WJE

SOLUTIONS FOR THE BUILT WORLD

Town of Miami Lakes Blasting Advisory Board

FSFM FM410 Report Review

February 11, 2019

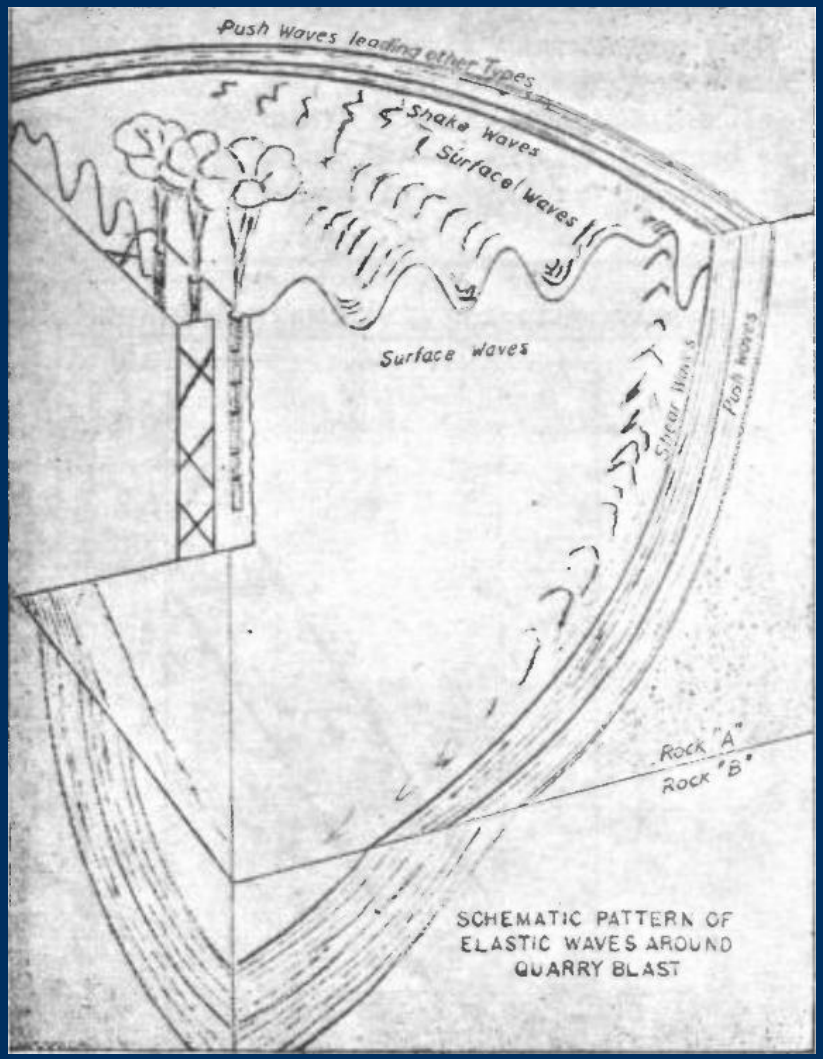
www.wje.com

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.

Vibration Fundamentals

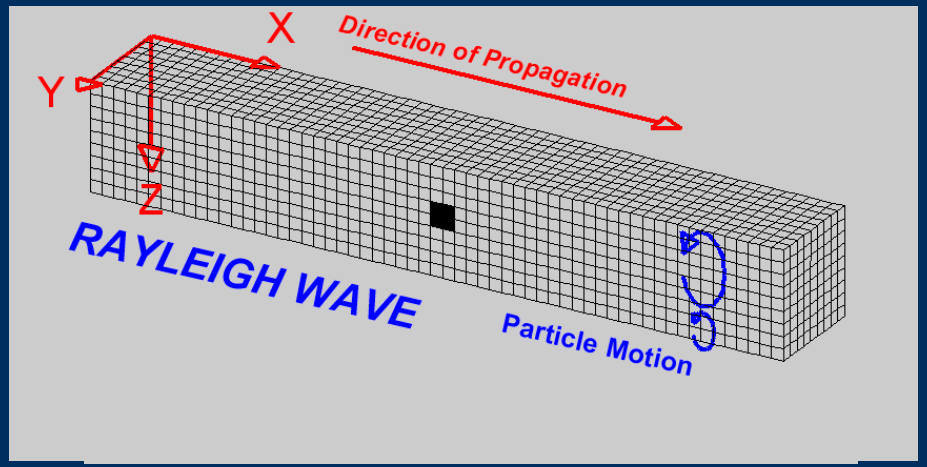
Vibration Fundamentals - Ground Vibration Types

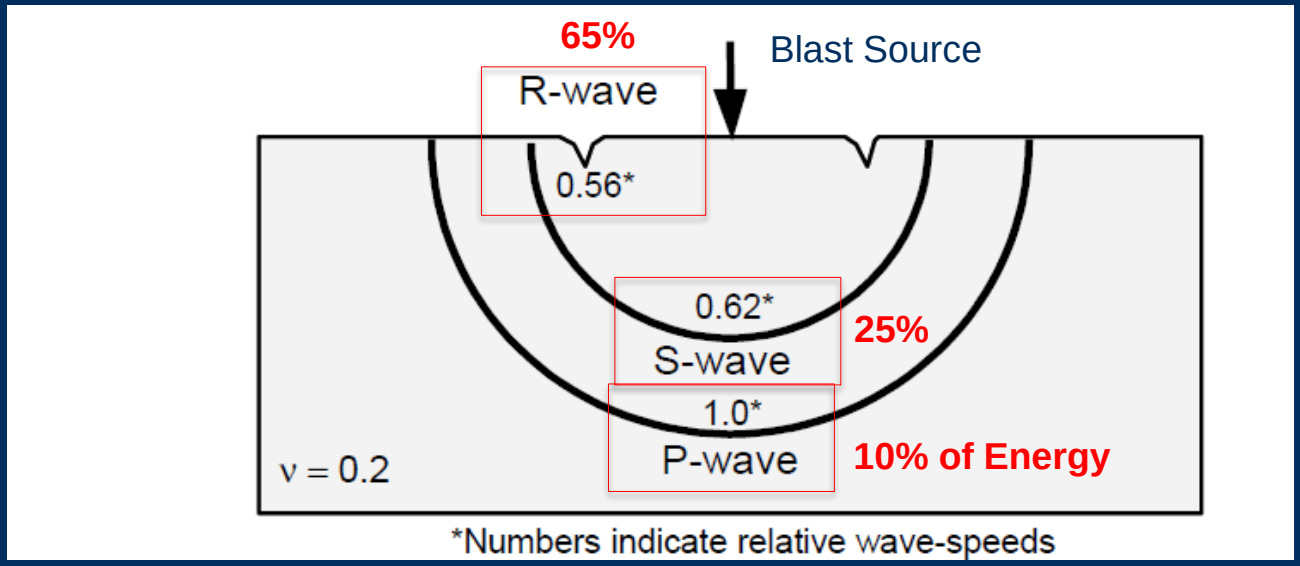


Vibration Fundamentals - Ground Vibration Types

Ground stress wave types:

- Compression (P-) Wave [Primary, Longitudinal]
- Shear (S-) Wave [Secondary, Transverse]
- Rayleigh (R-) Wave [Surface, Long – Ground Roll]



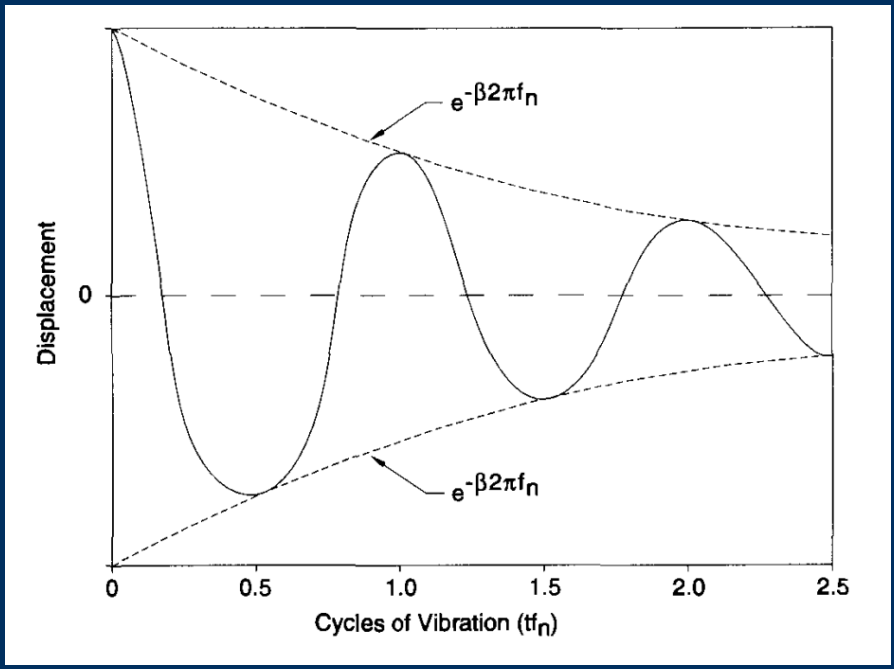


Vibration Fundamentals - Ground Vibration Types

	Particle Motion Wave Direction →	Wave Speed	Relative Speed
P-Wave		$V_P = \sqrt{\frac{E_c(1-v)}{\rho(1+v)(1-2v)}}$	1.0
S-Wave		$V_S = \sqrt{\frac{G}{\rho}} \quad V_S = \sqrt{\frac{E_c(1-v)}{2\rho(1+v)}}$	0.62
R-Wave		$V_R = V_S \frac{0.87+1.2\nu}{1+\nu}$	0.56

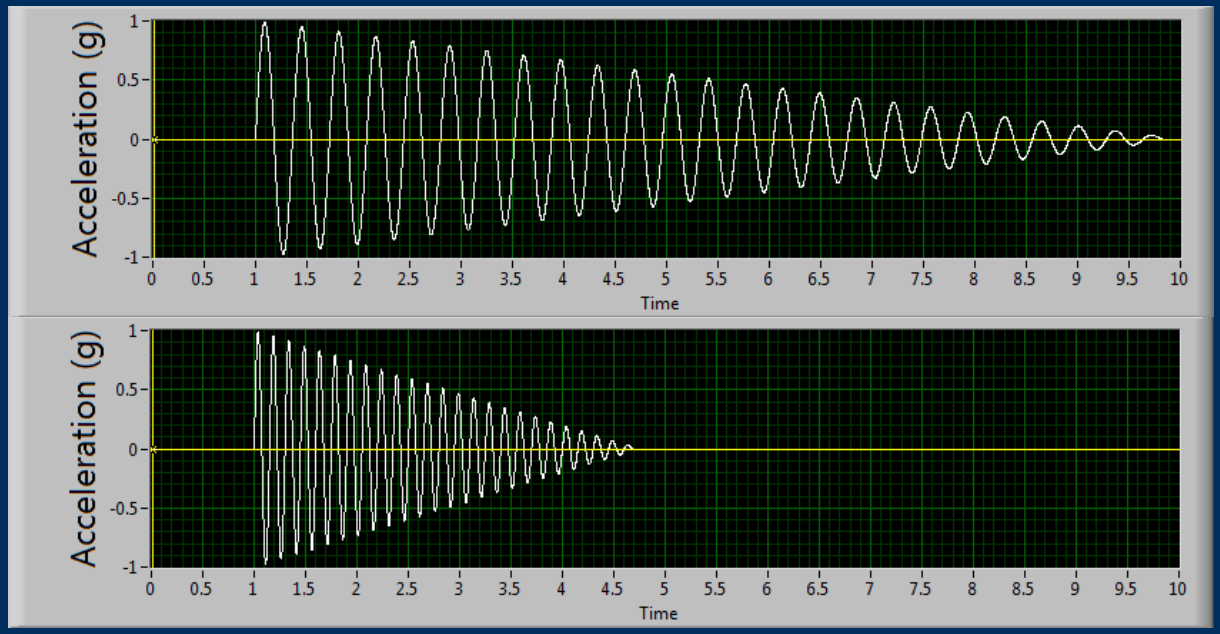
Vibration Fundamentals – Effect of Soil Type

- Attenuation (energy dissipation) depends on soil type, wave type and frequency
  - Geometric (radiation) damping
  - Material (hysteretic) damping



Vibration Fundamentals – Effect of Soil Type

- Vibrations attenuate at a greater rate in soft soil than hard soil or rock
- High frequency vibrations attenuate at a greater rate than low frequency vibrations



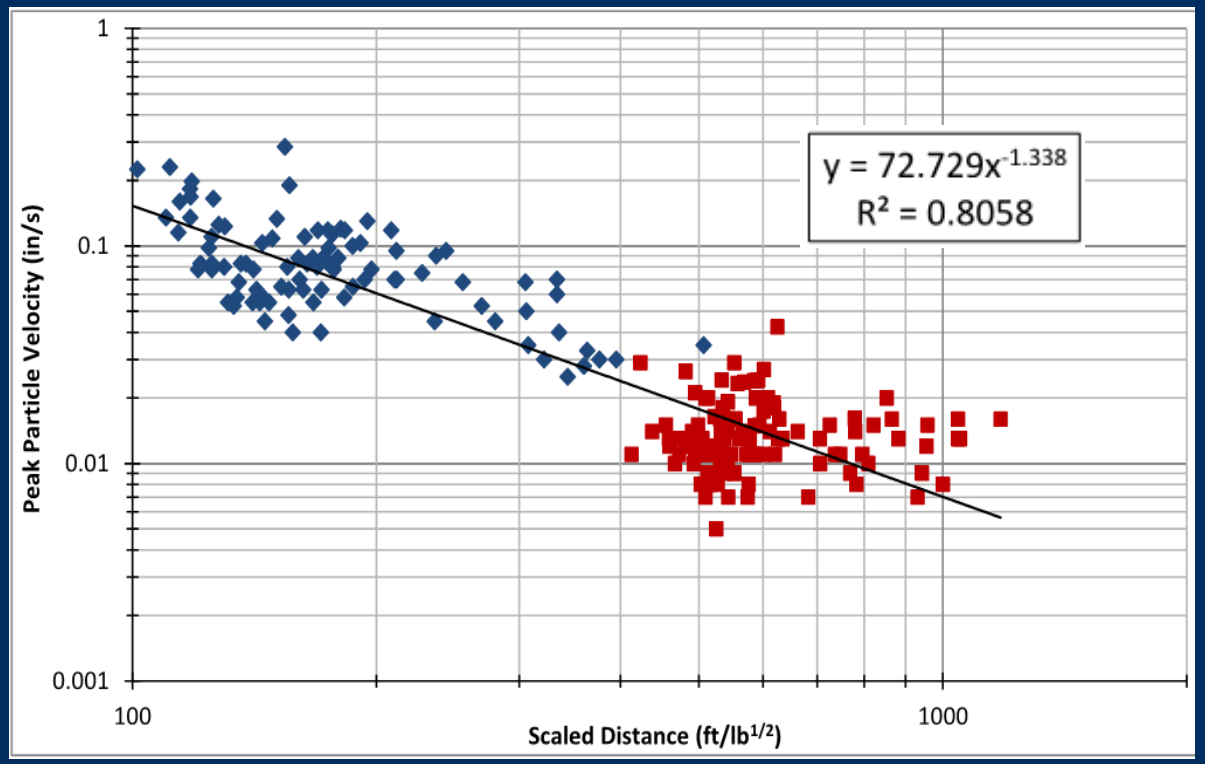
Vibration Fundamentals – Attenuation with Distance

- Characterized as Power Equation normalized to blast size

$$PPV = I * Scaled\ Distance^{-Slope}$$

$$Scaled\ Distance = \frac{Distance}{\sqrt{Blast}}$$

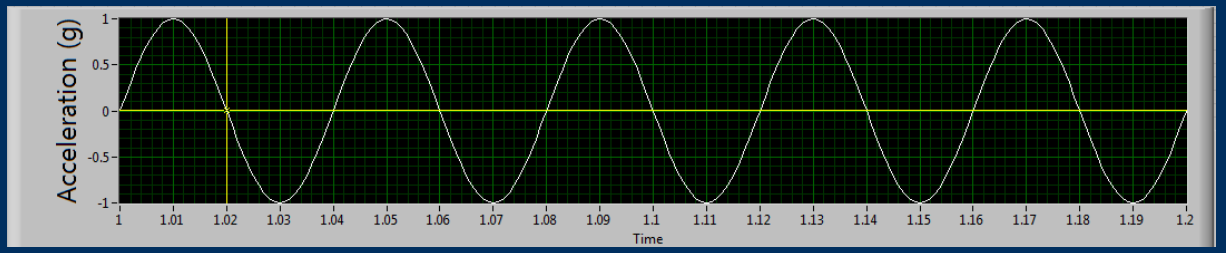
PPV (ips)
Scaled Distance (ft/lb$^{1/2}$)
Distance (ft)
Blast loading size (lbs/delay)



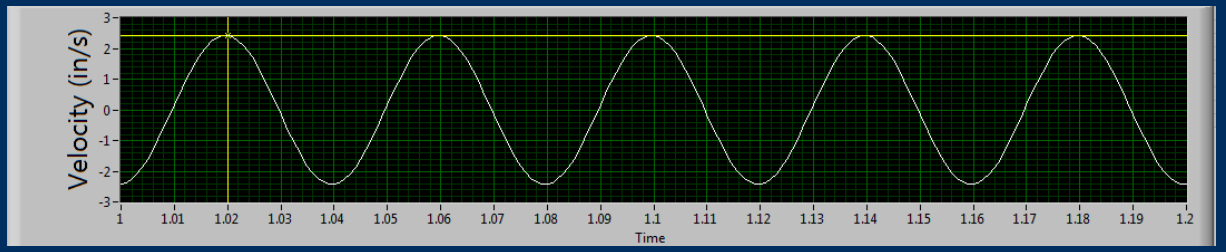
Vibration Monitoring

Vibration Measurement Units

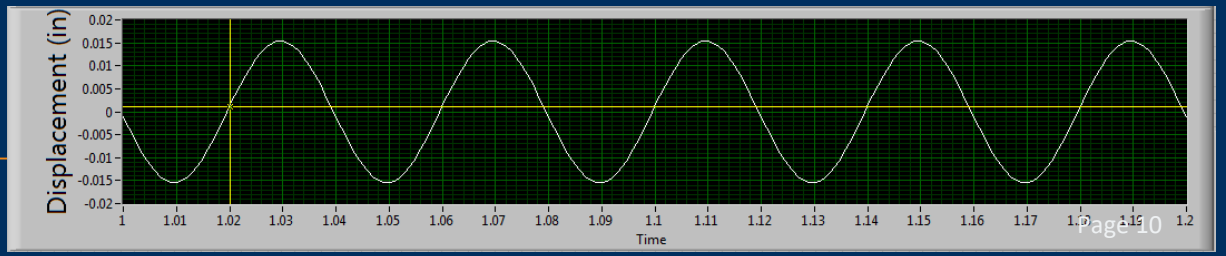
- Ground Vibrations can be measured in units of
  - Acceleration (in/s^2 , g, m/s^2)



  - Velocity (in/s, m/s) *PPV*



  - Displacement (in, m)



Vibration Monitoring Equipment - Seismographs

- Seismographs
  - Instantel
    - Minimate Plus
    - Minimate Pro4, Pro6
    - Micromate
  - Geosonics/Vibratech
    - 3000LC
    - 3000-EZ Plus
    - 3000LCP
    - 5500
  - White Industrial Seismology
    - Mini-Seis III
    - Mini-Seis
  - Sigicom
    - C12
    - C22

Vibration Monitoring Equipment - Seismographs

Instantel

- Minimate Plus
- Minimate Pro4
- Micromate

Vibration Monitoring Equipment - Seismographs

Geosonics/ Vibratech

- 3000LC
- 3000-EZ Plus
- 3000LCP
- 5500

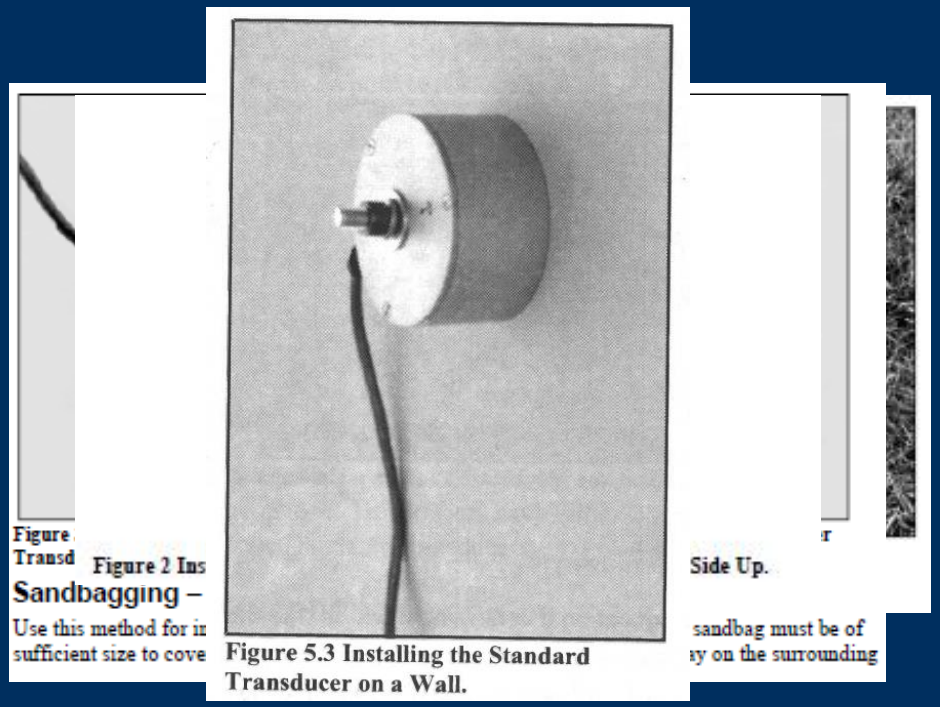
Vibration Monitoring Equipment - Seismographs

Sigicom

- C12
- C22

Vibration Monitoring Equipment - Installation

- Attaching Seismometer
  - In Ground
  - Hard Surface
  - Underside of slab
  - Vertical - Wall



Vibration Monitoring Equipment - Installation

- Communication (Remote Access)
  - Land-line modem
  - Cellular modem
    - Airlink RavenXT
    - Sierra Wireless LS300
    - Serial interface
    - Static IP address for remote access
      - i.e. 166.156.17.70
  - Satellite modem

Vibration Monitoring Equipment - Installation

Seismograph Installation Best Practices

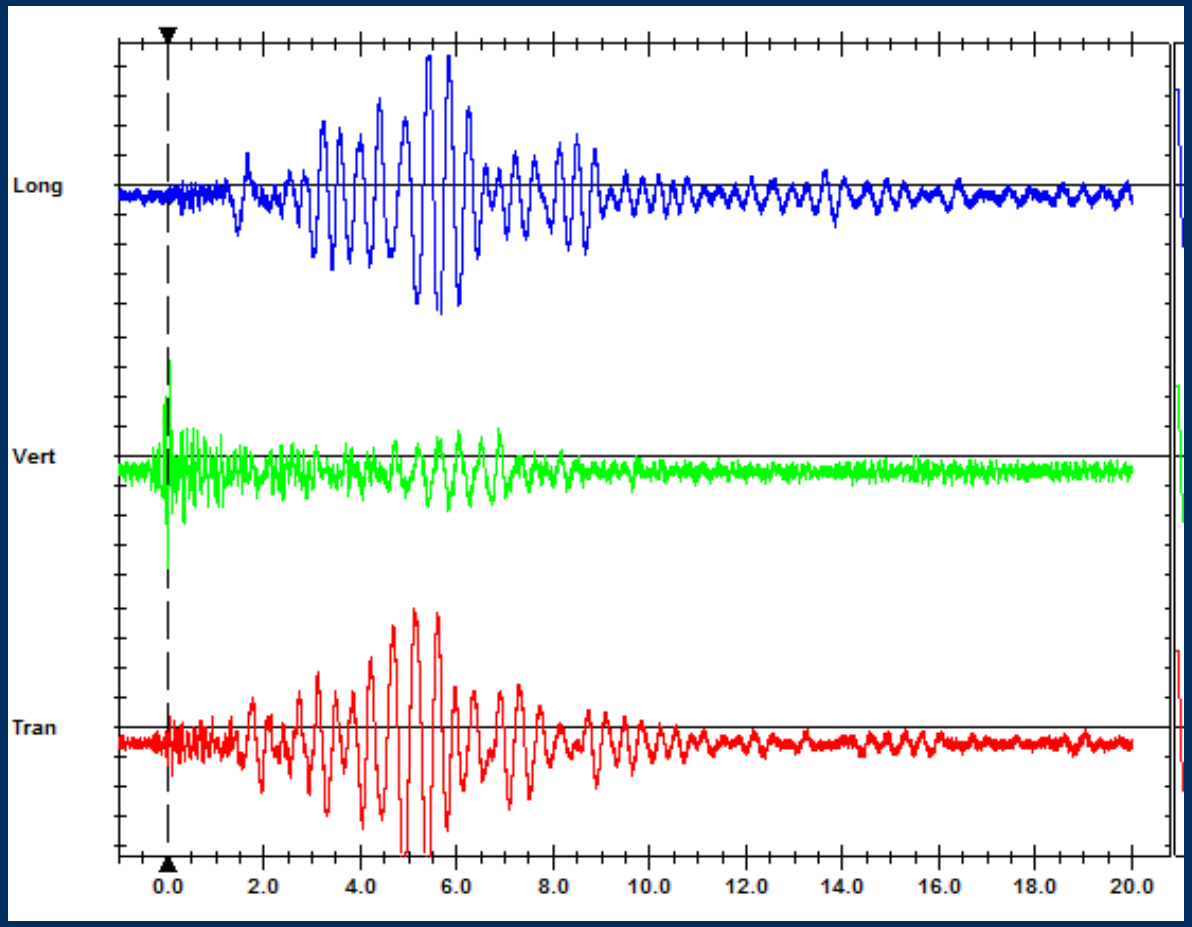
- Units are typically calibrated annually by supplier (~500$)
- In-ground installation is best reflection of the USBM guidelines
- Interior installation - basement slab
- May be affected by magnetic, electrical interference
  - Avoid boilers, furnaces, sump pumps, dehumidifiers
  - Avoid use of hand-held radios, other EM signal sources
- Protect logging unit from water
- Establish cellular signal connection
- Use AC power when possible

Vibration Monitoring Equipment - Installation

- When AC Power is not available:
  - Solar panel
  - Enclosure with battery

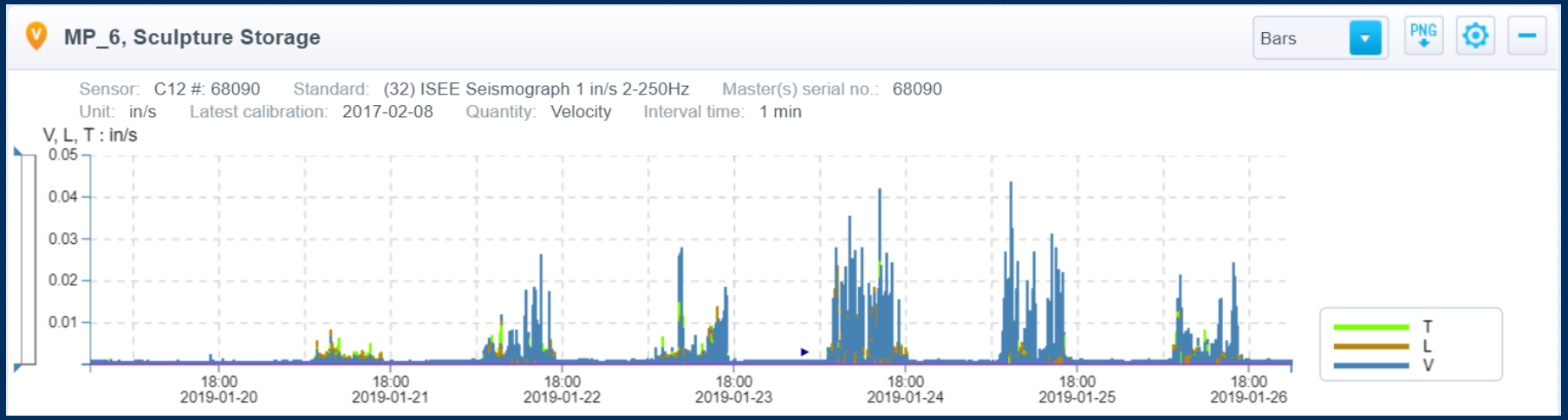
Vibration Monitoring Equipment - Monitoring Modes

- Waveform Recording
  - Fixed length or Auto-record



Vibration Monitoring Equipment - Monitoring Modes

- Histogram
  - Defined Logging Interval
  - Stores amplitudes (PPV, in/s), frequency (Hz)



Vibration Monitoring Equipment - Monitoring Modes

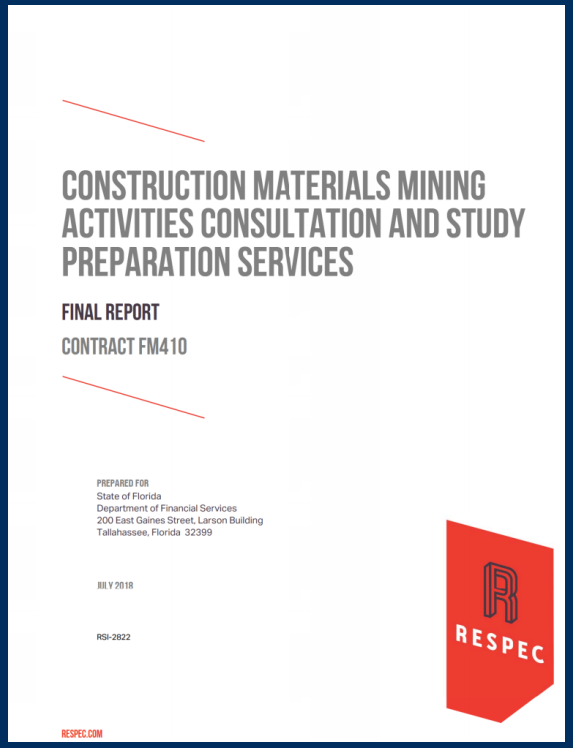
- Histogram/Combo
  - Histogram data at defined intervals
  - Trigger level set to capture waveform event if a threshold is exceeded

WJE

FSFM Contract FM410
Mine Blasting Study

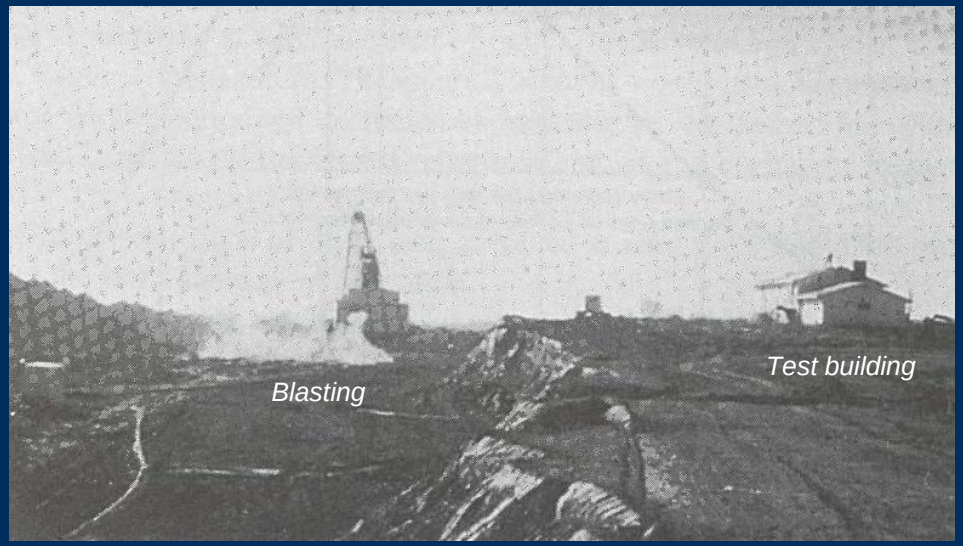
FSFM Contract FM410 *Mine Blasting Study*

- RESPEC contracted by FSFM (February 2018)
  - Complete comprehensive review of US Bureau of Mines USBM Report of Investigations RI 8507
  - Review Florida regulations, local regulations
  - Review geological and soil characteristics
  - Review blasting reports, complaint reports, & blast vibration records

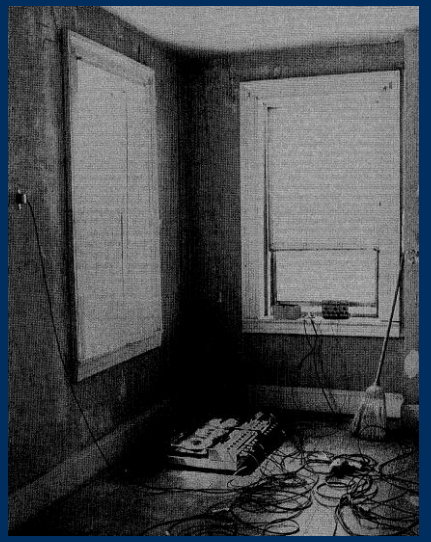


USBM RI 8507 Criteria

- *Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting.* 1980
- Developed based on empirical testing of 76 residential structures during 219 production blasts
- Produced a significant amount of damage in the homes



John F. (Jack) Wiss

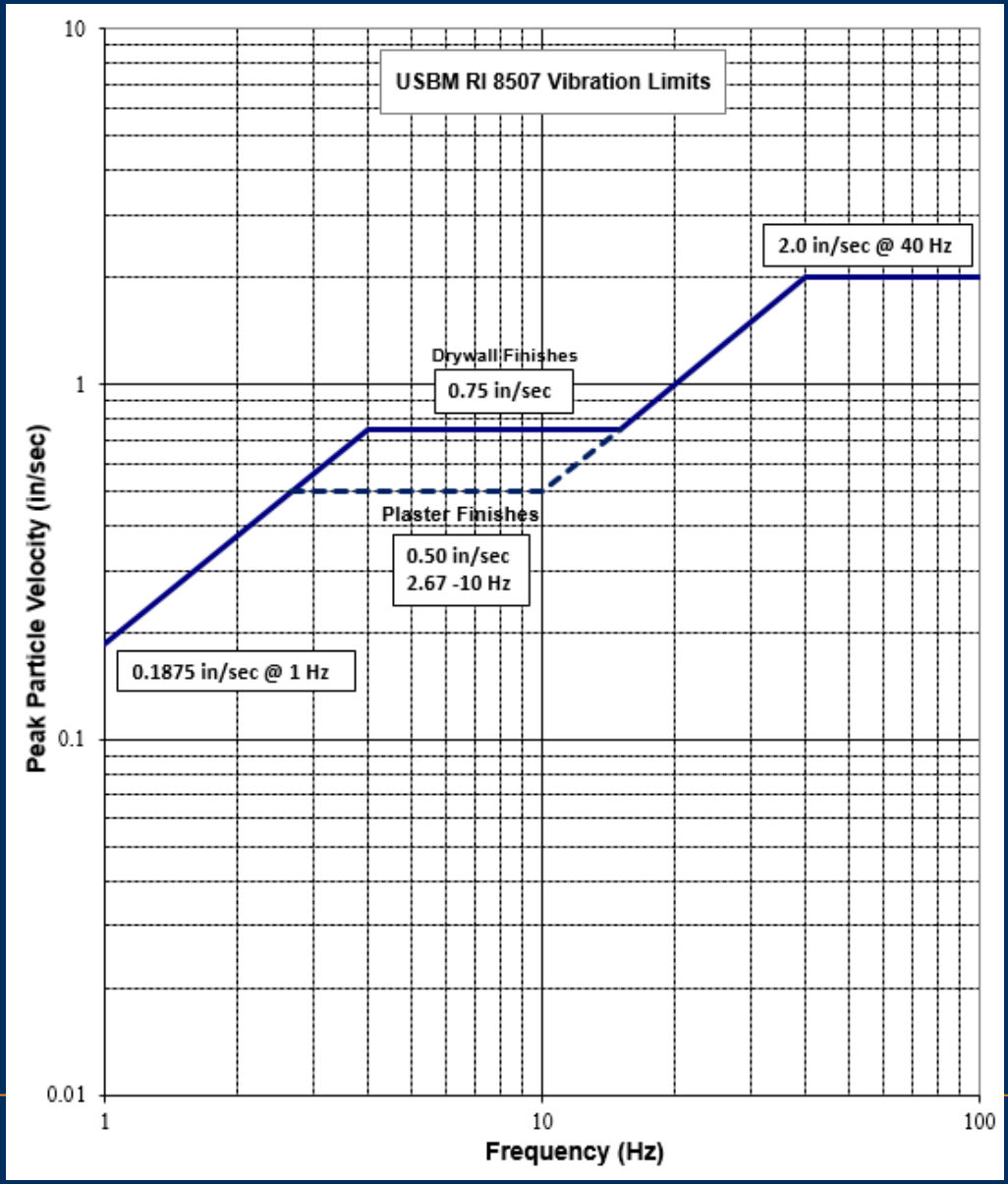


Instrumentation setup

USBM RI 8507 Criteria

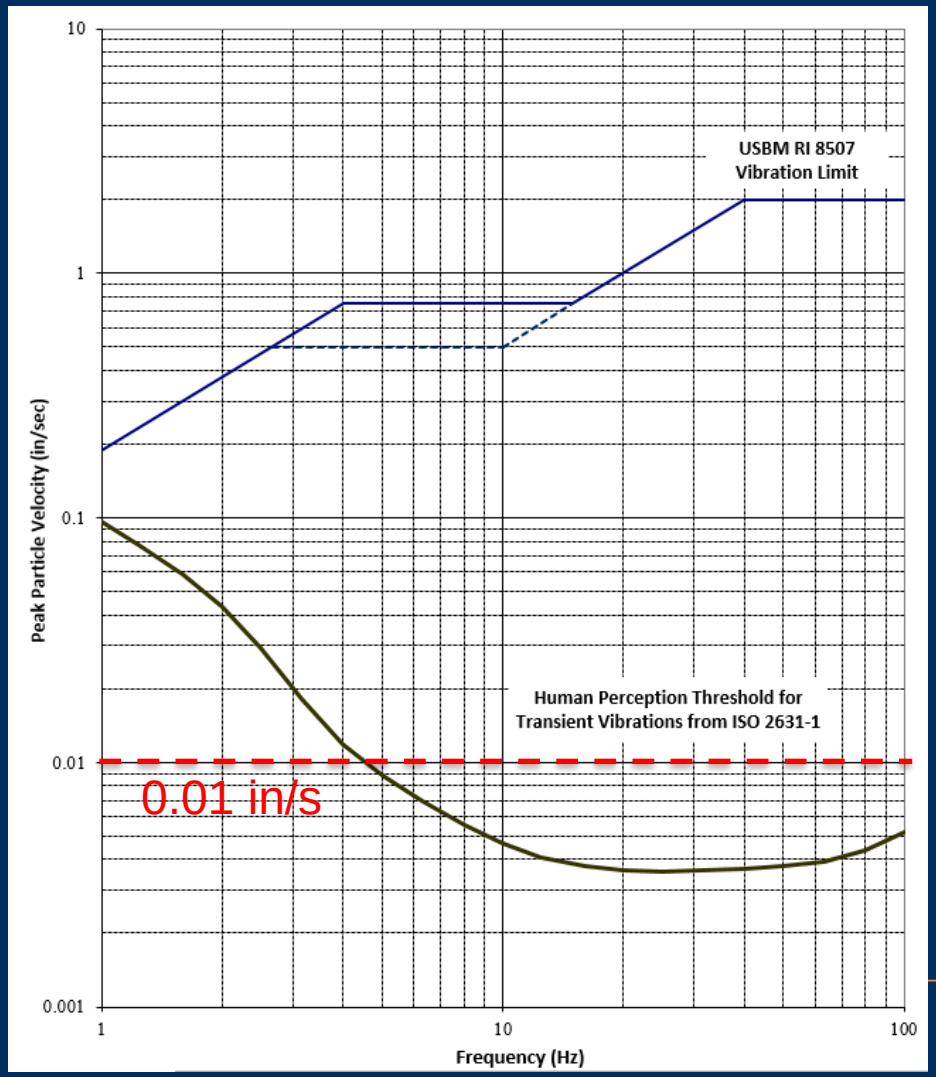
- Resulted in a frequency-dependent vibration limit for threshold damage
- Applies to residential structures sited on a firm foundation, do not exceed 2 stories, have dimensions of typical residences, and that the vibration durations are not longer than a few seconds.
- The RI 8507 results are overly conservative for engineered structures
- Referenced widely for blasting and transient vibrations
- RESPEC recommends that Florida Administrative Code (FAC) reference only the USBM vibration limit

USBM RI 8507 Criteria

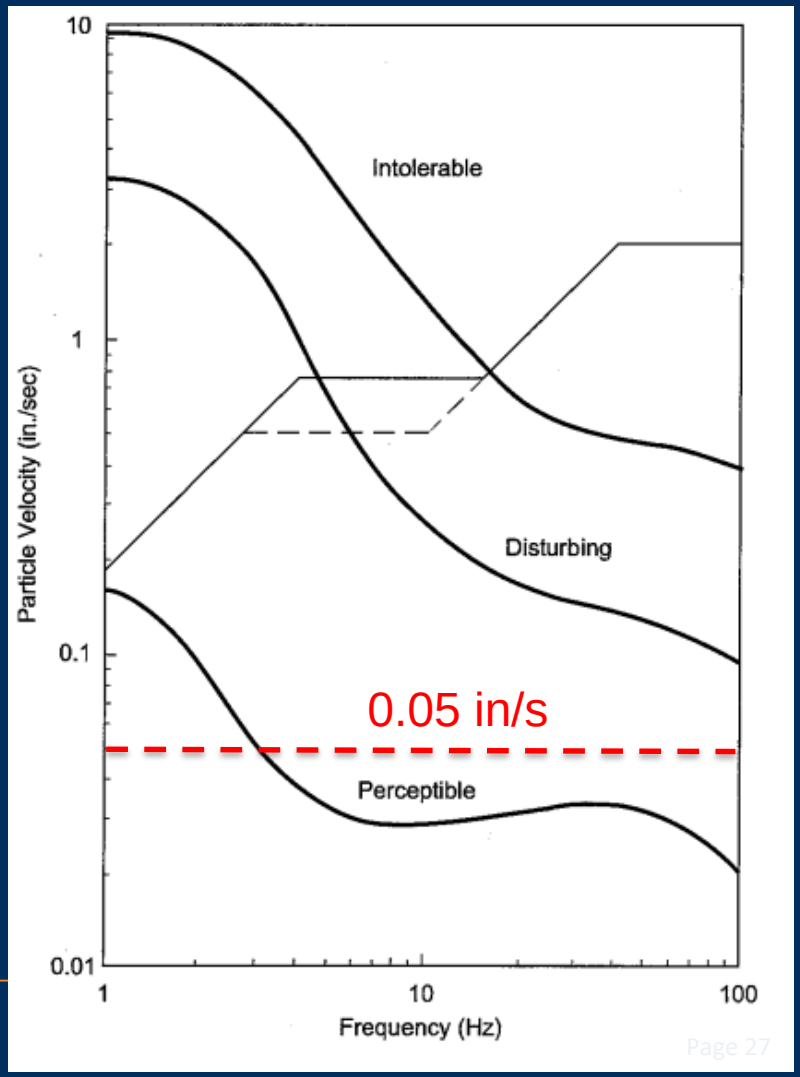


Human Perception Criteria

- ISO 2631-1



- AASHTO R8-96 (2004)



FSFM Contract FM410 *Mine Blasting Study*

- ***2.1 Structural Damage and Material Failure Characteristics***
  - Drywall cracking was observed to have occurred at wall joints at vibration amplitudes measuring 1.8-2.0 in/s PPV.
  - Masonry cracking occurs at joints at vibration amplitudes measuring 3.0 in/s PPV.
  - Monolithic concrete may withstand vibrations of 10 in/s PPV
  - Blasting does not cause damage through fatigue
    - *Individual blast events may be analyzed independently to determine the potential for damage*

FSFM Contract FM410 *Mine Blasting Study*

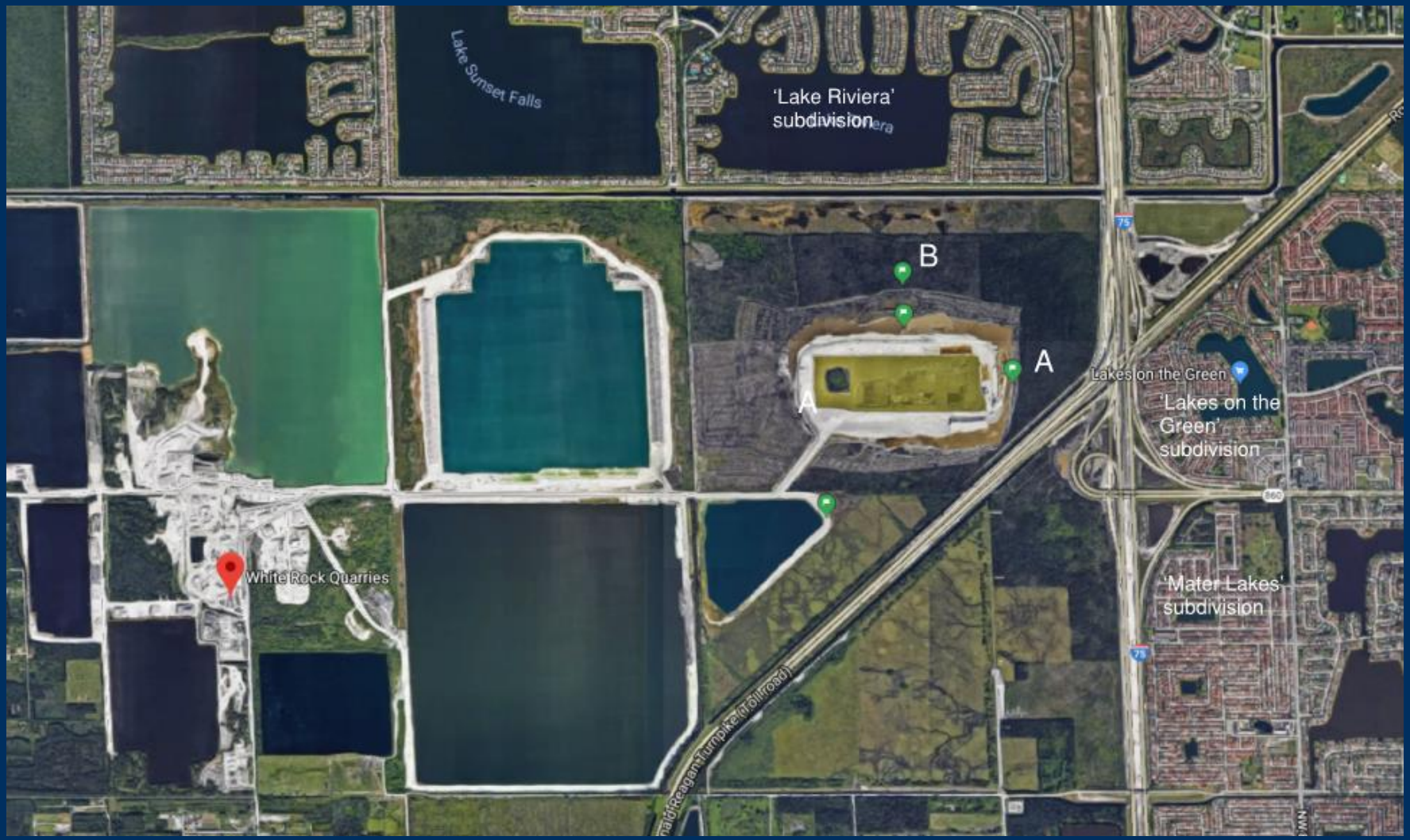
- ***2.2 Effect of Nonblasting Sources on Residential Structures***
  - Construction practices, material curing and aging, minor settlement cause significant strains.
  - Natural events – thermal fluctuations, humidity, weather, cause significant strains equivalent to blast events measuring over 3.0 in/s PPV

  Discussion suggests that non-blast sources likely contribute more significantly to observed distress in homes adjacent to quarry sites and may likely be the cause of a majority of the damage claimed by homeowners

FSFM Contract FM410 *Mine Blasting Study*

- **3.0 Representative Mines and Data in Florida**
- White Rock Quarries (Vecellio and Grogan, Inc.)
  - 25.937443, -80.399116 Hialeah, FL 33018
- Nearest apparent started quarry pit location adjacent to communities
  - 25.947394, -80.357157 (Location A)
  - 25.952117, -80.363096 (Location B)

FSFM Contract FM410 *Mine Blasting Study*



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- Nearest apparent started quarry pit location adjacent to communities
  - 25.947394, -80.357157 (Location A)
  - 25.952117, -80.363096 (Location B)
  - 1875 feet across Canal to 'Lake Riviera' subdivision
  - 2200 feet across I-75 to 'Lakes on the Green' subdivision
  - 4000 feet across I-75 to 'Mater Lakes' subdivision

FSFM Contract FM410 *Mine Blasting Study*

- 145 Blast Records (2017) and 32 Blast Records (2018)
- PPV and Air Blast values provided (the only data that is required)
  - No Seismograph Reports were obtained.
  - Seismograph locations not reported
  - Specific blast data not reported

Table 3-11. White Rock Quarries Blasting Parameters

Blast Parameter	Count	Minimum	Maximum	Median
Total Explosives Weight in Blast (lbs)	177	515	74,291	46,789
Maximum Holes/8 Millisecond Delay	177	0.5	3	1
Charge Weight/Delay (lbs)	177	247	1,665	557
Scaled Distance ($ft/lb^{0.5}$)	0	N/R	N/R	N/R
Powder Factor (lb/yd^3)	0	N/R	N/R	N/R
Reported Distance to the Nearest Structure (ft)	177	1,704	7,284	3,468

FSFM Contract FM410 *Mine Blasting Study*

- *Blasting records suggest:*
  - *Very active mine, with blasting occurring ~3 times a week*
  - *Perceptible vibration levels would likely be exceeded*
  - *Frequent blast vibrations would be disturbing to some residents.*
  - *The maximum charge per delay is the highest reported in this study and highest WJE has ever seen used.*
  - *The blast location and attenuation characteristics of the geology would need to be known in order to estimate vibration amplitudes at nearby communities.*

FSFM Contract FM410 *Mine Blasting Study*

- White Rock Quarries monitors with 3 seismographs for each blast
  - Maximum PPV (in/s): 0.44

Table 3-12. White Rock Quarries Seismograph Reports

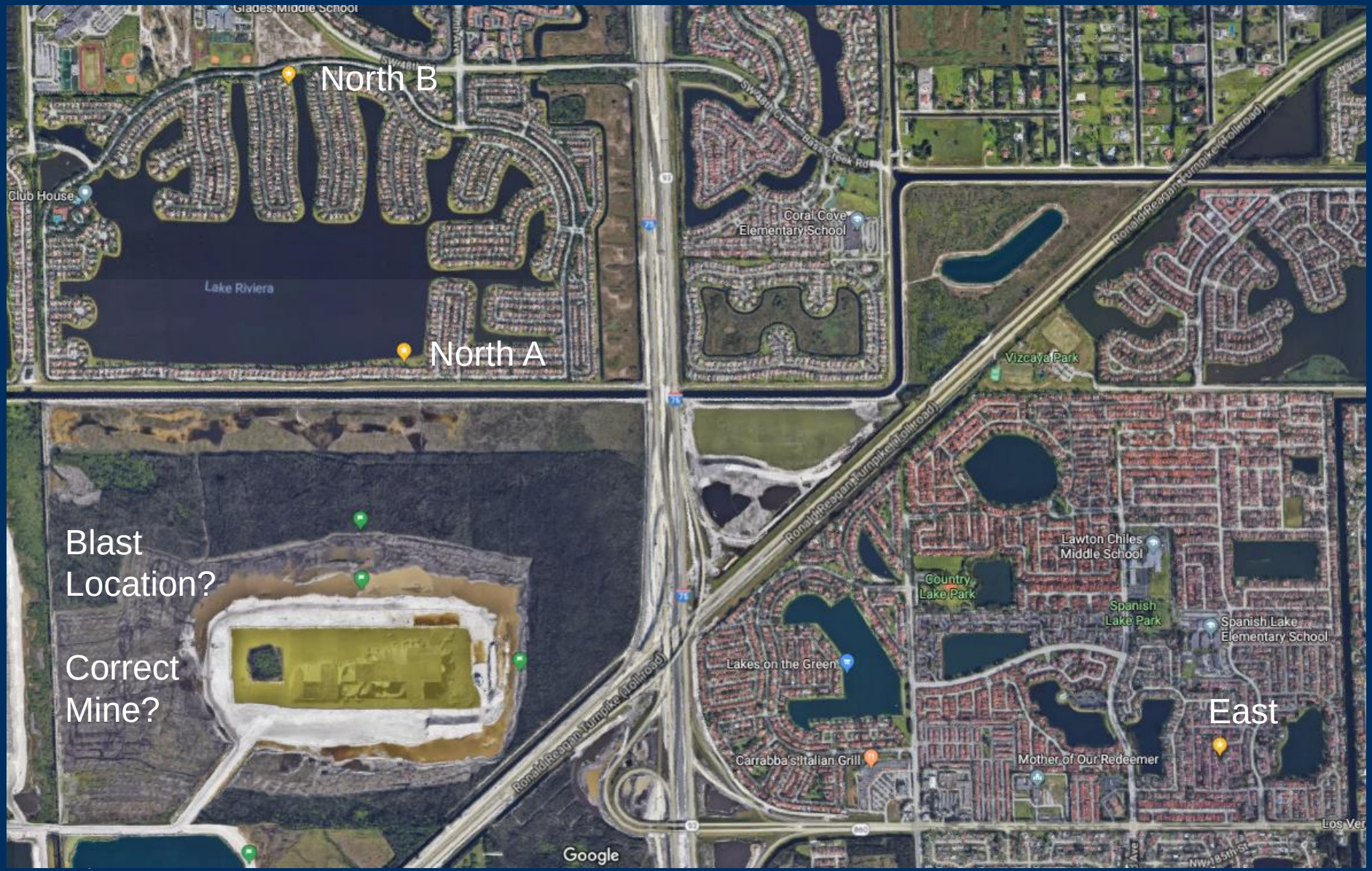
Vibration Parameter	Count	Minimum	Maximum	Median
PPV (in/sec)	244	0.04	0.44	0.16
Airblast (dB)	244	95	137	110

- RESPEC performed an analysis to determine if the seismographs were installed in appropriate locations to monitor blast vibrations within adjacent communities (Appendix G); however, White Rock Quarries did not provide enough information to FSM to complete this analysis.

FSFM Contract FM410 *Mine Blasting Study*

- RESPEC Monitoring
- Two vibration monitor locations for White Rock Quarry
  - North of White Rock Quarries
    - Seismograph A (25.957725, -80.361472)
    - Siesmograph B (25.96698871, -80.36575500)
  - East of White Rock Quarries (25.944566, -80.331138)

FSFM Contract FM410 *Mine Blasting Study*



FSFM Contract FM410 *Mine Blasting Study*

- RESPEC Monitoring
- Two vibration monitor locations for White Rock Quarry
  - North of White Rock Quarries (25.957725, -80.361472)
  - East of White Rock Quarries (25.944566, -80.331138)
- Maximum 0.12 PPV (1.4-44.5 Hz)
- *Data not correlated to Blast Location – needed to determine if limits may have been exceeded at other nearer residences. East monitor is well east of the western edge of the subdivision.*
- Propagation velocity measures 13,200 ft/sec
  - *Typical surface wave velocity of 200 – 1000 ft/s*

FSFM Contract FM410 *Mine Blasting Study*

- ***3.2 Citizen Complaints***
- 360 unique complaints from the White Rock Quarries
  - 42% claimed damage to residences or property
    - 28% interior cracking
    - 15% exterior stucco cracking
    - 23% related to cracking of concrete (Driveways, sidewalks, patios, garage floors)
    - 4% foundation damage
    - 10% pool cracks/leaks
    - 20% from one individual *Questions the validity of data if many of these complaints are from one residence*
- General annoyance, fear of damage, shaking/rattling furniture, startling

FSFM Contract FM410 *Mine Blasting Study*

- **5.0 Blast Vibration Limits and Regulations in Florida**
- 2017 Florida Statutes - Chapter 552
  - FSFM has established ground vibration limits which conform to RI-8507 ABLC
  - Local governments may regulate more strictly than statewide codes
  - Banning explosives for mining construction materials is against the Florida Statutes
- Florida Admin Code FAC 69A02.024
  - Adopts RI-8507 ABLC and Table 8-1.3 of NFPA 495, which is a table of maximum allowable PPV values based on distance. *These two standards are not equal, so this adoption is vague. RESPEC recommends dropping the NFPA 495 reference*
  - Ground vibrations should be measured at nearest building that is not owned or leased by the mining operation, or one mile in the direction of the nearest building.
  - When use of explosives occurs within 2 miles of an urban development, measurements shall be collected by an independent seismologist
  - Minimum information to be reported is seismograph location, maximum vibration amplitude (PPV) and maximum sound pressure (decibels).
    - *Need frequency information, blast location, blast parameters for proper analysis*

WJE

Lee County Port Authority
Fort Myers Airport
Cemex Phase 3C Expansion

Cemex Phase 3C Expansion - Estimated Vibration Analysis
April 2018

Overhead view of the Site

Adjacent subject properties:

- Southwest Florida International Airport (RSW) Midfield Terminal Complex
- Lee County Port Authority (LCPA) Detention Pond
- Lee County Utilities Green Meadows Water Treatment Plant (WTP)
- Planned Air Traffic Control Tower (ATCT) facility

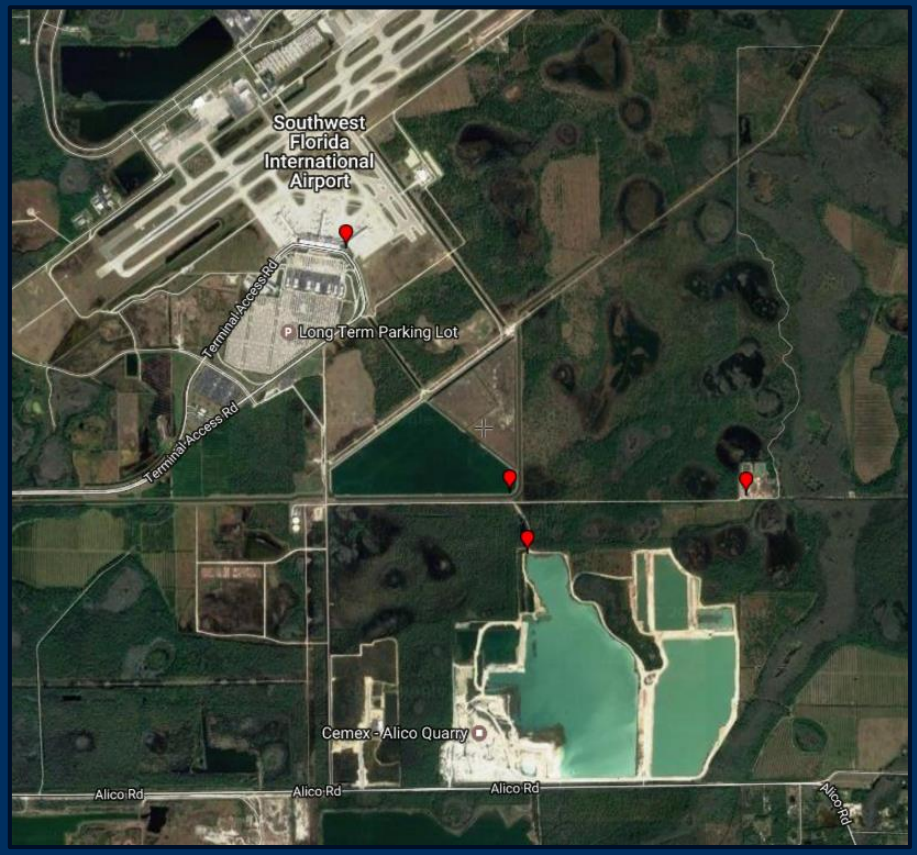
Ongoing Vibration Monitoring

WJE Monitors:

- East wing of the RSW Terminal Building- Ground level (August 2014 - January 2018)
- The executive office on the third floor of the RSW Terminal Building (July 2017- January 2018)
- Southeast corner of the LCPA Detention Pond (July 2017- January 2018)

GeoSonics-CEMEX Monitor

(Green Meadows Seismograph)



Recorded Waveforms

August 7, 2017 12:06 pm

- RSW Terminal Building-Ground level

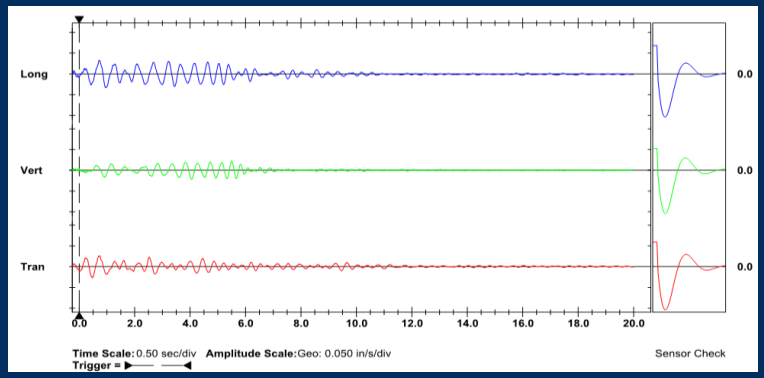
	Tran	Vert	Long	
PPV	0.027	0.022	0.033	in/s
ZC Freq	2.1	2.4	1.9	Hz

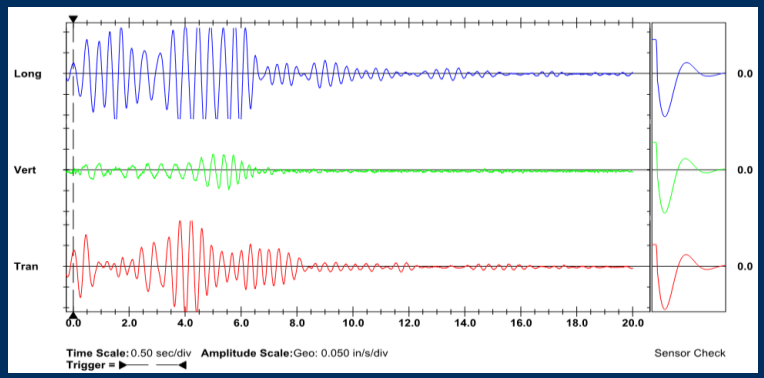
- RSW Terminal Building- Third floor

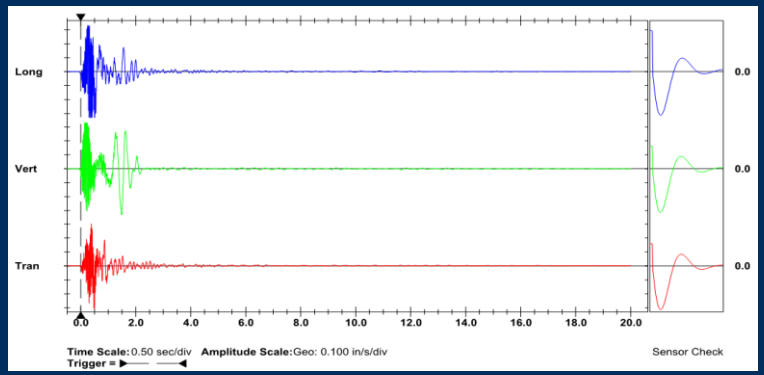
	Tran	Vert	Long	
PPV	0.133	0.048	0.140	in/s
ZC Freq	2.5	2.9	2.6	Hz

- Southeast corner of Detention Pond

	Tran	Vert	Long	
PPV	0.312	0.423	0.503	in/s
ZC Freq	11.5	38	34	Hz







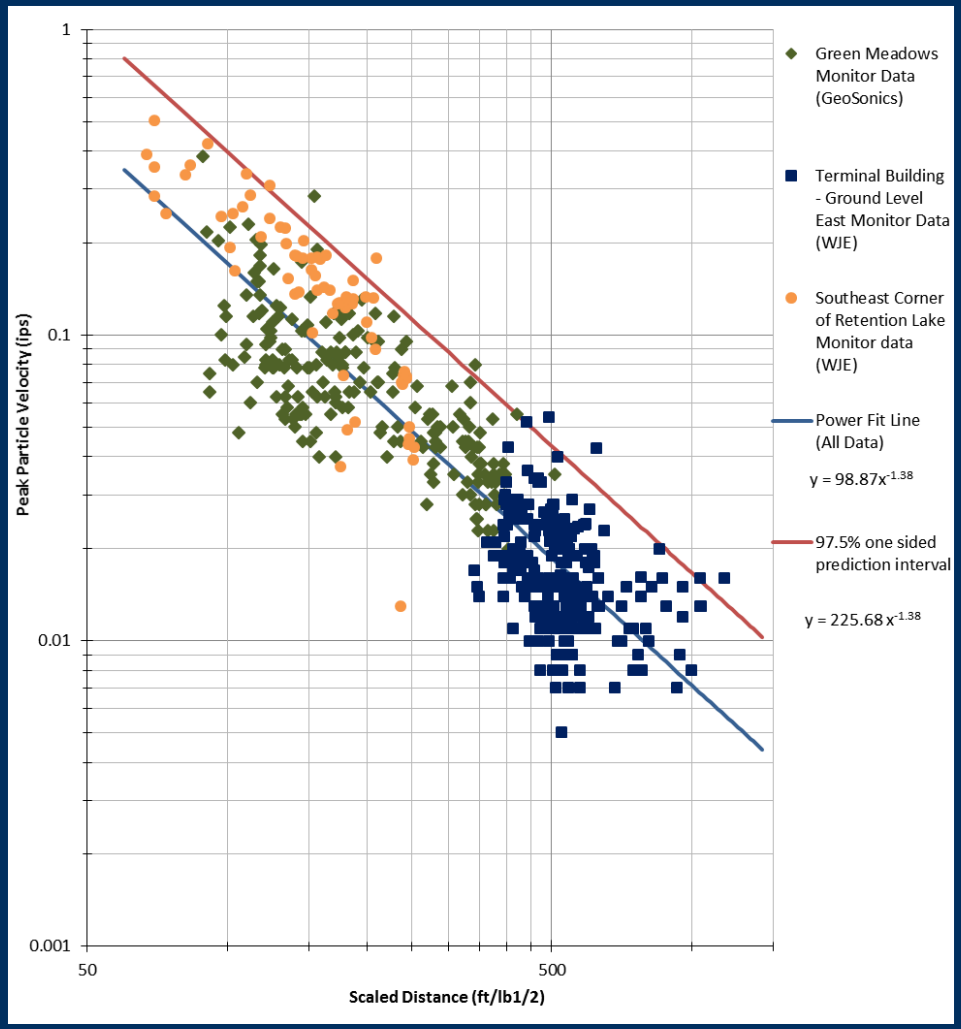
Attenuation Characteristics for Blast-related Ground Vibrations on the Site

- WJE used vibration data collected and analyzed to-date
- 97.5% one-sided prediction interval was utilized in the analysis

$$PPV\ (\ 97.5\%\ PI) = 225.68 * Scaled\ Distance^{-1.38}$$

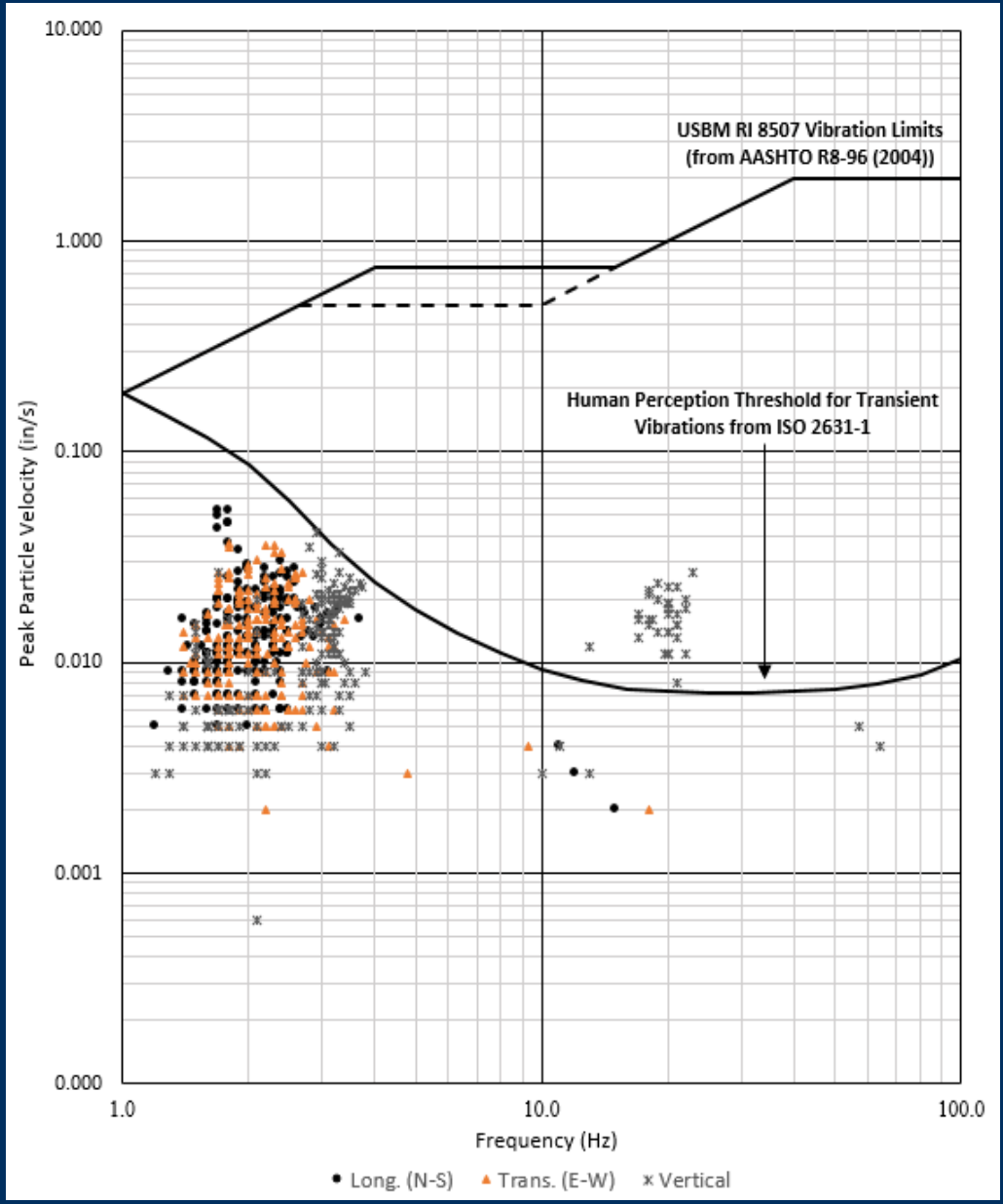
$$Scaled\ Distance = \frac{Distance}{\sqrt{Blast}}$$

- Where PPV (ips),
- Scaled Distance (ft/lb$^{1/2}$),
- Distance (ft),
- Blast represents blast loading size (lbs/delay)



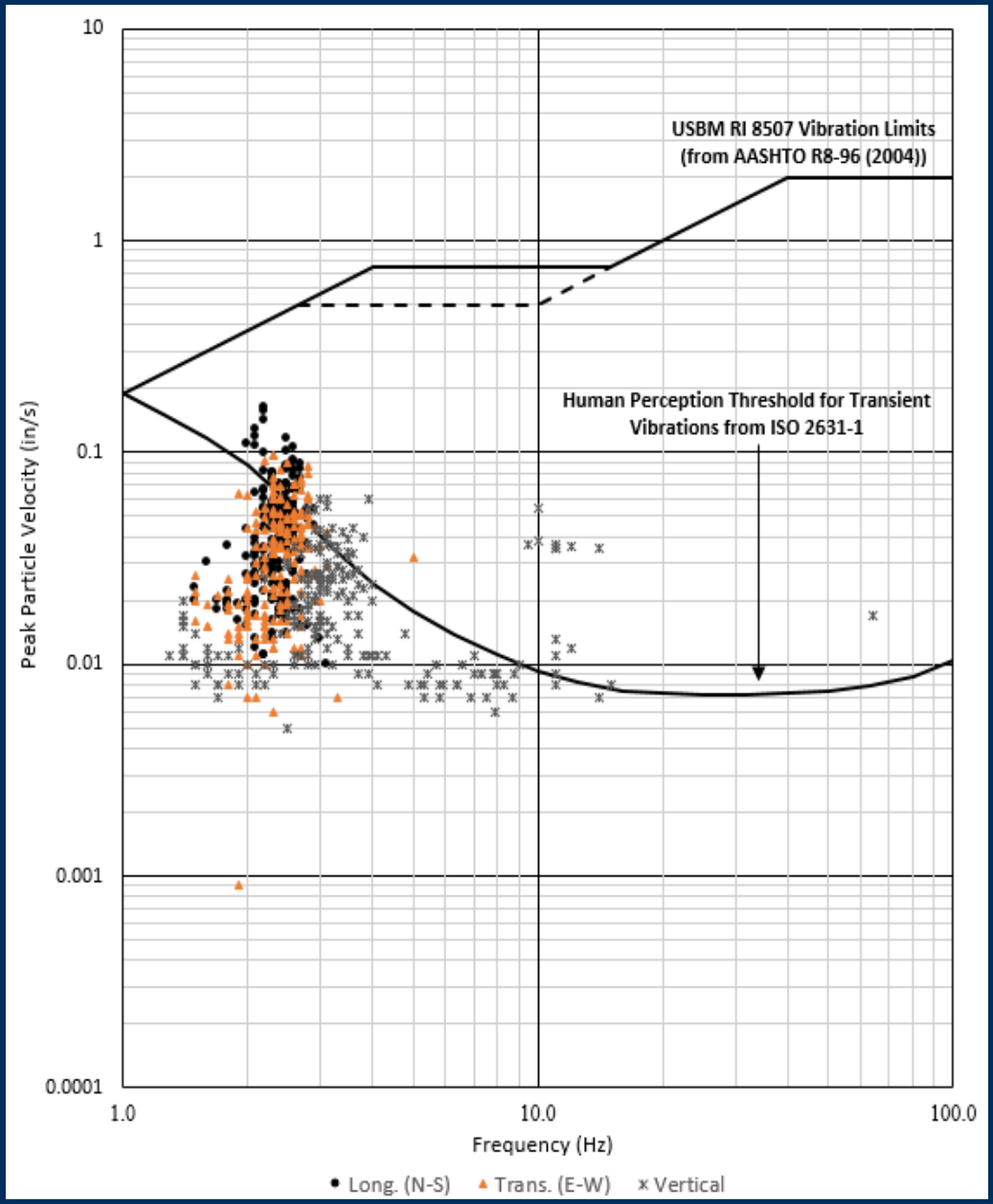
Vibration Compared to Reference Limits

RSW Terminal Building - Ground level



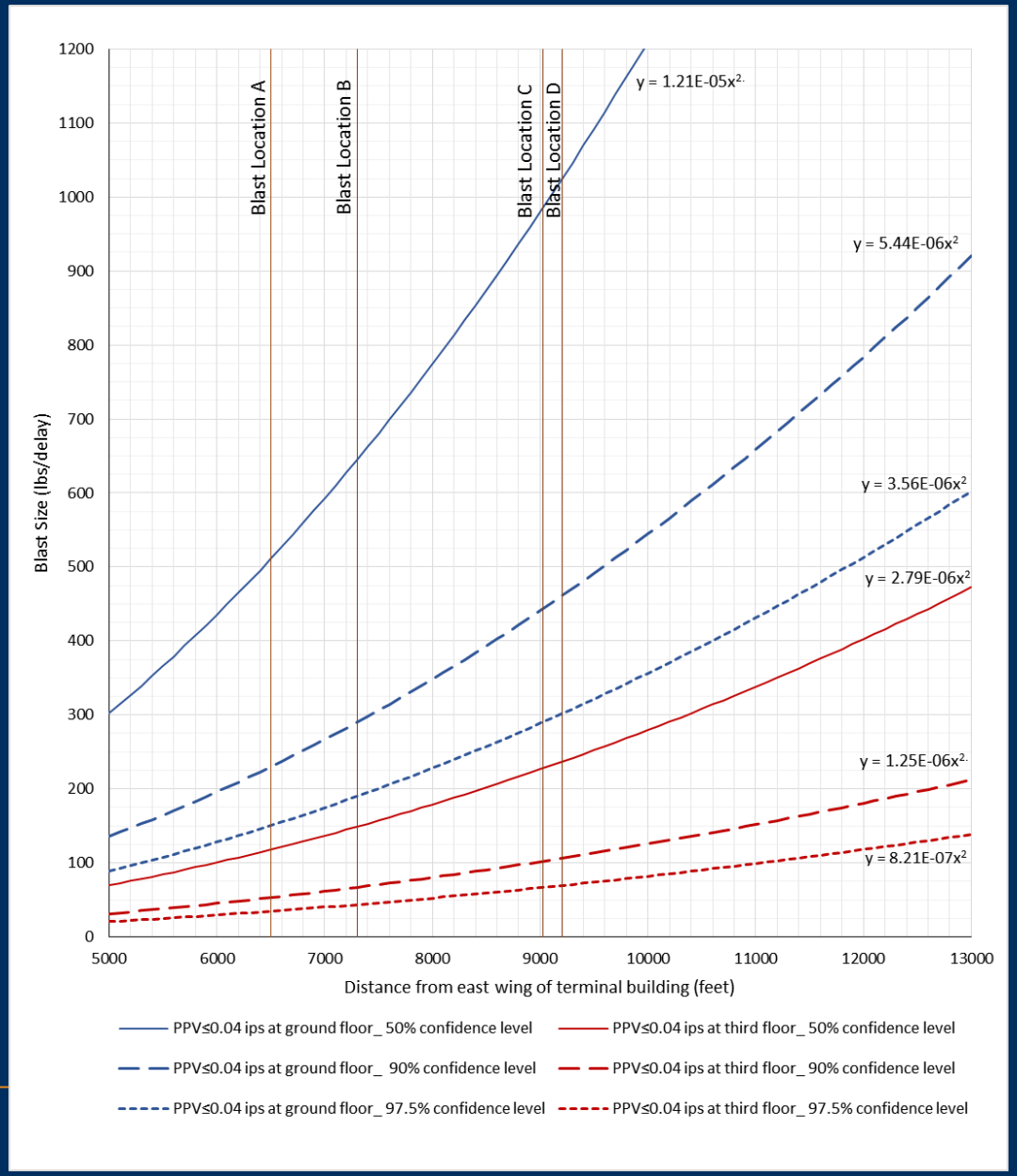
Vibration Compared to Reference Limits

RSW Terminal Building - Third level



Estimated Blast Sizes for Non-Perceptible Vibrations at Terminal Building

- Maximum blast sizes estimated as a function of distance
- Required blast sizes, for non-perceptible vibrations, are significantly below the average blast loading size reported during our monitoring period



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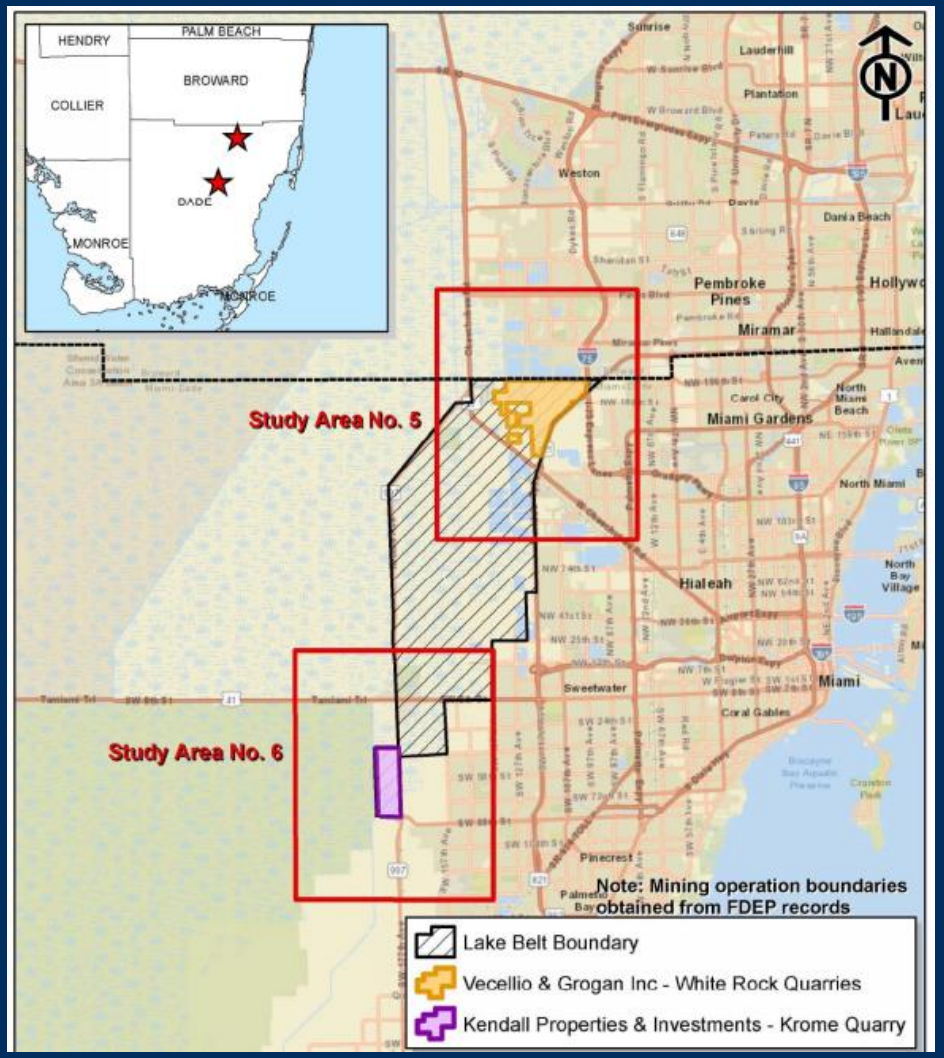
Evaluating Quarry Blasting Locations

Questions from Blasting Advisory Board

- How far can the energy wave travel underground?
- How far can the energy wave travel through water?
- How much does the energy wave diminish over distance/time?
- How can differences in strata affect the energy wave?
  - Do we have that condition locally?

Questions from Blasting Advisory Board



Peat Surficial Soils

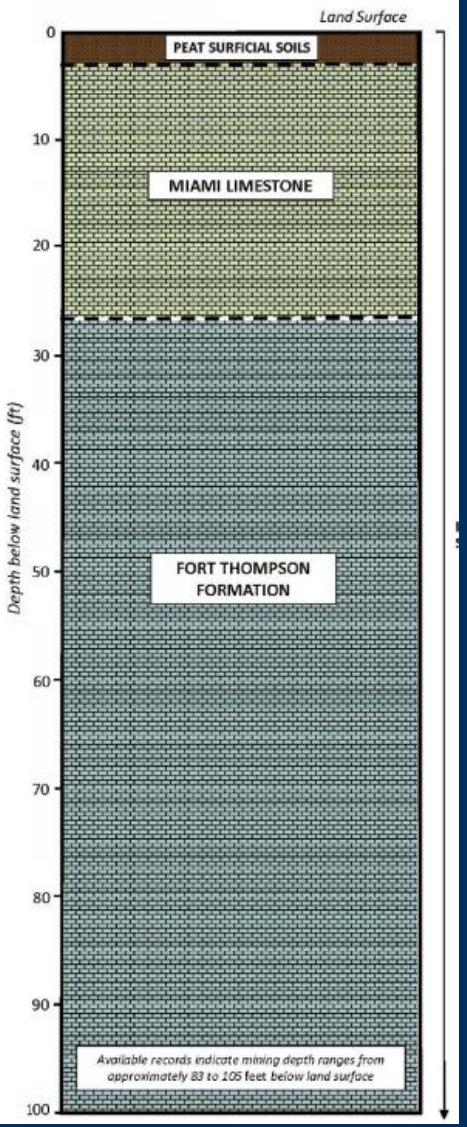
Generally, highly disturbed and altered organic rich (peat) soils which vary in thickness due to soil deposition to maintain structures above the seasonal high water table.

Miami Limestone

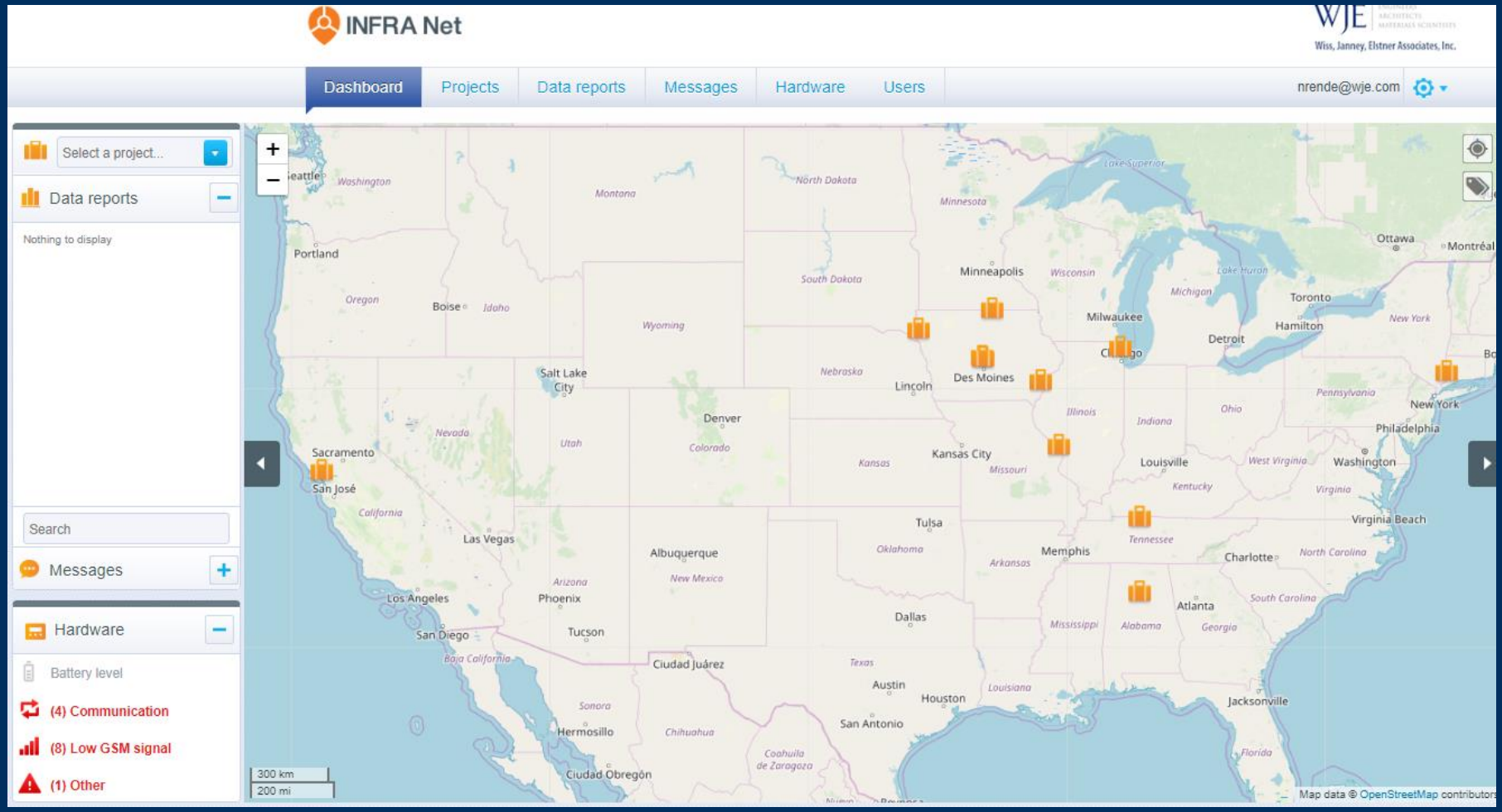
Generally, occurs at, or very near to, land surface and consists of two facies: an oolitic-rich facies which formed under high energy conditions similar to those in present day Bahamas and a bryozoan facies which formed under lower energy, lagoon-type environment. The higher energy conditions of the oolitic facies is evidenced by pronounced cross-bedding commonly observed in exposures. Generally white to orangish gray, poorly to moderately indurated, sandy, limestone with scattered concentration of fossils.

Fort Thompson Formation

Generally, composed of alternating fresh-water and marine marls and limestones with sand, shell marl, sandstones present. Fluctuations in water level elevations reportedly caused increased cementation with calcite, hardening the rock and making the unit a significant source of aggregate.



Sigicom C12 Live Mode Demo



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Questions?

- Nathaniel S. Rende (NRende@wje.com)