Objective data proves trains run fast at night and vibrations are getting worse

Jeff Parke, DVM, Montlake neighborhood, Seattle

Introduction:

I am beginning this essay at 5 AM on Saturday morning Dec 3. It isn't my choice to be up at this hour; I was jolted out of my bed earlier by vibrations.

I am trying to remember I can be a good person. Right now, I resemble a zombie. And, I'm challenged to record some objective interpretations on objective terms.

I want to say I am writing this on my own, for me and for others to reflect on. I don't intend to represent my neighbors or spouse in the opinions expressed at the end.

The Issue:

I became aware of Sound Transit (ST) tunnel noises in my neighborhood November 9th and 10th. This happened to a number of neighbors about the same time and ST immediately scheduled a Nov 15 meeting to tell us how they were going to take care of things. For a number of reasons I immediately was concerned by what I heard there. For me, the biggest concerns were that no serious efforts to study the issues were part of the plans. Ever since, I have spent hours and now days of effort in an escalating campaign to nudge ST in the direction of human factors, engineering and scientific analysis of what is a very serious problem for me, I have heard for a number of neighbors, and I think for all of us who care about public transportation construction efforts in Puget Sound.

Methodology of the present paper:

I was fortunate to make contact early in this process with a group of scientists at the University of Washington Seismology group (Pacific Northwest Seismology Network). The PNSN has the main mission of tracking earthquakes and providing an early warning system for all of us. Part of that includes increasing urban densities of earthquake monitors. I asked and was granted the privilege of making my home part of that network. The URL for the sensor in my basement is:
http://earthquake.usgs.gov/monitoring/netquakes/station/QEMI_UW_--/

This earthquake sensor (QEMI) is a very sensitive, Swiss made instrument. It can detect minute vibrations, such as tapping as on an iPad or other touch screen. It picks up footsteps in the house, airplanes flying overhead, trucks and cars outside on the street. It is normally intended to ignore these things and look for Richter Scale 3 and above earthquakes. It is an "event" based device that dumps a large amount of data over the Internet when it thinks something significant has happened. When earthquakes are sensed elsewhere, seismometers like QEMI can be remotely requested to dump their data to see if they "saw" the smaller magnitude vibrations from a remote earthquake.

Because the UW Seismology folks have wide interest in a variety of seismic signals, I was able to glean precious moments of their time to remotely capture various environmental and what I believed to be ST train events. I've been trying to be sure ST test runs (2 that I know of) and as many environmental and ST train related data records

as possible have been retrieved from the device. It became clear in a short while that the ST train events were the largest signals QEMI is getting, and that they had a particular signature, temporally and in the frequency domain.

On Dec 2 I met with the UW group and we discussed the situation. They are very busy and have a big meeting to attend. It was felt that the pattern of ST signals showed an increase in magnitude this last week. Later that day, commands were sent to QEMI to lower its trigger threshold to look for larger train events.

Throughout the later part of the day and night of Dec 2-3, 10 ST train events were triggered for automatic display on the QEMI web site and central server data capture. Two other QEMI events from earlier are part of this particular discussion. All are found appended.

The automatically-created GIF pictures from the server are only 2 minutes' worth near the trigger point. The real data is much longer and at 200 samples/sec/channel, with 3 channels, it comprises many megabytes at this time. It is stored in a very arcane format on computer servers that are not easy for mere mortals to access. I am awaiting a chance to analyze that as well. I hope ST is too.

This is a very rough analysis, basically what one can do "by eye" alone.

Analysis:
All of the QEMI data is UTC. This time of year, that is 8 hours ahead of PST. Subtract 8 hours to get local time. Each of the plots is about 2 minutes long. The time scale is constant among them. Major ticks occur each 10 seconds. Minor ticks are at one second.

The time for the loudest signals of the train passage is approximately 45 seconds in each of these. I eyeball that as the time of crescendo-descrescendo magnitudes on both sides of the peak shock waves. The time between the couplets of peak shock waves is quite constant –agreeing with the observed period between "thumps" of about .6-.9 seconds.

There seem to be at least a couple of patterns in this data, which may represent trains going in opposite directions. The predominate pattern is what I will call the "large pair, smaller pair" pattern. My body sensations of this are "thump-thump, [count to 9 or 10], thump-thump". The "thump-thump" seem to take less than one second to happen. When one examines these data for that pattern, one can readily see these pairs of couplets of shock waves, with the number of seconds between them ranging from 8-12 seconds. Most are in the 8-9 second range. This data correlates with my perceived timings very well.

All of this timing information: 45 second passage time, nearly constant times for periodicity of thumps and times between pair of thumps, lead me to conclude these trains are all going nearly the same speed. None seem to be traveling half or twice as fast as any of the others. I know that one data record was from a fully loaded train going

maximum daytime speed and assume most which are happening during the daytime are also maximum daytime speed.

Vertical scaling of these GIFs presents problems, because the server automatically scales them according to peak Gal sensed. A Gal, also known as a galileo, is an acceleration of 1cm per second per second (1cm/sec/sec or 1cm/sec^2).

For the purpose of this quick study it is to be noted the vertical scales for these waveforms give us approximate peak shock wave magnitudes. These peak magnitudes are shown below

Waveform ID	**Peak scaling Gal**	
QEMI_UW_--.20111203.002142.TRG.gif	3.661	
QEMI_UW_--.20111203.003210.TRG.gif	3.925	
QEMI_UW_--.20111203.011237.TRG.gif	2.977	
QEMI_UW_--.20111203.025703.TRG.gif	3.767	
QEMI_UW_--.20111203.034705.TRG.gif	4.349	
QEMI_UW_--.20111203.045312.TRG.gif	4.426	
QEMI_UW_--.20111203.062907.TRG.gif	3.145	
QEMI_UW_--.20111203.074030.TRG.gif	4.015	
QEMI_UW_--.20111203.091413.TRG.gif	3.326	
QEMI_UW_--.20111203.124006.TRG.gif	3.868	
	3.7459	(Mean Dec 3 peak Gal)
QEMI_UW_--.20111119.044858.USR.gif	2.731	worst case test run
QEMI_UW_--.20111123.083458.USR.gif	2.138	previous worst case captured passage

The smallest Dec 3 peak magnitude is 3.145, which easily exceeds the Nov 19 worse case test run of 2.731. Several Dec 3 trains produced shock waves more than twice as large as those seen just before Thanksgiving. The average of Dec 3 peak shock magnitudes, 3.75 Gal, is substantially larger than the previous worst case of 2.14 Gal.

Time of day considerations. QEMI_UW_--.20111203.062907.TRG.gif, QEMI_UW_--.20111203.074030.TRG.gif, QEMI_UW_--.20111203.091413.TRG.gif, QEMI_UW_--.20111203.124006.TRG.gif and QEMI_UW_--.20111123.083458.USR.gif all happen between the hours of 10:29 PM PST and 4:40 AM PST

Sensation threshold:

I don't have the original literature for it to cite, but one neighbor who works at Los Alamos Labs and the scientists at the University have all said these ST related seismic events are above what is considered the ability of the human body to feel or detect. I believe that threshold is near 1.5-2 Gal. I can say with certainty something in that range seems near my own value from the last three weeks of making notes of sensations paired with objective data I manage to see several days later. And, neighbors have contacted me

about feeling trains at a specific time, which yields the same result – QEMI records train passages when people say they feel them.

Conclusions:

• ST trains are producing shock waves in the earth that well exceed the thresholds of human perception, even at a long distance (QEMI is about 400 feet from the ST tunnel).

• Sound Transit trains passing underneath the "Boyer Basin" neighborhood of Montlake are producing more ground vibrations than they were 10 and 14 days ago.

• All of these train passages in this study are from trains traveling at the same or similar speeds. This may be the second of three speeds the train can travel at or might be the maximum speed.

• Some Sound Transit mining trains are not running at low speeds during the night hours. Consequently, some produce large shock waves during middle of the night.

• These imprecise GIF plots of data indicate there must be reasons besides train speed for the increase in ground vibrations. These reasons may be considered when noting the increased levels of vibrations present between the peak shock waves. Vibrations occurring between peaks are assumed to be caused by train wheels on track itself.

Discussion:

First, this is a very small sample. Quieter/slower trains overnight might well have not triggered QEMI data captures. Comparison data from earlier periods is currently hung up with the obstacles involved in retrieving it all and properly examining it. Doing this right is a huge project, one that I would never be able to undertake alone. However, insofar as this data is from the worst events captured in the late Dec 2 – early Dec 3 period, and my previous data was correlated with the worst shock waves I felt or from the worst that ST could intentionally create during a test, I think this little study is valid.

I need to put my zombie hat on now. ST officials have uniformly dismissed repeated urgings, questions and suggestions about their need to take this more seriously. City officials have done everything they can to wash their hands of this affair. These things are well documented in the public record.

For two reasons, I believe ST oversight officials have lost track of reality regarding this.

One, they claimed that the trains are running slower at night. This data refutes that claim. To give them some credit, vibration events did seem to decrease at night, presumably because some train operators paid heed. Does the ST public relations effort represent falsehoods, or have ST officials lost control over the construction crew doing the actual digging and putting up with what must be an enormous racket down there

underground? Either way, it is not a good situation for me and my neighbors trying to sleep.

Two, by announcing knee-jerk mitigation efforts with little to no studies aimed at understanding the causes of this tunnel-to-surface noise/vibration problem, I believe ST is setting themselves up for worse problems. The latest mitigation efforts, which all make sense intuitively, are simply a somewhat more focused version of what they tried and apparently failed at earlier in this tunnel project in the Shelby-Hamlin area of Montlake. The tests being done in the "Boyer Basin" area appear to me to be a repeat of the sporadic sampling done of residences in Shelby-Hamlin. I would not be surprised the data is being collected by the same engineering firm. I've already heard via an email sent to a neighbor ST may be heading for similar conclusions.

ST paid good public money for a study in the Shelby-Hamlin neighborhood that has lots of pretty graphs, prettier than the ones in this short paper, but the first conclusion of that study is that the data was far below what human beings can perceive. That may be well true, and, I believe it means they studied the wrong data! If they ever come to me and start trying to convince me I can't feel what I feel, I already can help guide them to reality.

I believe the City is misguided in its approach to this problem. Regulations notwithstanding, this is a construction project that is producing significant impact on citizens trying to enjoy private life or work in their own homes. Night time construction regulations must be looked at from their intention in this case, not from the perspective of what limiting language they may have about air-transmitted sounds versus shock waves that turn structures into monstrous extra-low-frequency drums. It is time for the city to represent us in examining and elucidating what constitutes abnormal night time vibration activity in the ground beneath our feet.

It is time for Sound Transit to dedicate the resources, i.e. more of our hard-fought tax dollars, to getting this truly figured out with appropriate levels of staffing and instrumentation. Then come up with a definitive solution to the problem.

I'm hoping to be proven wrong with this worry, but I am increasingly prone to skepticism that the objective data will change enough with a bunch of thicker rubber pads, wooden rail ties and more grinding and straightening on what may be considered decent rails for coal miners. We already know having the trains go as slow as possible helps, so maybe will need to be done 24/7.

The data gathered so far from QEMI must be analyzed further regarding my last conclusion, and here is the short version of what it could mean. Track material being used is may be substandard for this particular situation. Mining train wheels themselves may be suspect. Loads and train speeds in these imperfect conditions may need to be kept as slow as possible.

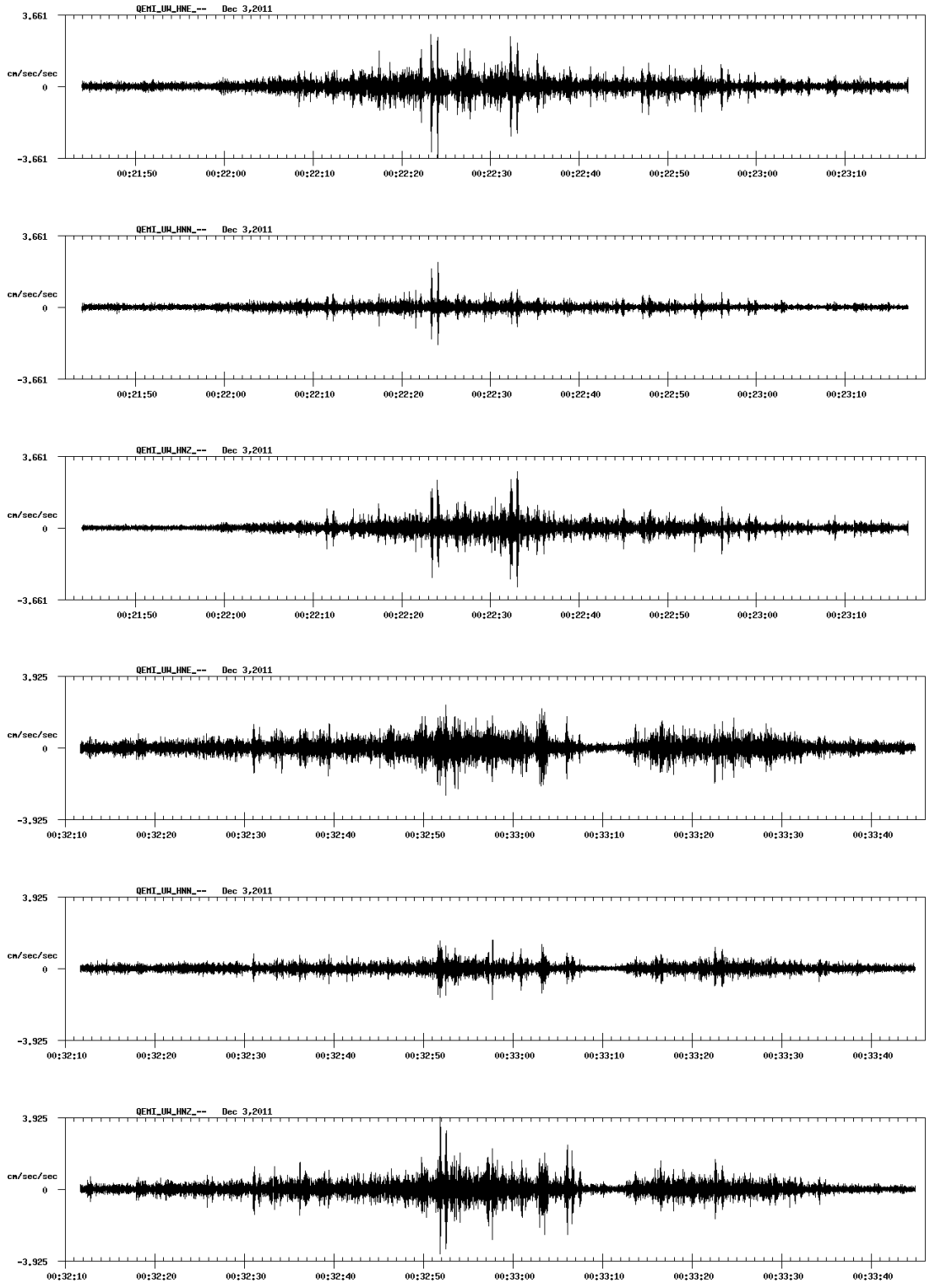
Finally, there may well be conditions in the Montlake situation that have impact everywhere that ST digs these tunnels. Some neighbors speculate about a large underground storm sewer which may be acting like a big echo chamber for these vibrations. If that is worthy of consideration, the notion that the tunnels themselves are large hollow tubes and could be serving to make these vibrations worse surely also needs careful study for mitigation efforts. Examination of ST records could help establish if the increase in vibrations seen here coincide with the second tunnel being dug in parallel with the first during the week ending Dec 3.

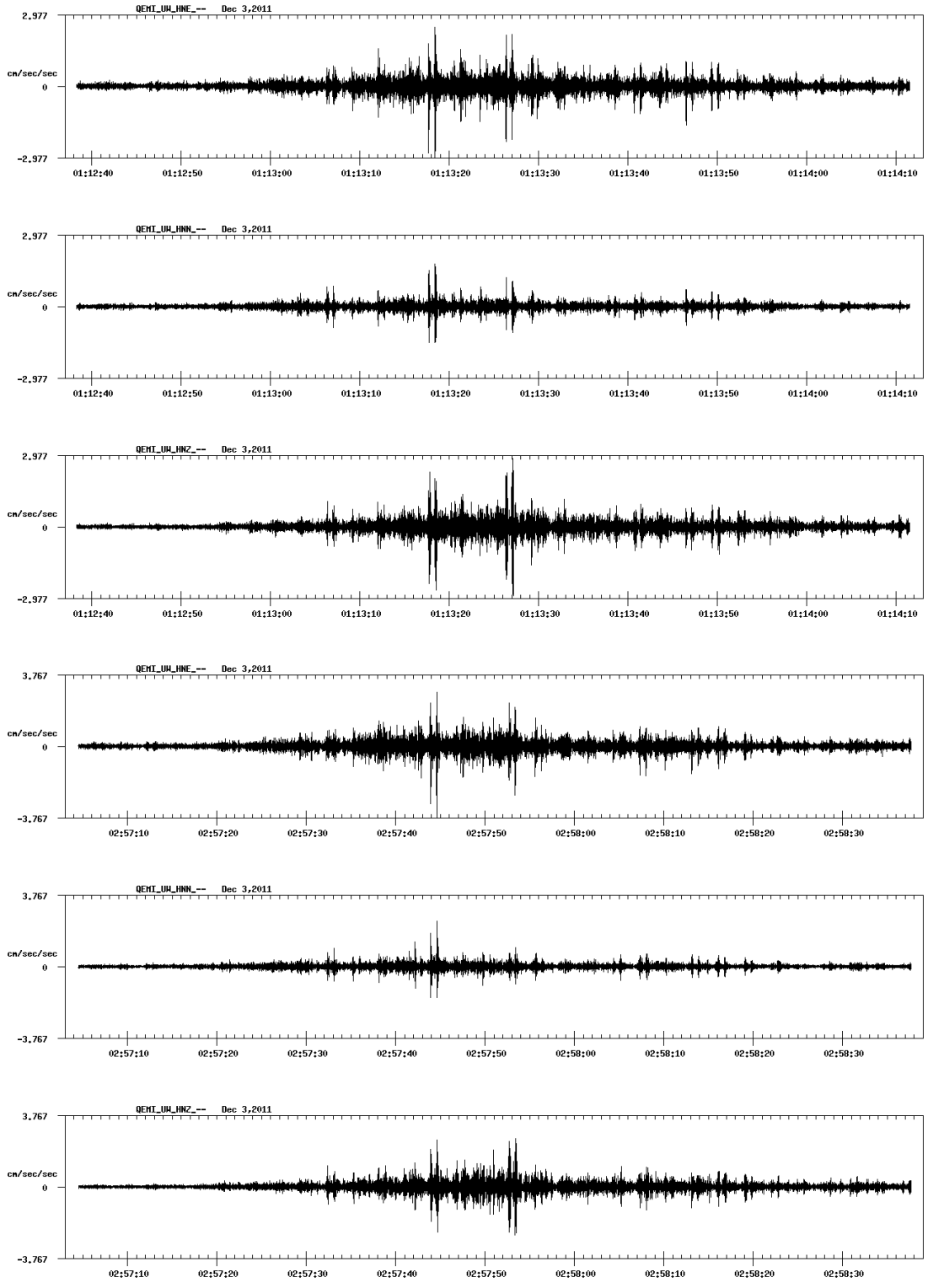
NOW is the time for ST and the City to really look at this situation. Put vibration sensors in the ground and study it. Communicate and cooperate with citizens affected. Figure out what problems really are and fix them.

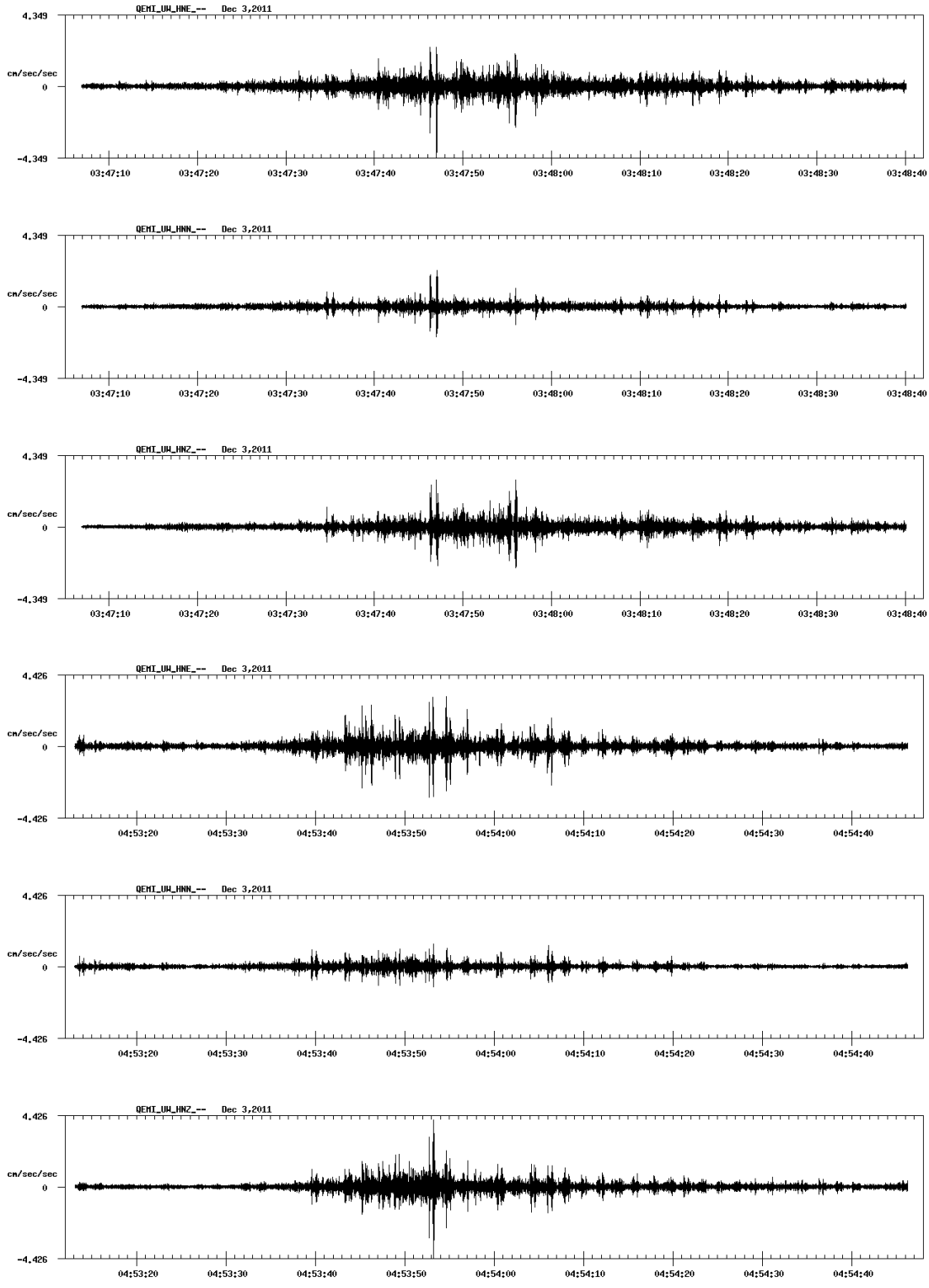
It will be too late two or three years from now if this has degenerated to a series of lawsuits about loss of property values [affected residences would already lose money if they had to sell their homes right now], or breach of contract [easement agreements stipulate that normal operation is not anticipated to cause noise or vibration noticeable upon the property].

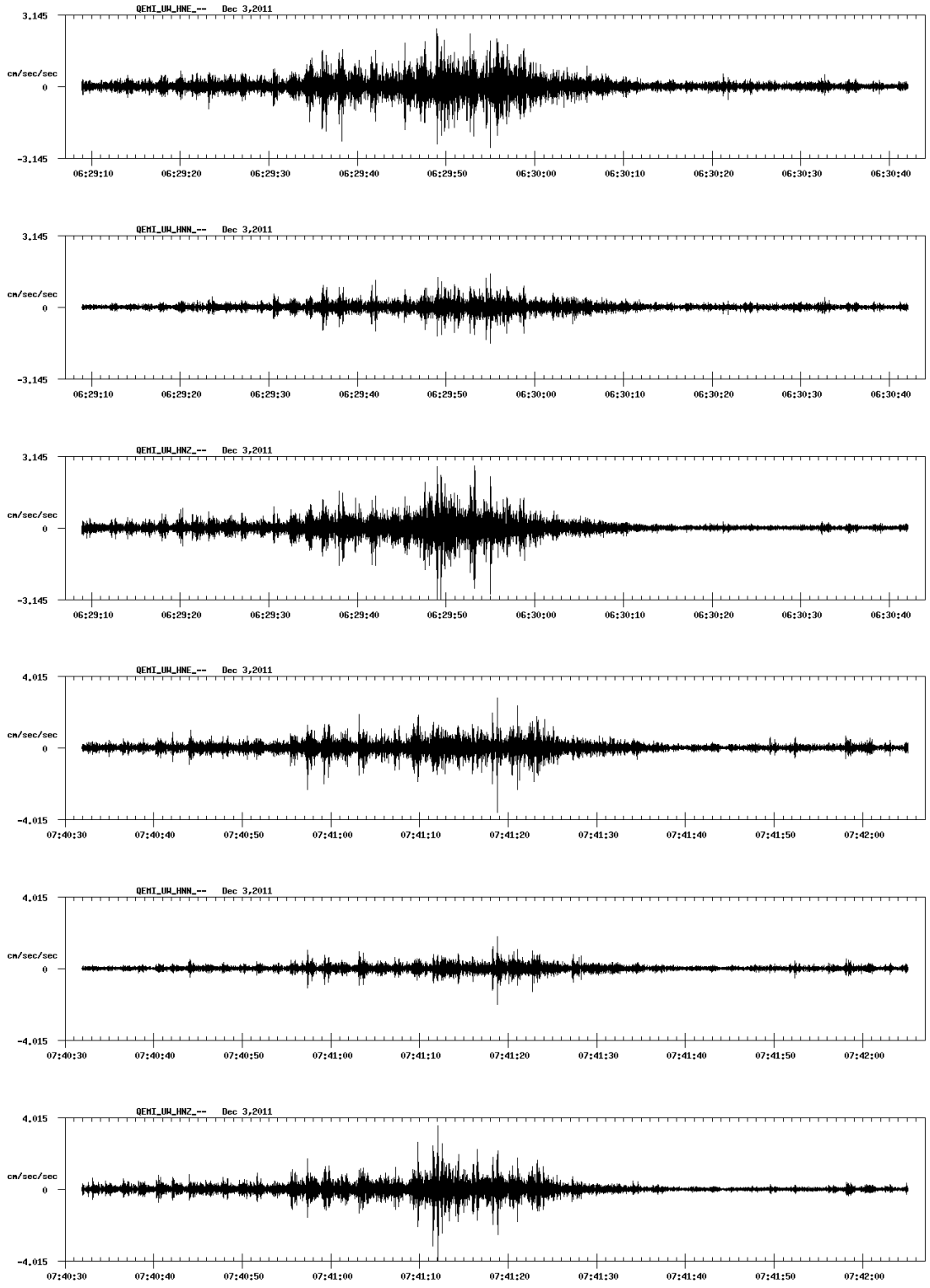
DATA:

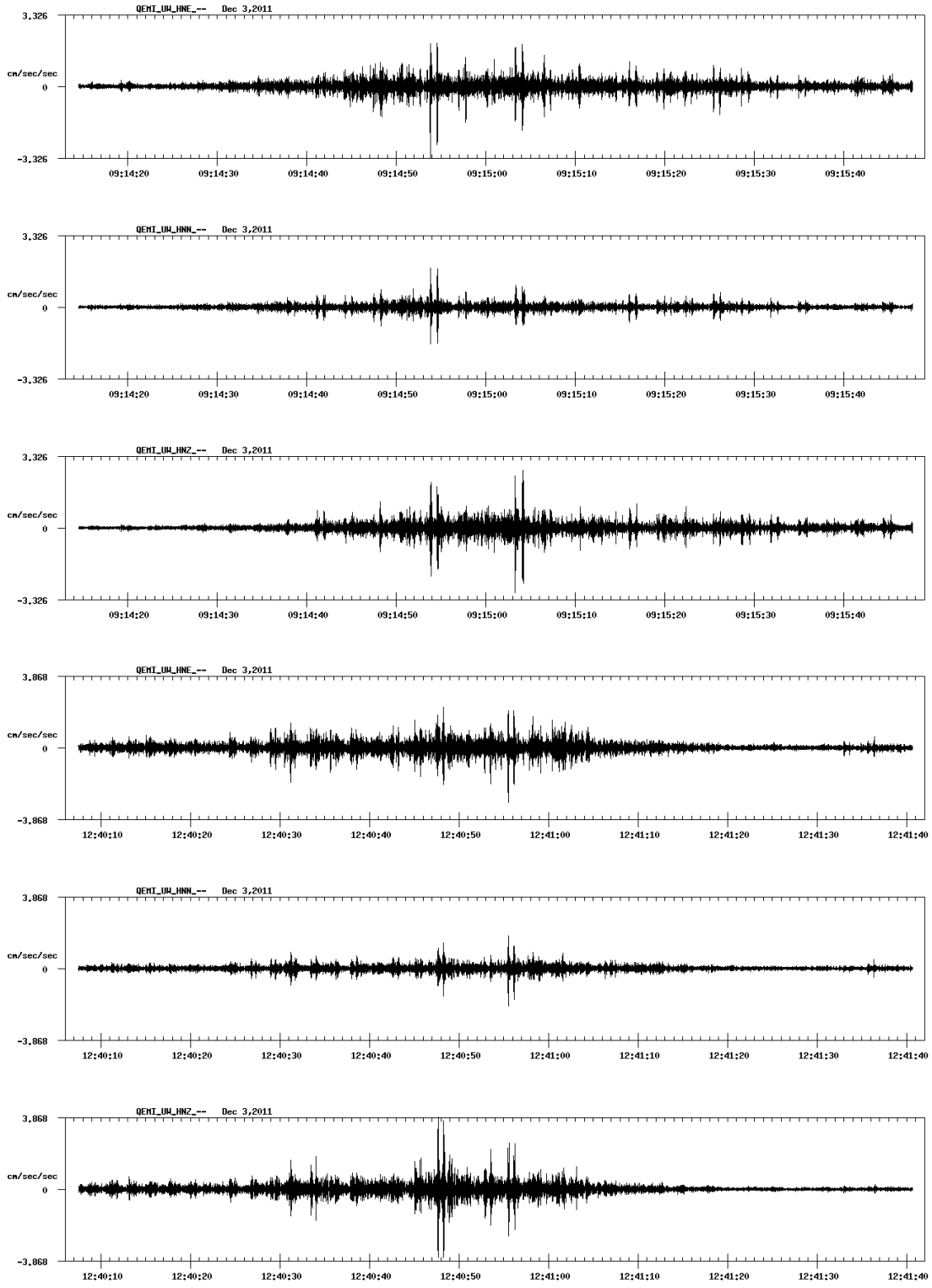
These next ten waveforms are from Dec. 2 through Dec 3, PST


QEMI_UW_HNE_-- Dec 3,2011
3.661
cm/sec/sec
0
-3.661
00:21:50
00:22:00
00:22:10
00:22:20
00:22:30
00:22:40
00:22:50
00:23:00
00:23:10
QEMI_UW_HNN_-- Dec 3,2011
3.661
cm/sec/sec
0
-3.661
00:21:50
00:22:00
00:22:10
00:22:20
00:22:30
00:22:40
00:22:50
00:23:00
00:23:10
QEMI_UW_HNZ_-- Dec 3,2011
3.661
cm/sec/sec
0
-3.661
00:21:50
00:22:00
00:22:10
00:22:20
00:22:30
00:22:40
00:22:50
00:23:00
00:23:10
QEMI_UW_HNE_-- Dec 3,2011
3.925
cm/sec/sec
0
-3.925
00:32:10
00:32:20
00:32:30
00:32:40
00:32:50
00:33:00
00:33:10
00:33:20
00:33:30
00:33:40
QEMI_UW_HNN_-- Dec 3,2011
3.925
cm/sec/sec
0
-3.925
00:32:10
00:32:20
00:32:30
00:32:40
00:32:50
00:33:00
00:33:10
00:33:20
00:33:30
00:33:40
QEMI_UW_HNZ_-- Dec 3,2011
3.925
cm/sec/sec
0
-3.925
00:32:10
00:32:20
00:32:30
00:32:40
00:32:50
00:33:00
00:33:10
00:33:20
00:33:30
00:33:40

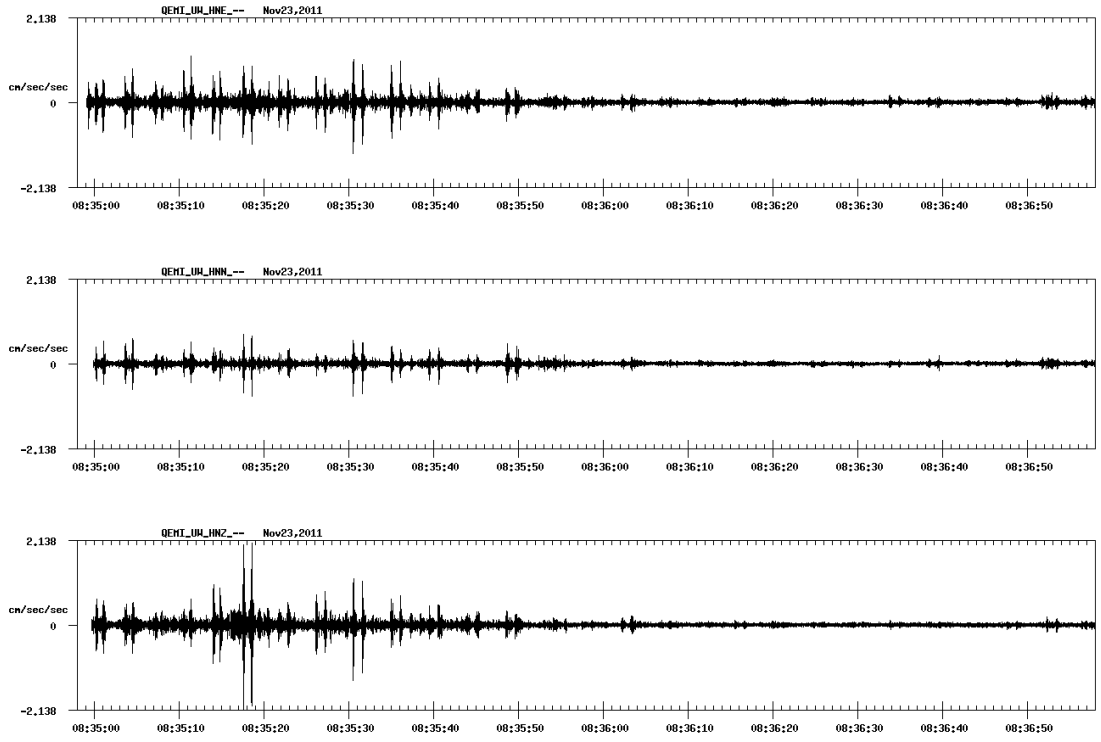

QEMI_UW_HNE_-- Dec 3,2011
2.977
cm/sec/sec
0
-2.977
01:12:40
01:12:50
01:13:00
01:13:10
01:13:20
01:13:30
01:13:40
01:13:50
01:14:00
01:14:10
QEMI_UW_HNN_-- Dec 3,2011
2.977
cm/sec/sec
0
-2.977
01:12:40
01:12:50
01:13:00
01:13:10
01:13:20
01:13:30
01:13:40
01:13:50
01:14:00
01:14:10
QEMI_UW_HNZ_-- Dec 3,2011
2.977
cm/sec/sec
0
-2.977
01:12:40
01:12:50
01:13:00
01:13:10
01:13:20
01:13:30
01:13:40
01:13:50
01:14:00
01:14:10
QEMI_UW_HNE_-- Dec 3,2011
3.767
cm/sec/sec
0
-3.767
02:57:10
02:57:20
02:57:30
02:57:40
02:57:50
02:58:00
02:58:10
02:58:20
02:58:30
QEMI_UW_HNN_-- Dec 3,2011
3.767
cm/sec/sec
0
-3.767
02:57:10
02:57:20
02:57:30
02:57:40
02:57:50
02:58:00
02:58:10
02:58:20
02:58:30
QEMI_UW_HNZ_-- Dec 3,2011
3.767
cm/sec/sec
0
-3.767
02:57:10
02:57:20
02:57:30
02:57:40
02:57:50
02:58:00
02:58:10
02:58:20
02:58:30


QEMI_UW_HNE_-- Dec 3,2011
4.349
cm/sec/sec
0
-4.349
03:47:10
03:47:20
03:47:30
03:47:40
03:47:50
03:48:00
03:48:10
03:48:20
03:48:30
03:48:40
QEMI_UW_HNN_-- Dec 3,2011
4.349
cm/sec/sec
0
-4.349
03:47:10
03:47:20
03:47:30
03:47:40
03:47:50
03:48:00
03:48:10
03:48:20
03:48:30
03:48:40
QEMI_UW_HNZ_-- Dec 3,2011
4.349
cm/sec/sec
0
-4.349
03:47:10
03:47:20
03:47:30
03:47:40
03:47:50
03:48:00
03:48:10
03:48:20
03:48:30
03:48:40
QEMI_UW_HNE_-- Dec 3,2011
4.426
cm/sec/sec
0
-4.426
04:53:20
04:53:30
04:53:40
04:53:50
04:54:00
04:54:10
04:54:20
04:54:30
04:54:40
QEMI_UW_HNN_-- Dec 3,2011
4.426
cm/sec/sec
0
-4.426
04:53:20
04:53:30
04:53:40
04:53:50
04:54:00
04:54:10
04:54:20
04:54:30
04:54:40
QEMI_UW_HNZ_-- Dec 3,2011
4.426
cm/sec/sec
0
-4.426
04:53:20
04:53:30
04:53:40
04:53:50
04:54:00
04:54:10
04:54:20
04:54:30
04:54:40


QEMI_UW_HNE_-- Dec 3,2011
3.145
cm/sec/sec
0
-3.145
06:29:10
06:29:20
06:29:30
06:29:40
06:29:50
06:30:00
06:30:10
06:30:20
06:30:30
06:30:40
QEMI_UW_HNN_-- Dec 3,2011
3.145
cm/sec/sec
0
-3.145
06:29:10
06:29:20
06:29:30
06:29:40
06:29:50
06:30:00
06:30:10
06:30:20
06:30:30
06:30:40
QEMI_UW_HNZ_-- Dec 3,2011
3.145
cm/sec/sec
0
-3.145
06:29:10
06:29:20
06:29:30
06:29:40
06:29:50
06:30:00
06:30:10
06:30:20
06:30:30
06:30:40
QEMI_UW_HNE_-- Dec 3,2011
4.015
cm/sec/sec
0
-4.015
07:40:30
07:40:40
07:40:50
07:41:00
07:41:10
07:41:20
07:41:30
07:41:40
07:41:50
07:42:00
QEMI_UW_HNN_-- Dec 3,2011
4.015
cm/sec/sec
0
-4.015
07:40:30
07:40:40
07:40:50
07:41:00
07:41:10
07:41:20
07:41:30
07:41:40
07:41:50
07:42:00
QEMI_UW_HNZ_-- Dec 3,2011
4.015
cm/sec/sec
0
-4.015
07:40:30
07:40:40
07:40:50
07:41:00
07:41:10
07:41:20
07:41:30
07:41:40
07:41:50
07:42:00



Next waveform is the worst previous one we have managed to “capture” with the GIF plot technique, it occurred at 12:35 AM, Nov. 23:



Finally, this last one is from deliberate Sound Transit test runs of a fully loaded train going full speed on the evening of November 18