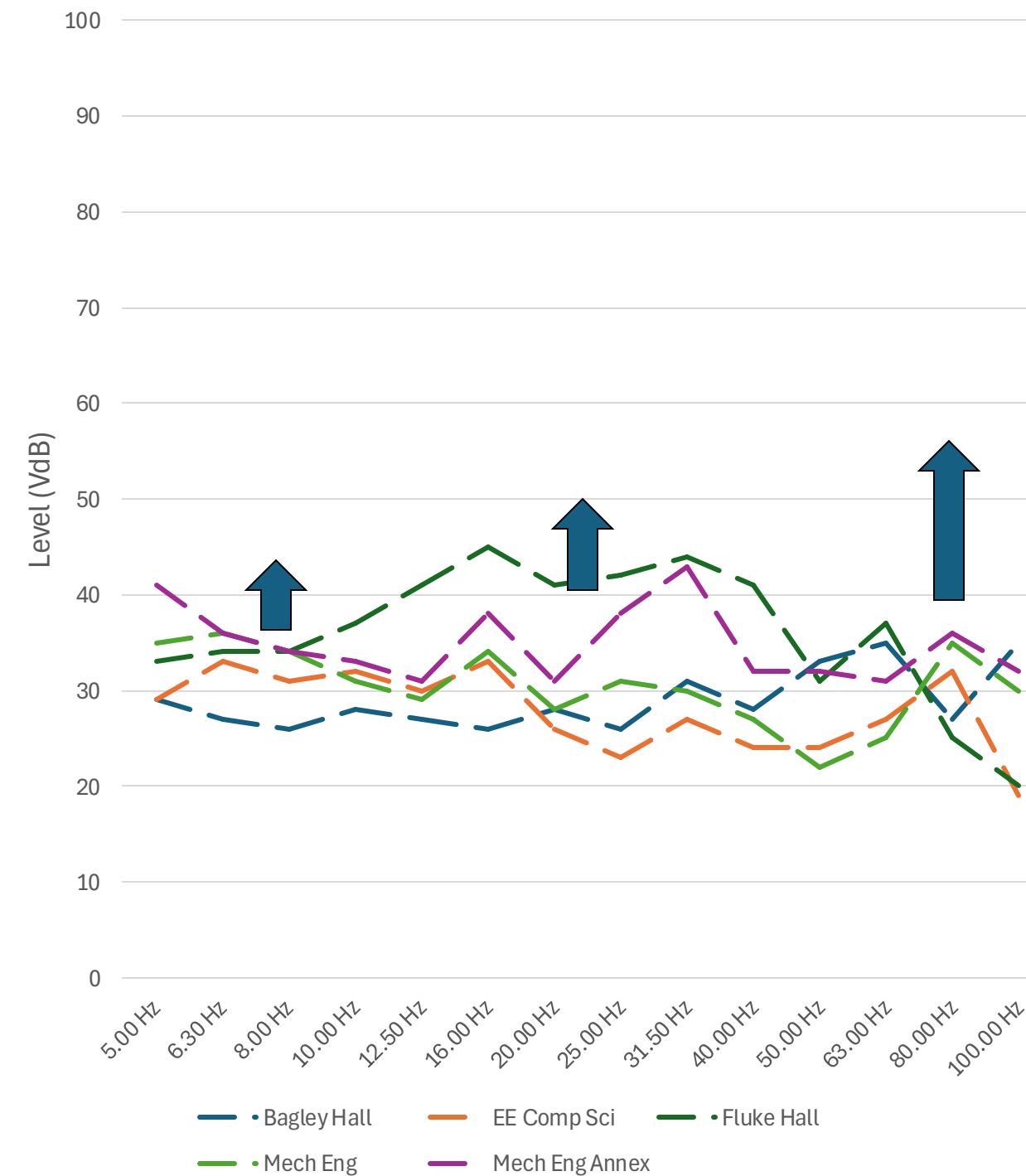
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Vibration Adjustment Estimate (VAE)

- Criteria at buildings
- Apply VAE



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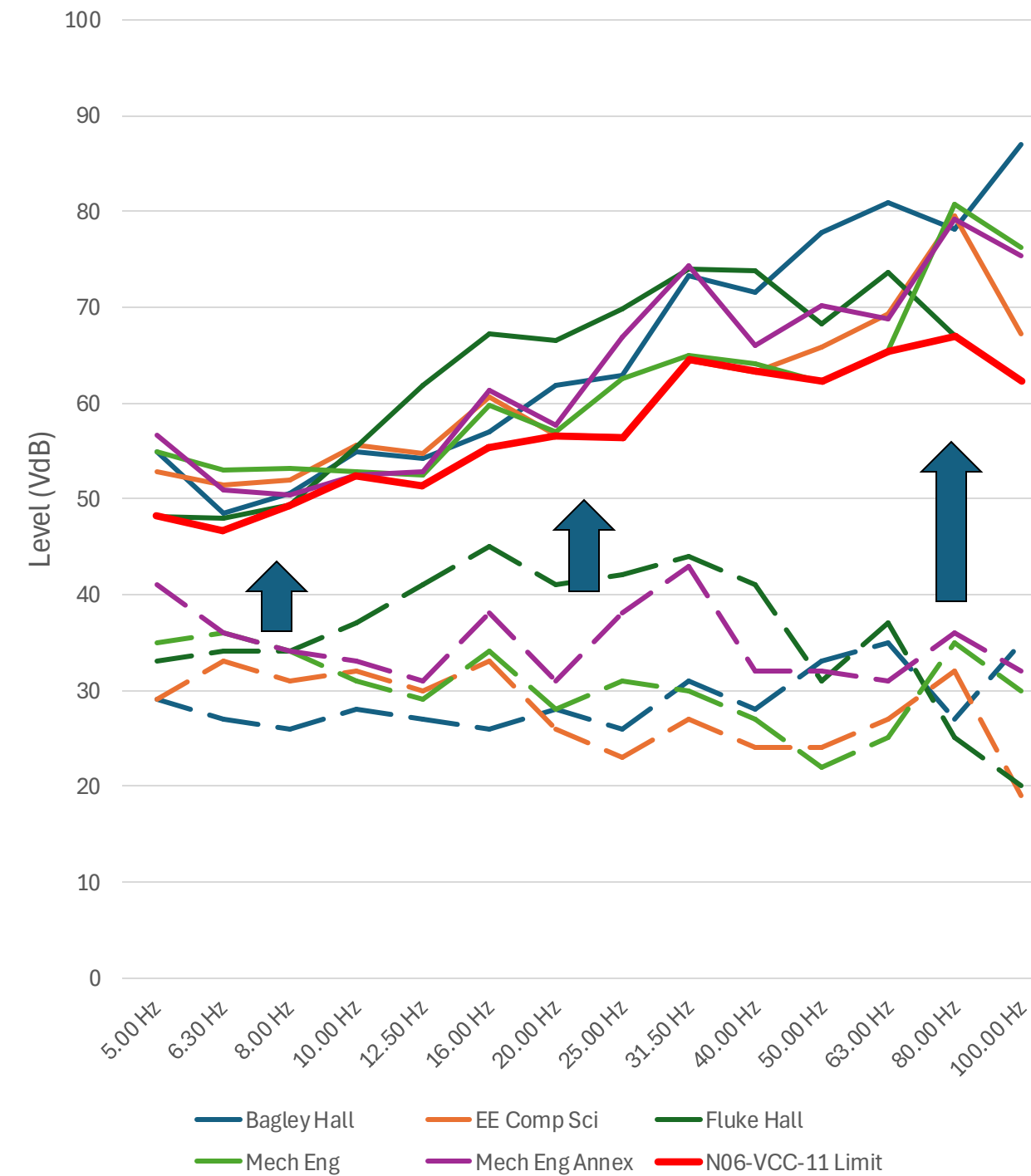
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Vibration Adjustment Estimate (VAE)

- Criteria at buildings
- Apply VAE
- Criteria at monitor



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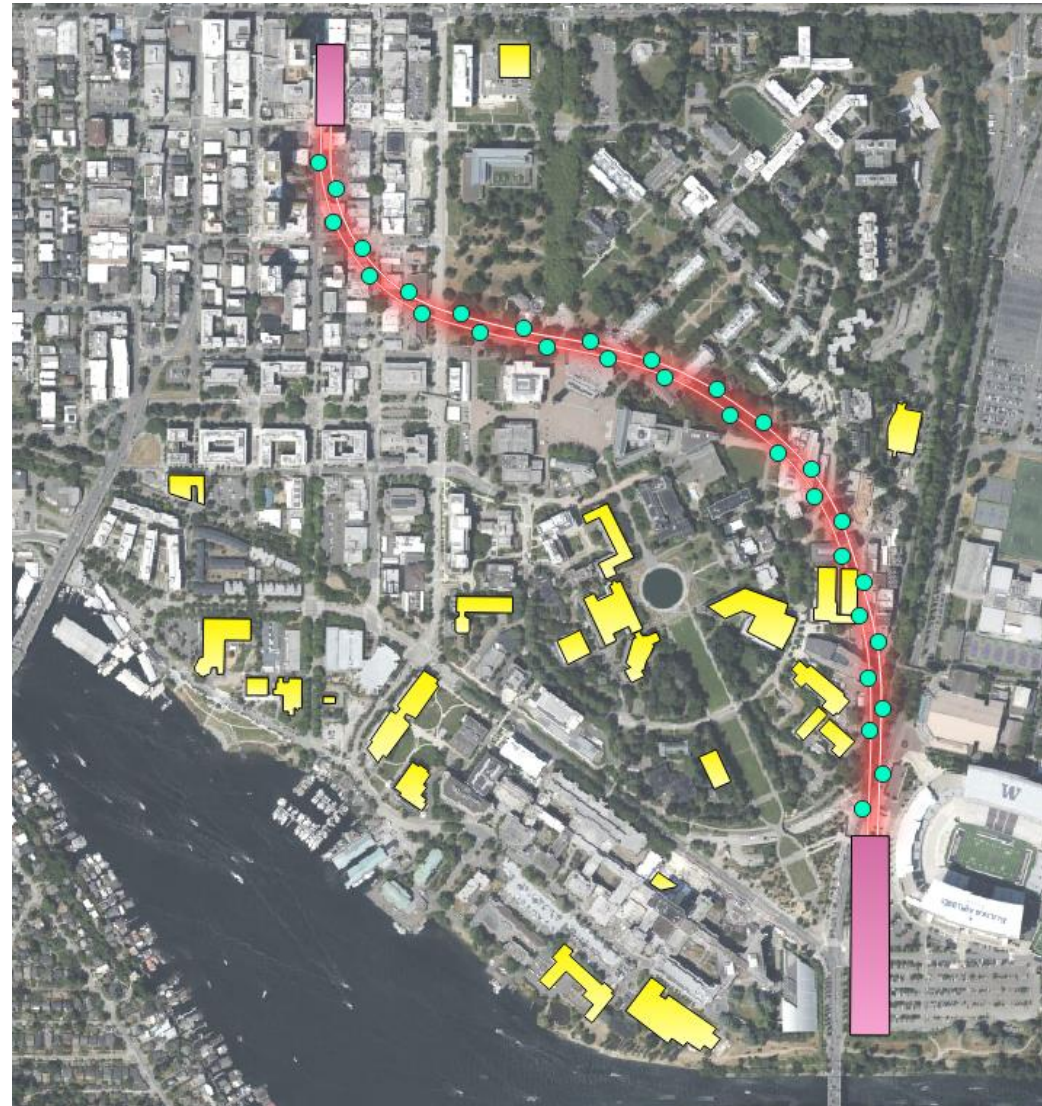
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31 monitor locations with redundant pairs



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Monitoring system

- 31 monitor locations
- 2 Hz – 100 Hz in 1/3-octave bands
- VAE adjustment
- Continuous monitoring
- Warning & exceedance alarms

- Wheel flat detector



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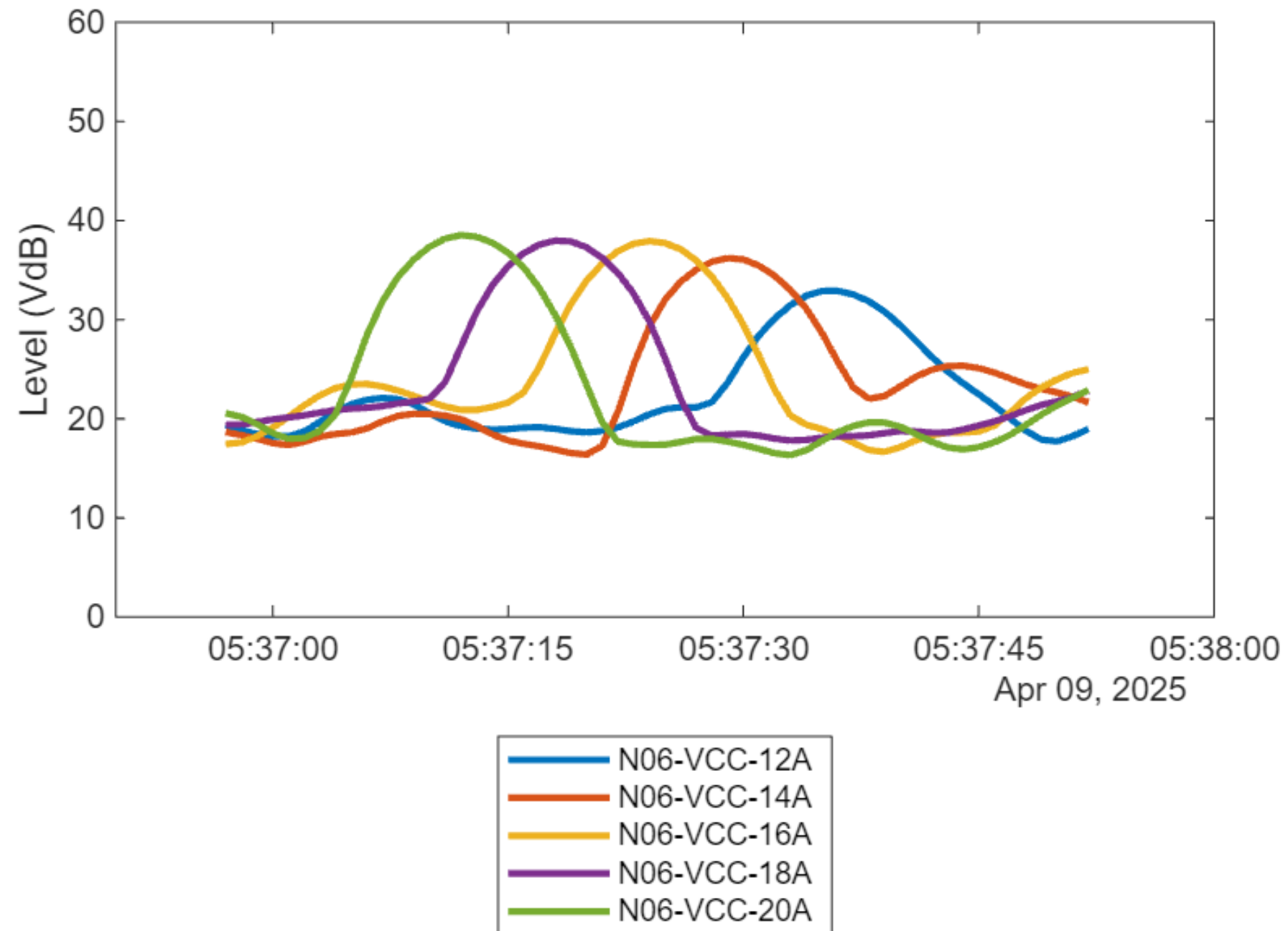
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Single passby (5 Hz)



Monitors 12-20

Southbound,
track on floating
slab



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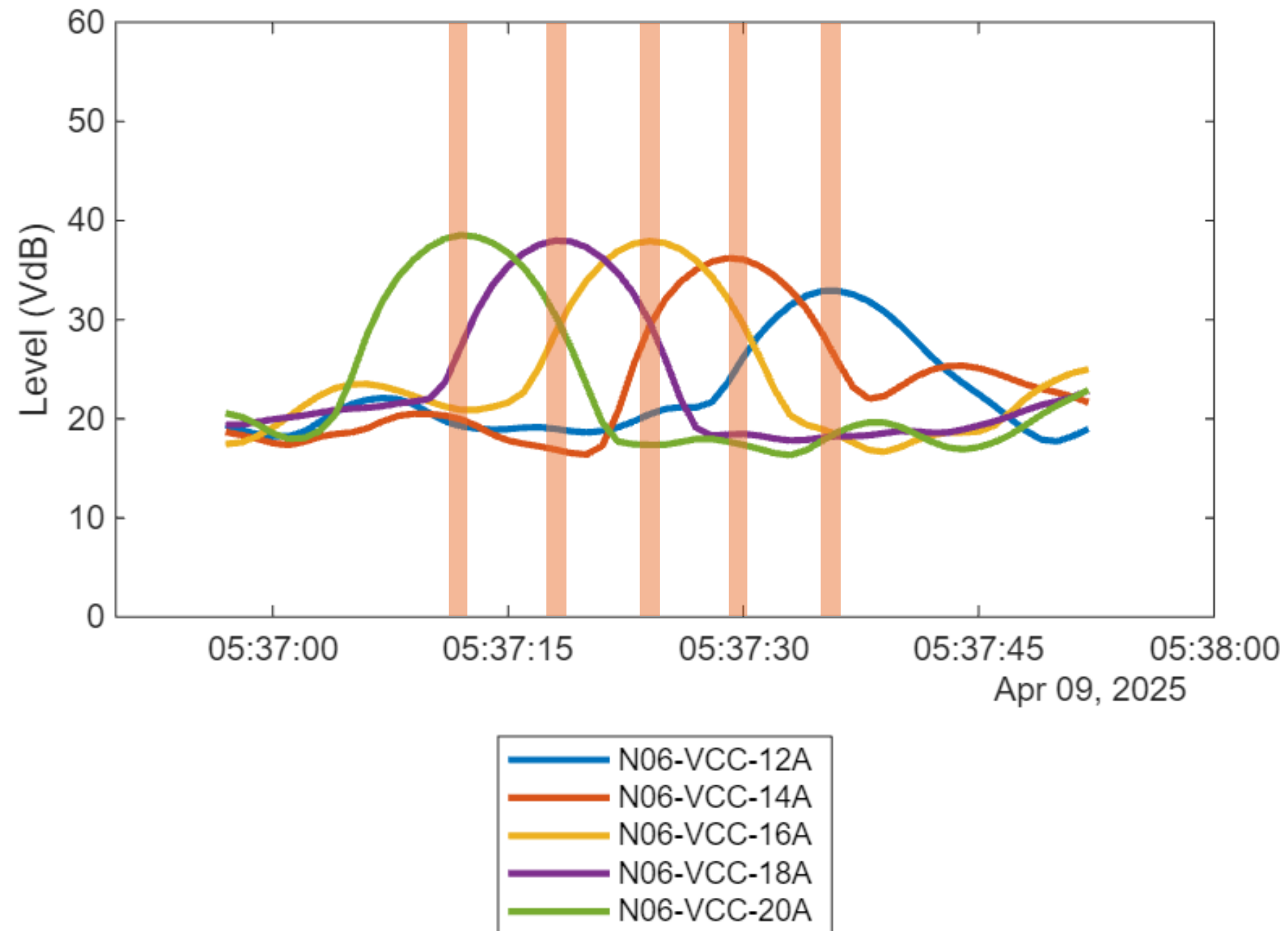
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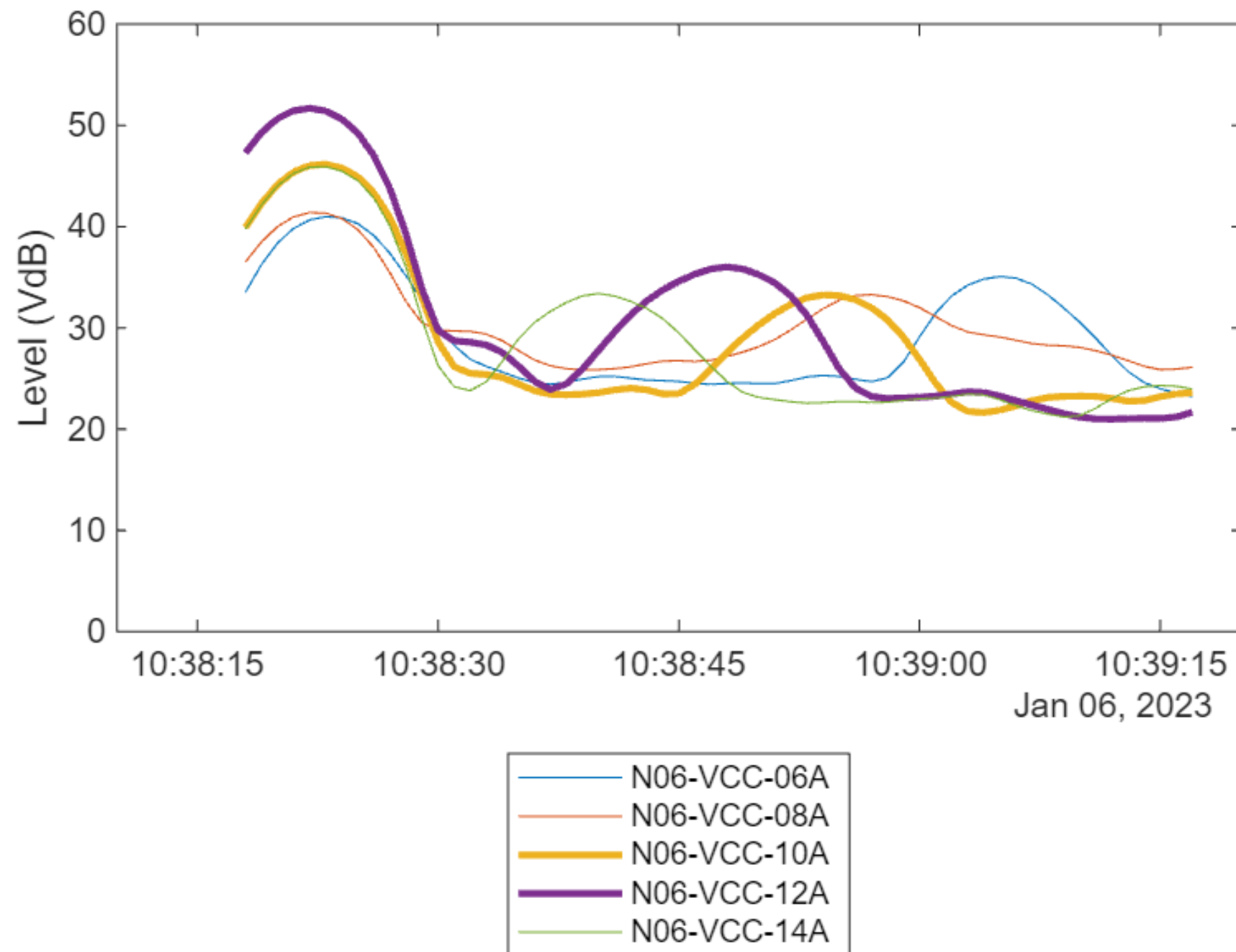
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Non-train exceedances



Monitors 6-14, 6.3 Hz

Southbound,
track on floating
slab

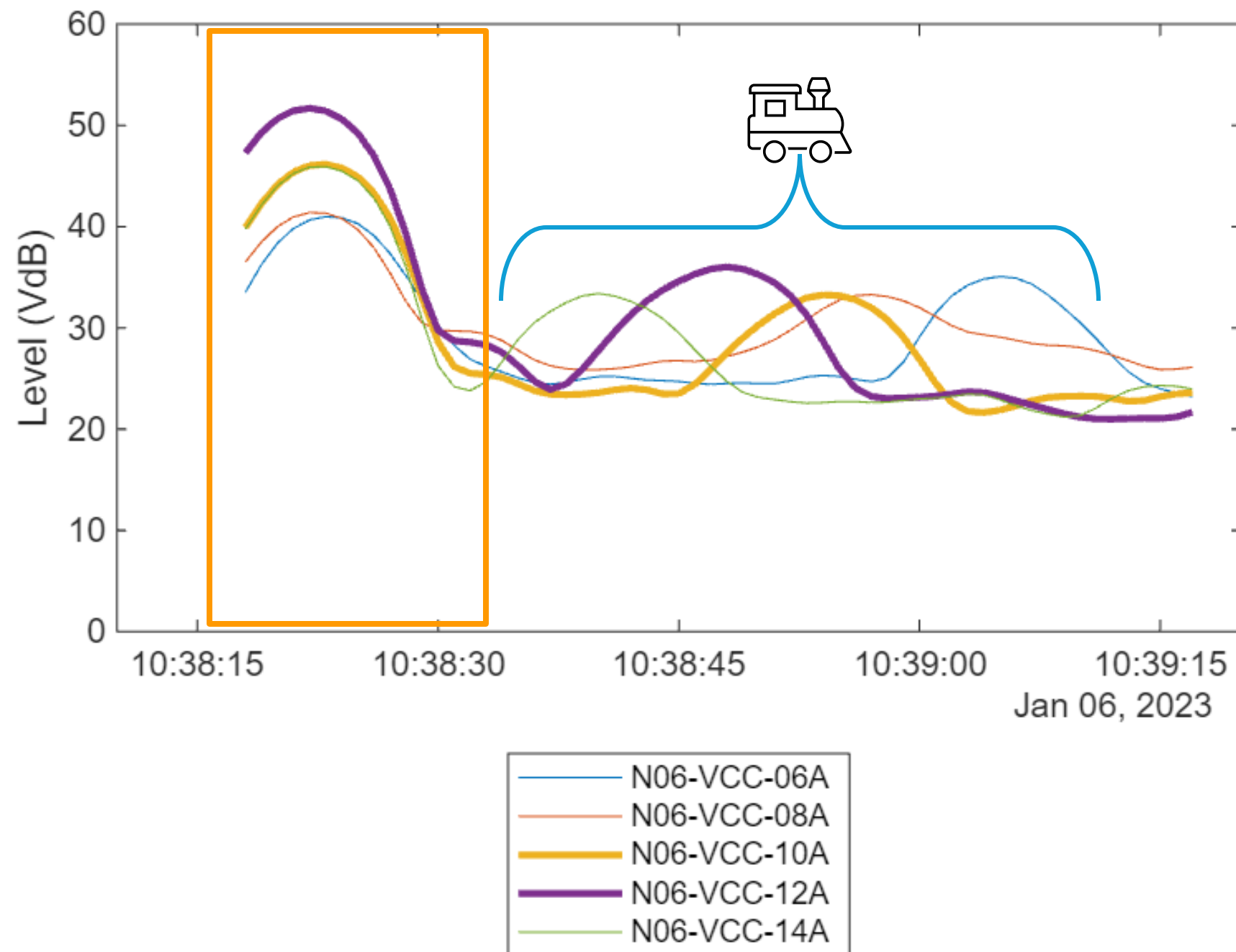
Exceedance
triggered at
Monitors 10 & 12





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Non-train exceedances



Monitors 6-14, 6.3 Hz

Southbound,
track on floating
slab

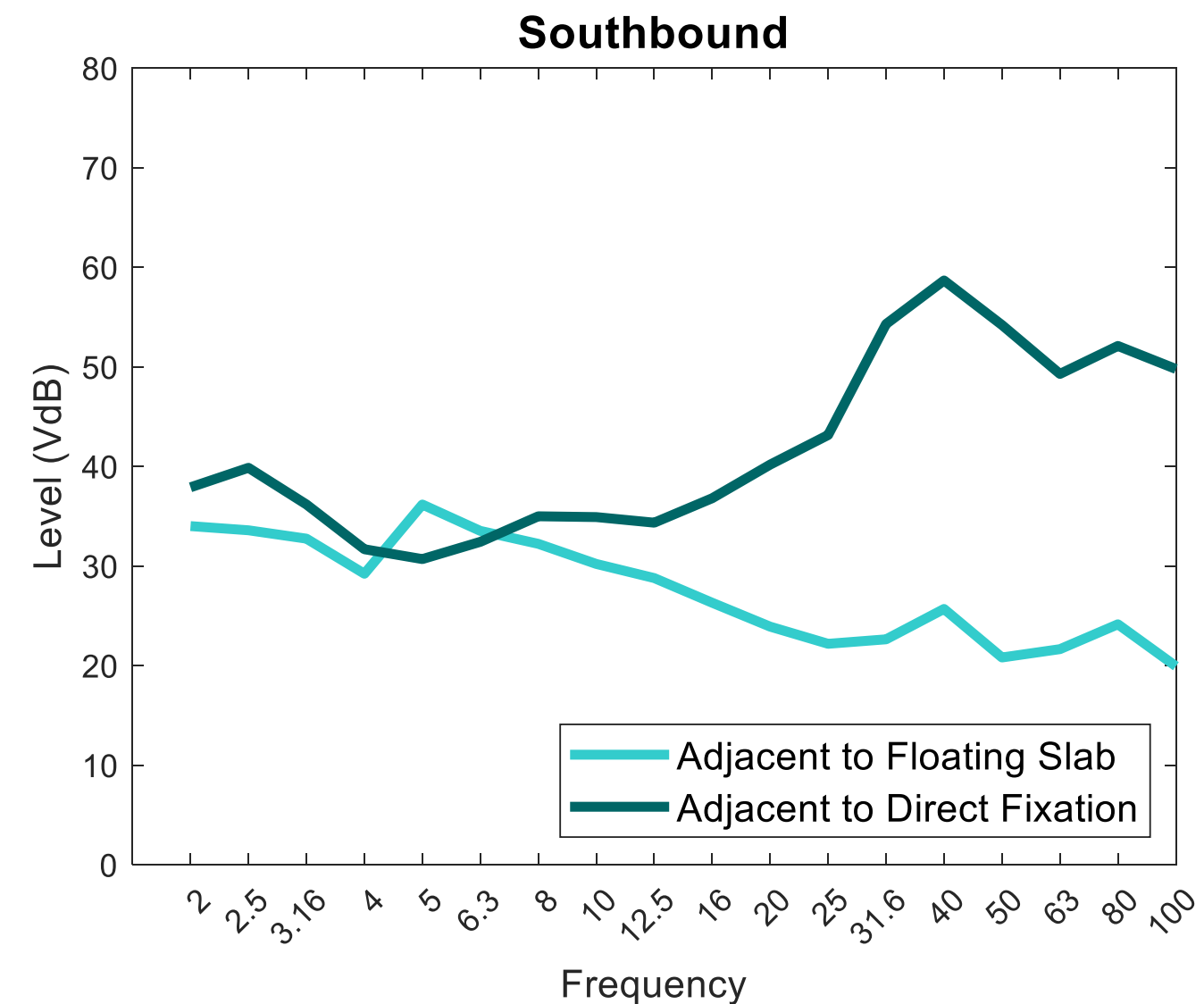
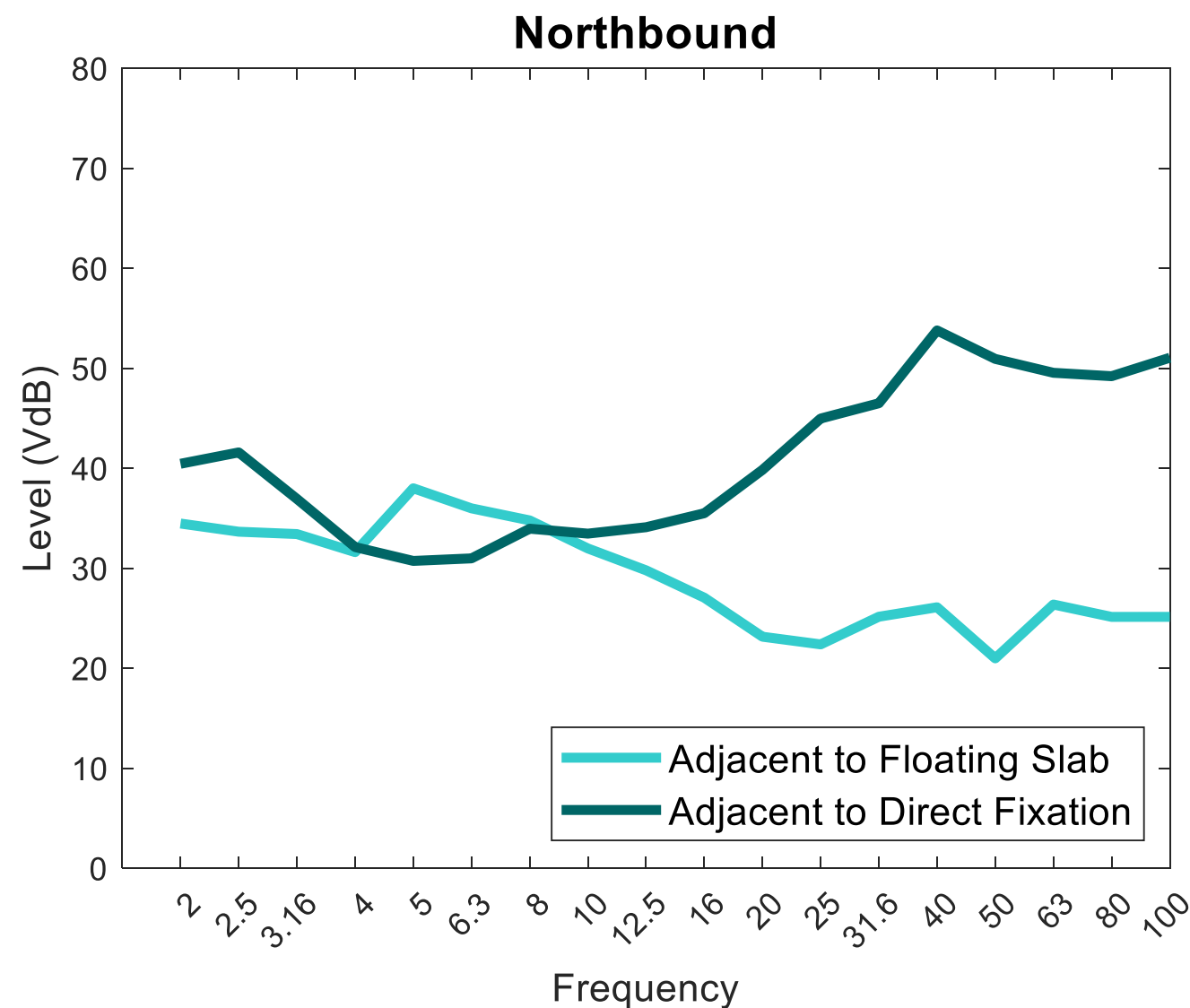
Exceedance
triggered at
Monitors 10 & 12





Track on Floating Slab vs Direct Fixation

- Vibration is overall higher off of 5 Hz floating slab
- On 5 Hz floating slab there is a peak at the 5 Hz resonant frequency, but higher frequency vibration is attenuated





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Trend Analysis

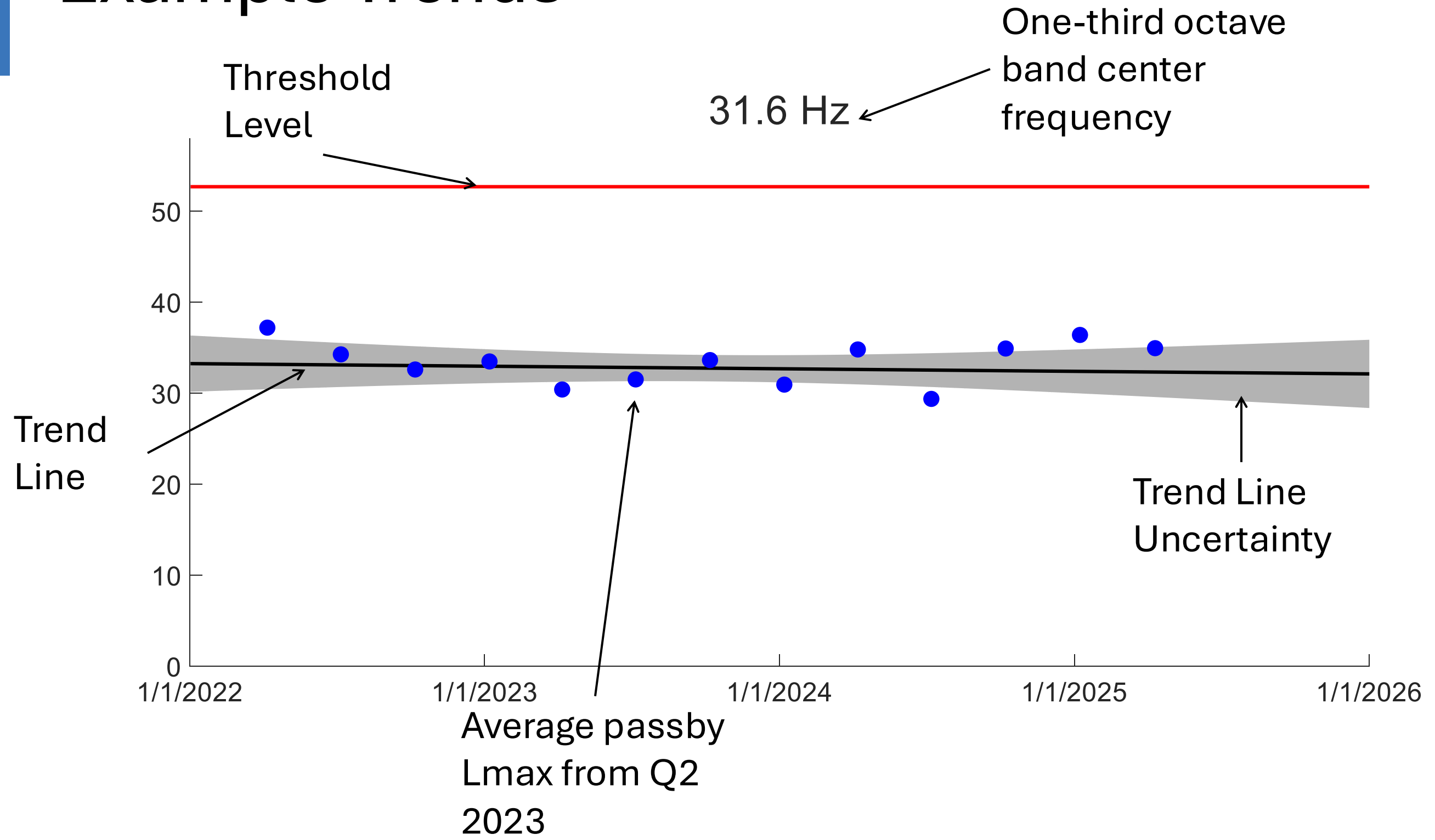
- Quarterly trend analysis
- Data from 2022 – present
- Pull 24h of data from the monitoring system each quarter
- Report & analyze data for each monitor at each frequency





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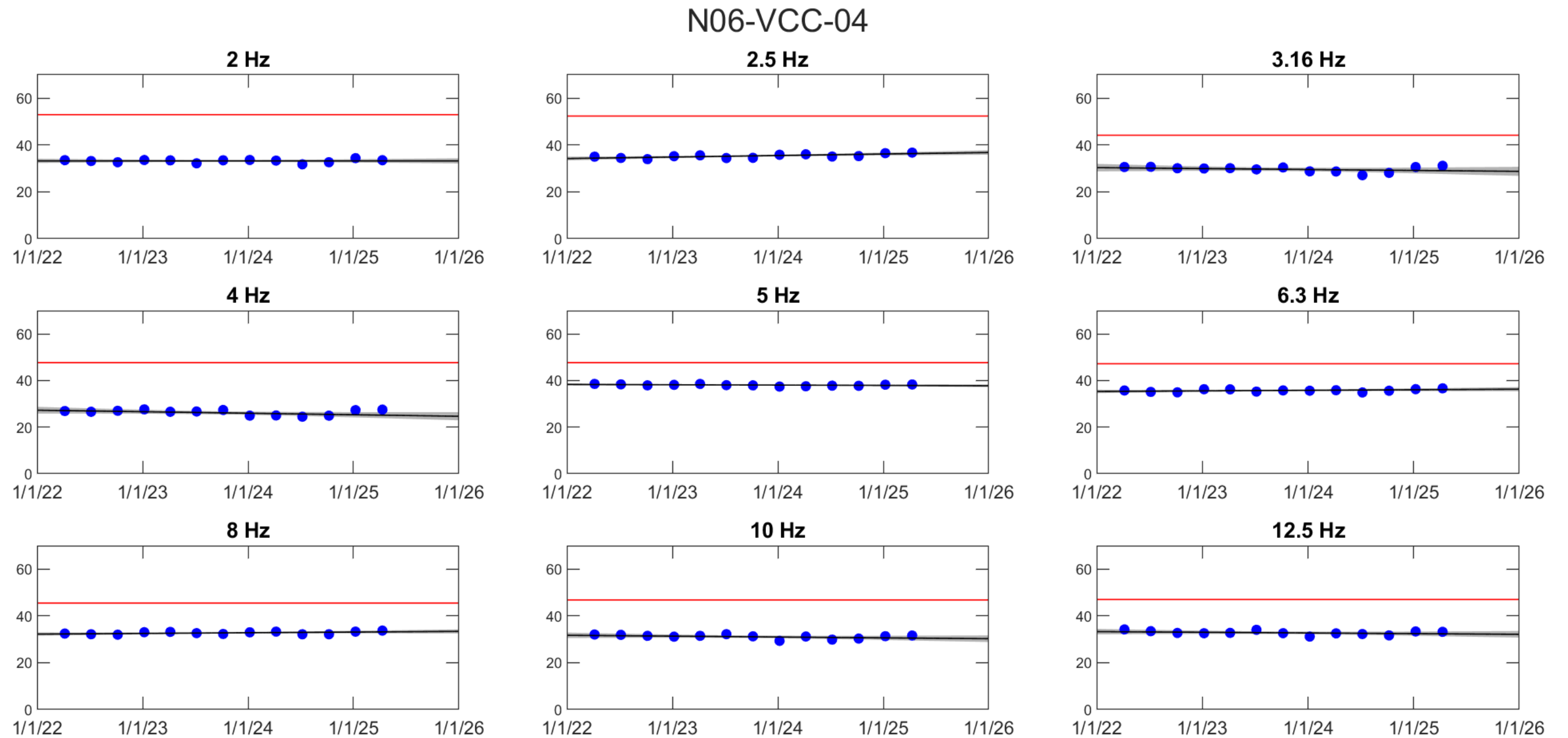
Example Trends





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Example Trends



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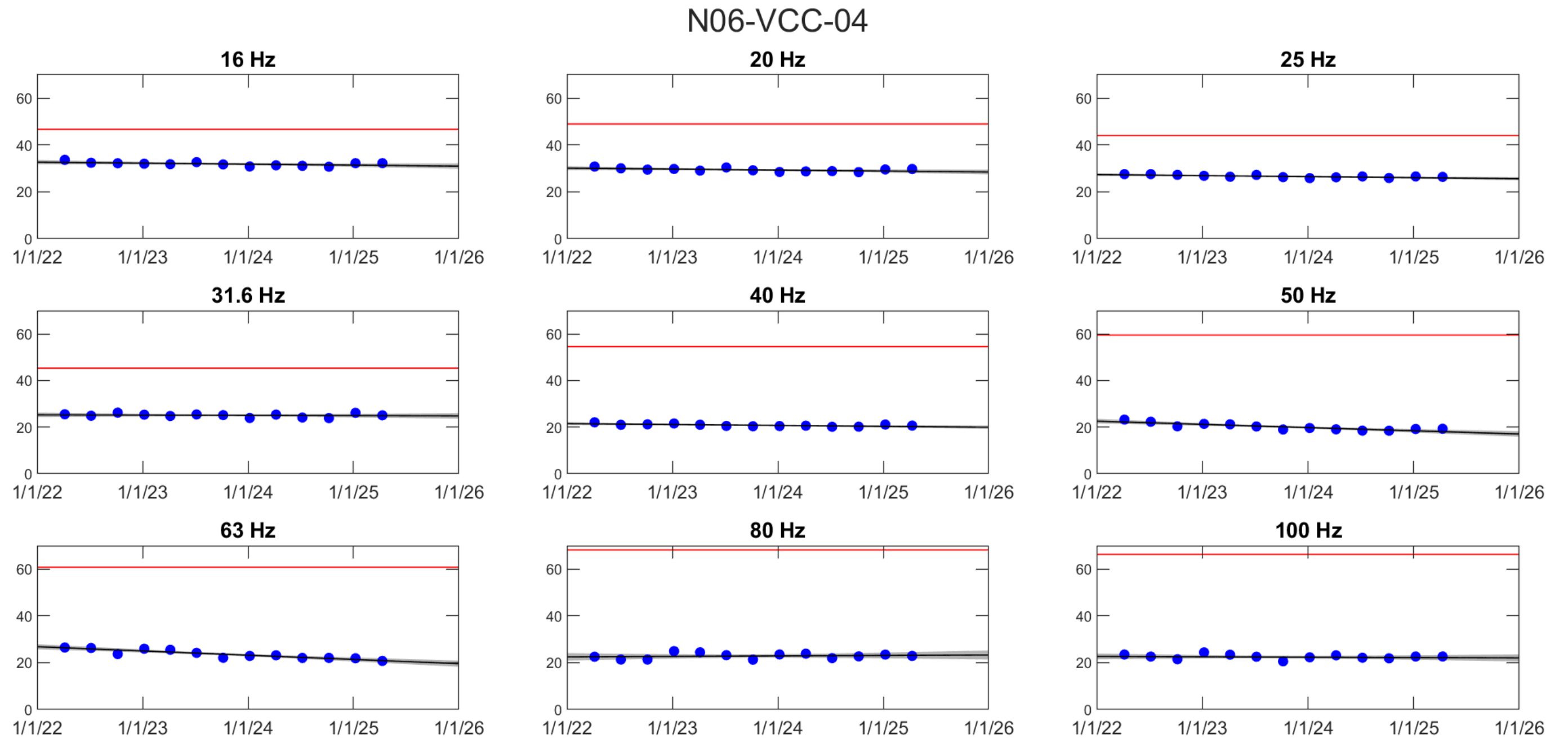
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Example Trends



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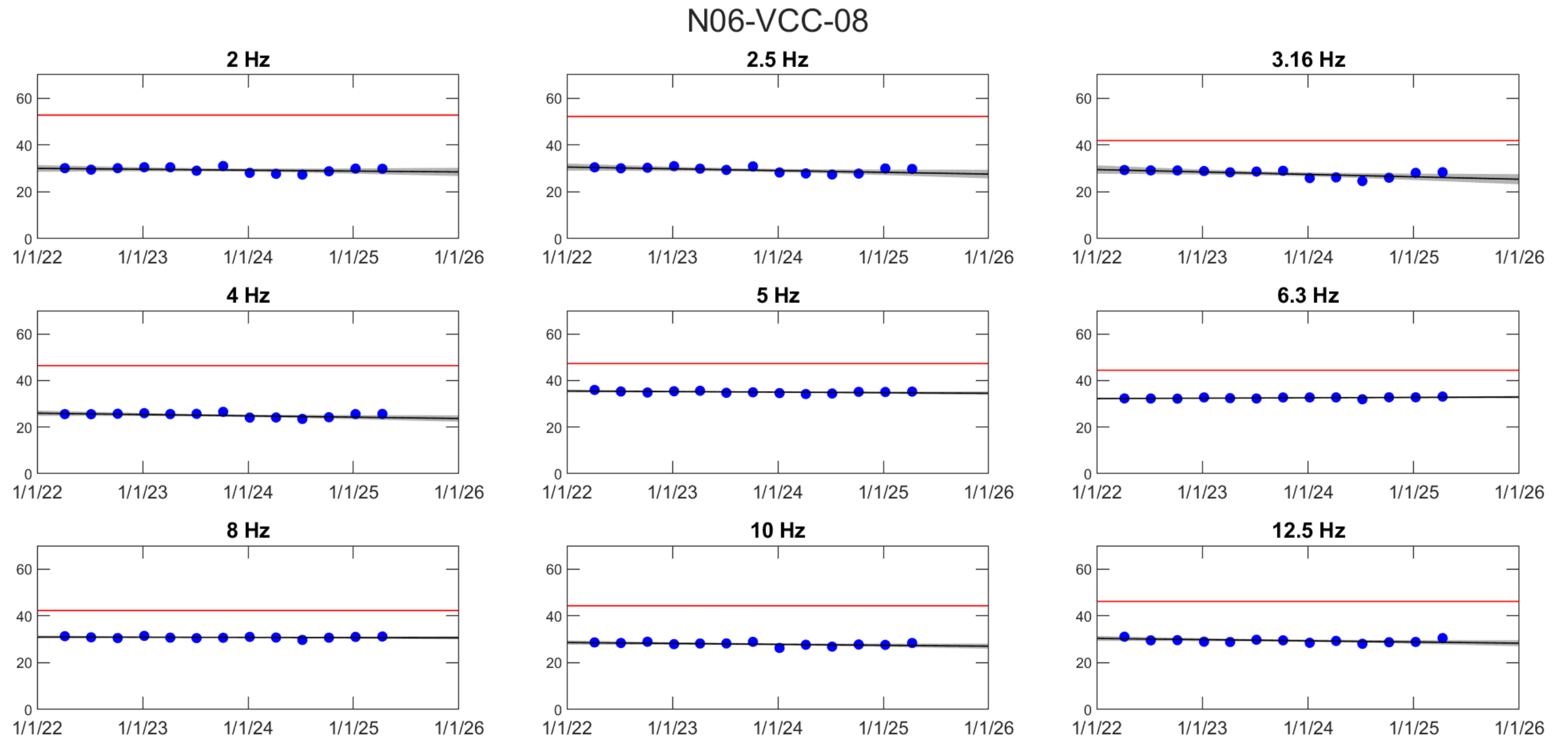
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Example Trends



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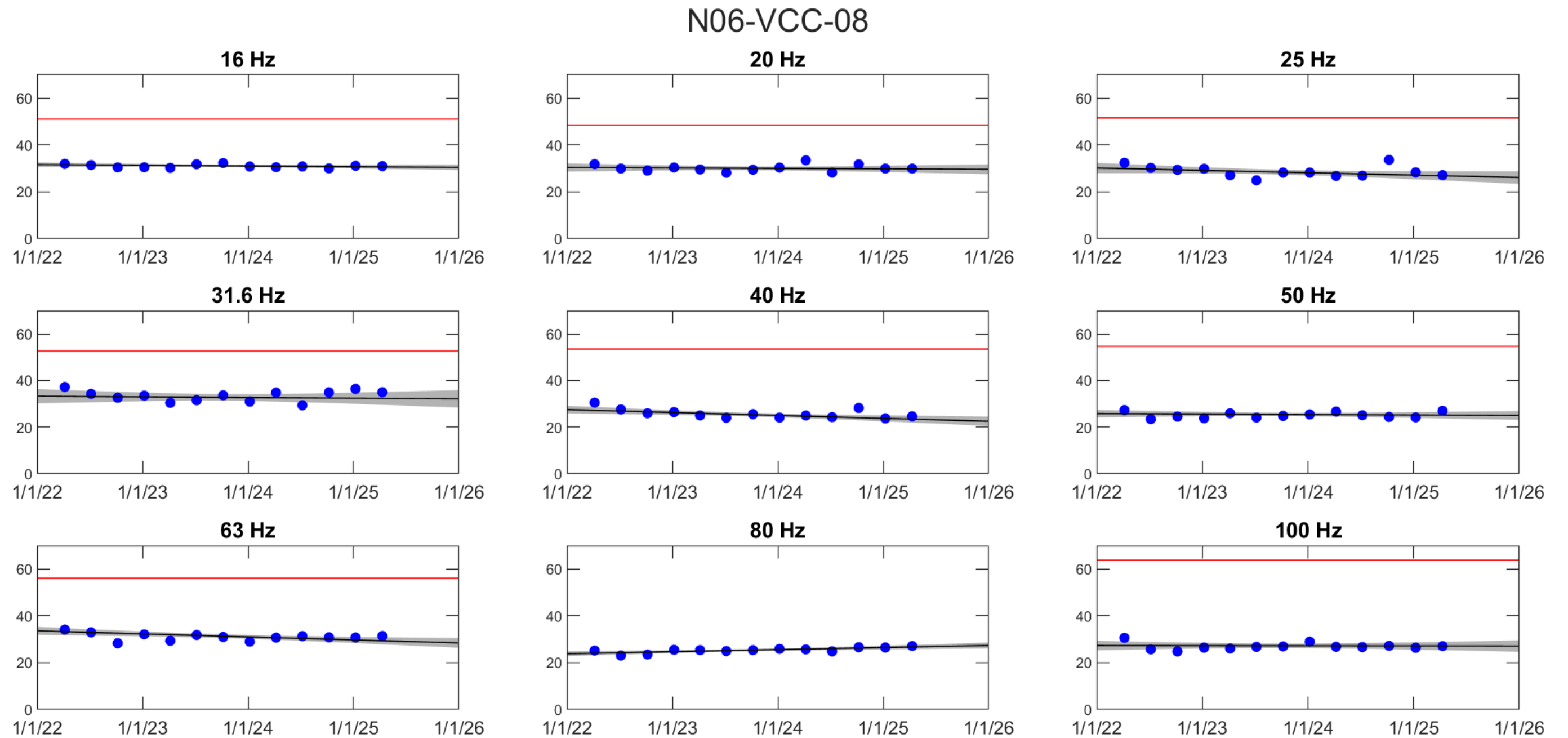
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Example Trends



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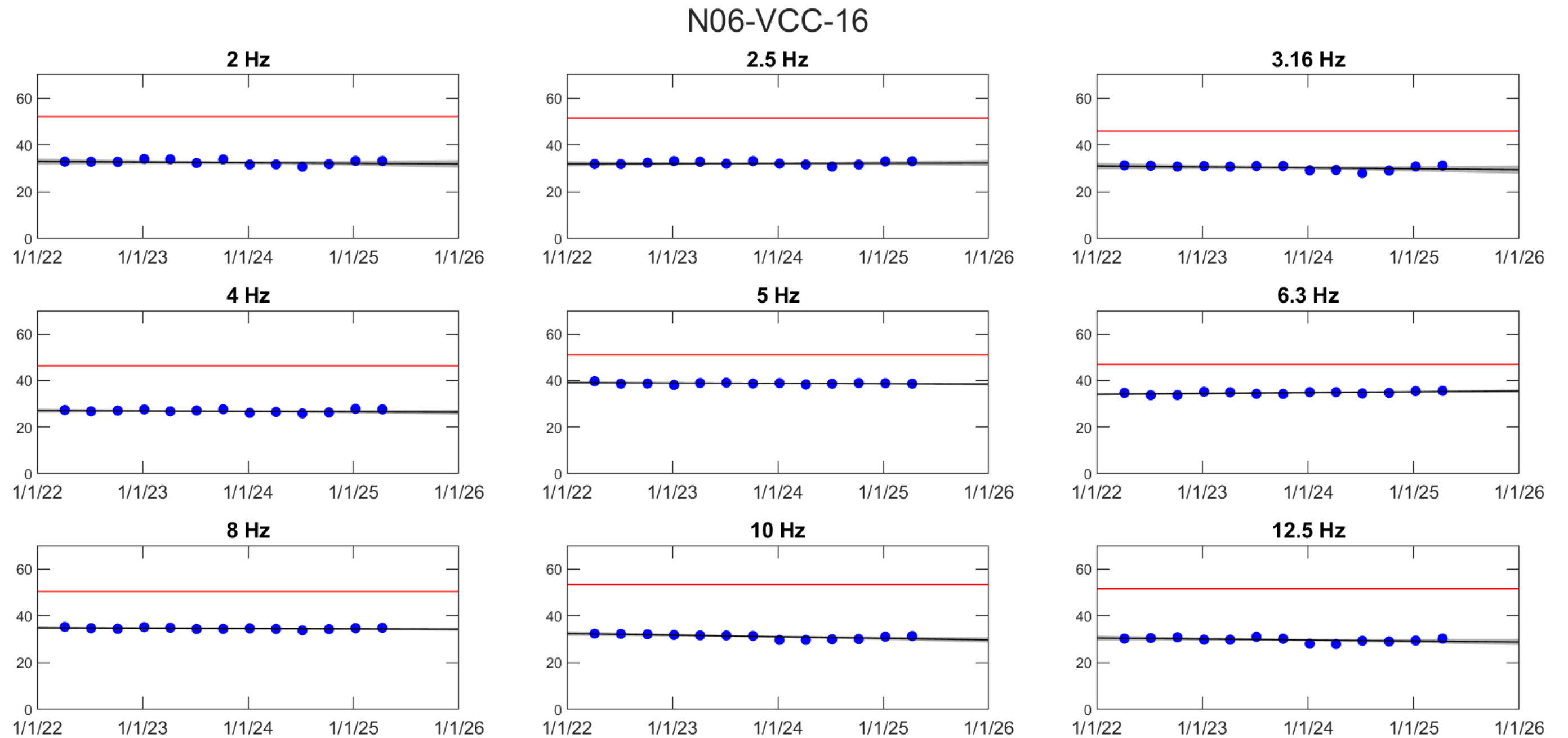
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Example Trends



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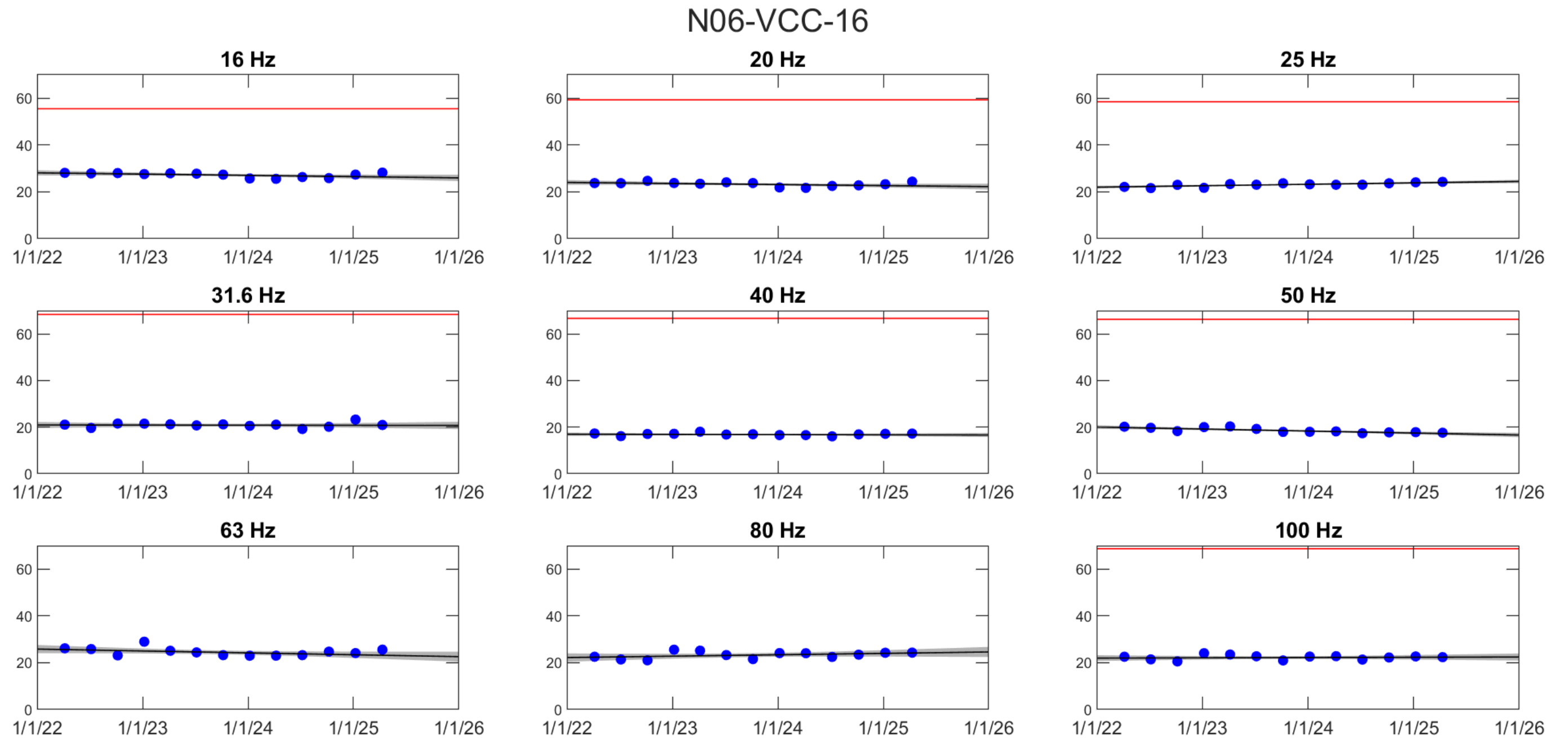
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Example Trends



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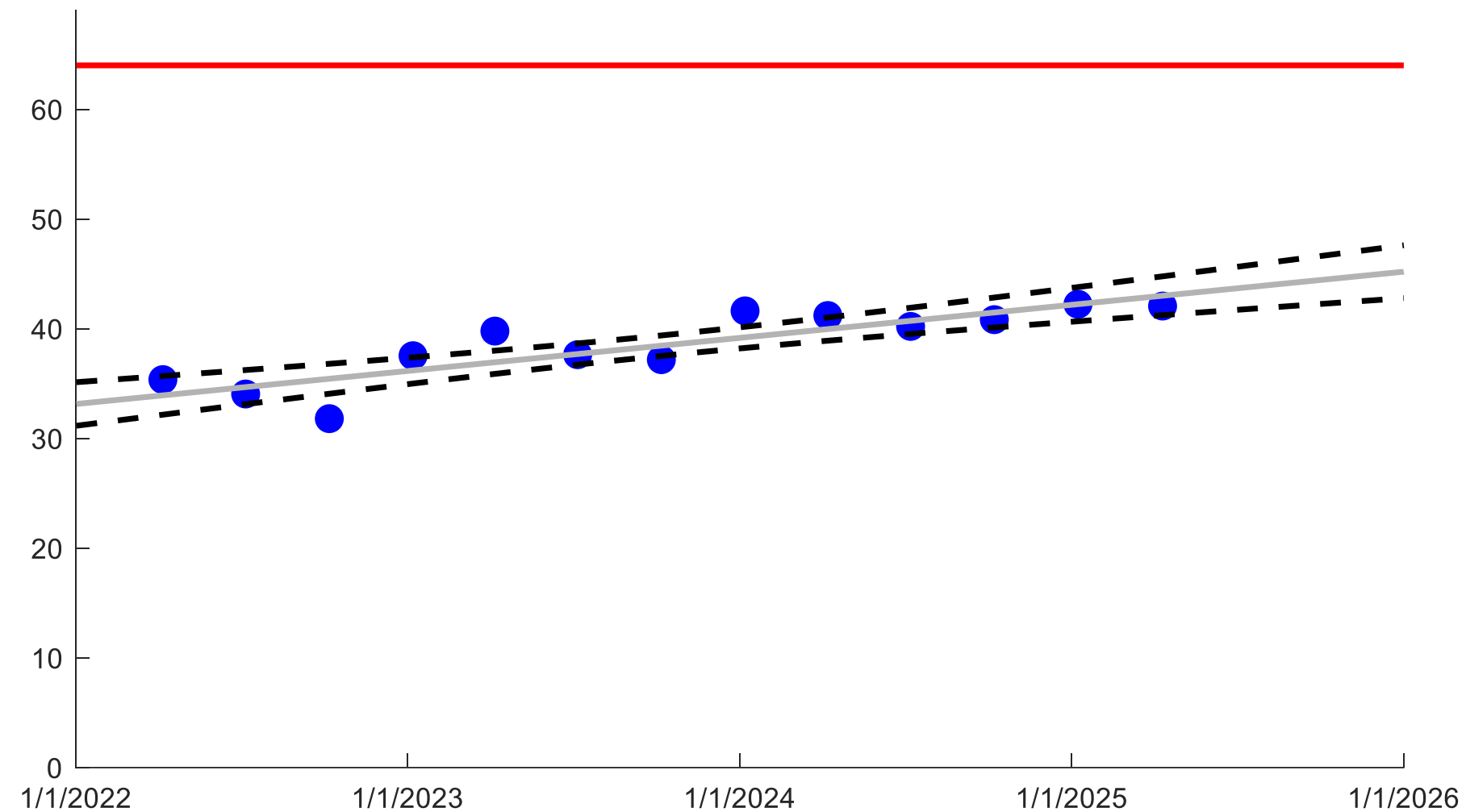




Example Trends – steepest trend

Monitor 29 (direct fixation, not on floating slab), 25 Hz

N06-VCC-29





Maintenance and Operational Practices

- Grinding in 2023 did not noticeably alter vibration trends
- Wheel truing
- Operators slow down if WFD is triggered
- Turned off alerts for 2 Hz, 3.15 Hz, and 4 Hz 1/3-octave bands



Expected changes for various conditions

- Wheel flats
 - Increased vibration in 1/3-octave bands 40 Hz and above, especially for speeds below 30 mph
- Rail Corrugation
 - Increase in vibration in the band with speed/(corrugation wavelength)
- Lack of lubrication
 - Expect wheel squeal at frequencies well above 100 Hz. This system cuts off at 100 Hz and therefore would not detect squeal through vibration.



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Future work

- Continue reporting trends to fulfill MIA requirements
- Data analysis beyond trending to identify broader patterns
- Opportunities for machine learning algorithms





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Acknowledgements

- Sound Transit
- James T Nelson, PhD
- IEM (International Electronic Machines Corp)





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Thank you!



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