DRAFT

This report will remain a draft until SR 520 East Landing construction and follow-up noise measurements are completed.

Washington State Department of Transportation

Memorandum

June 20, 2016

TO: Robyn Boyd, Project Engineer
Chris MacDonald, Assistant Project Engineer

FROM: Jim Laughlin, Manager, WSDOT Acoustics, Air Quality and Energy Program
Peter Soderberg, Acoustics and Air Quality Specialist

SUBJECT: SR 520 Noise Analysis: New vs. Old Bridge

Background

The new State Route 520 floating bridge opened to westbound traffic on April 11, 2016. Two weeks later, the bridge's eastbound lanes opened. Soon after the opening of the westbound lanes, Eastside residents living near the highway's east high-rise and landing began expressing concerns that traffic noise from the new bridge is louder than expected. More specifically, most said they hear a loud thumping or clanking noise, apparently as vehicles pass over the new expansion joints that connect the floating bridge and the fixed, east high-rise. Similar complaints, though fewer in number, were made by Madison Park residents living near the new bridge's west high-rise.

The new floating bridge and its connecting on-land highway were built with various features designed to reduce noise levels to nearby homes and businesses. These include grooved, noise-abating pavement, sound walls along both sides of the Eastside corridor, and encapsulated expansion joints that muffle noise on the exposed underside of the east and west high-rises as vehicles pass between the floating bridge and the high-rises. (Sound walls along the south side of SR 520 near the Medina shoreline will be completed in the fall.)

In response to the public's reports of unexpected noise levels from the new bridge, the SR 520 Construction office requested noise measurements to be collected during daytime and nighttime traffic conditions.

The measurements were taken in a variety of Eastside locations:

- Near the old expansion joints in the eastbound lanes of the old SR 520 east approach – prior to the April 25, 2016, opening of the new bridge and landing's eastbound lanes.
- Near the new expansion joints on the new east approach (westbound traffic only).

- On the west end of the Evergreen Point Road lid.
- At seven residential locations in Medina.
- At one residential location in Yarrow Point near the bridge.

Additional daytime measurements were collected at these same locations on the new bridge once it opened to traffic in both directions on April 25, 2016. Seven additional measurements were taken on the waters north and south of the bridge. Per WSDOT and Federal Highway Administration (FHWA) policy, each measurement was collected over a standardized 15-minute period to determine a weighted average noise level (Figure 1).

This report presents a Summary of the Findings, discusses the measurement results, and possible next steps.

Summary Findings of Noise Measurements

All noise readings indicate that the new bridge is quieter than the old bridge. In addition, the new expansion joints are quieter than the expansion joints on the old bridge and other modern regional bridges. Traffic crossing the new expansion joints emits a somewhat different tone than on the old bridge. This tone is identifiable separately from traffic noise on the concrete roadway.

The noise-measurement findings can be summarized in the following points:

- All neighborhood noise measurements were below the Federal Highway Administration (FWHA) criteria of 67 dBA Leq for consideration of noise abatement.
- Total near-field SR 520 traffic noise (near-field noise is the noise measured immediately adjacent to the roadway) is substantially lower on the new bridge (approximately 10 dBA Leq lower) than on the old bridge because of quieter pavement specifications for the new bridge.
- Near-field noise from the new bridge's expansion joints is less (approximately 5 dBA Leq) than from the old bridge.
- The tone (sound frequency) of the new expansion joints is about one-half octave lower than from the old bridge (peak sound level from the new joints is between 630 and 800 hertz (Hz),while it was around 1,000 Hz for the old bridge).
- Roadway tire noise peaks at around 1,000 Hz.
- Because background tire noise on the new bridge is substantially reduced and the peak tone sound level at the new joints is higher than the peak tone sound level for tire noise, the noise-masking effect that occurred with the old bridge has been diminished. In other words, while the old joints were louder, the sound from the new ones can be clearly heard over the lower background pavement noise.
- The expansion joints on the new SR 520 bridge are quieter (by up to 10 dBA) than similar joints on other major bridges in Washington.

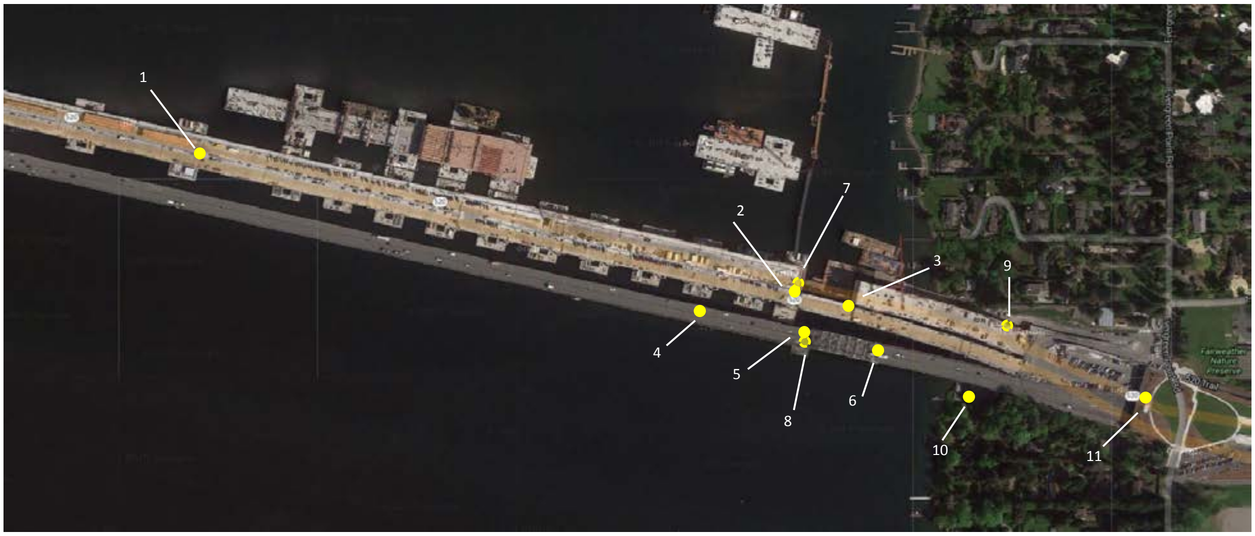

Figure 1: SR 520 Noise Measurement Locations

Sound is measured using the logarithmic decibel scale, so doubling the number of noise sources, such as the number of cars on a roadway, increases noise levels by 3 dBA. Therefore, when you combine two noise sources emitting 60 dBA, the combined noise level is 63 dBA, not 120 dBA. The human ear can barely perceive a 3 dBA increase, while a 5 dBA increase is about one and one-half times as loud. A 10 dBA increase appears to be a doubling in noise level to most listeners. A tenfold increase in the number of noise sources will add 10 dBA. The noise thermometer shown in Figure 2 represents relative sound levels of common activities.

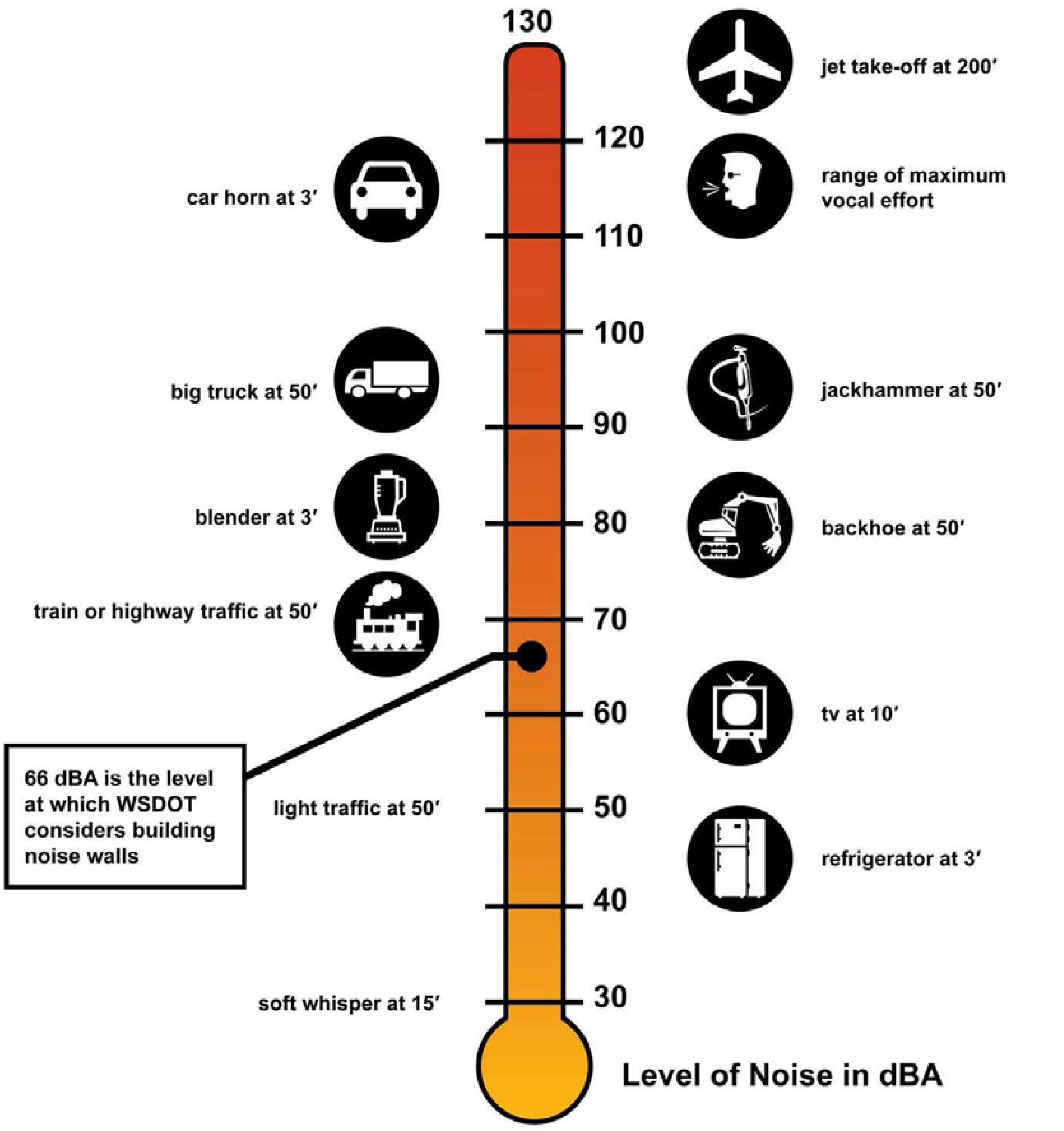
130
120
110
100
90
80
70
60
50
40
30
jet take-off at 200′
range of maximum vocal effort
car horn at 3′
big truck at 50′
jackhammer at 50′
blender at 3′
backhoe at 50′
train or highway traffic at 50′
tv at 10′
66 dBA is the level at which WSDOT considers building noise walls
light traffic at 50′
refrigerator at 3′
soft whisper at 15′
Level of Noise in dBA

Figure 2

Results

Table 1 shows the results of the daytime and nighttime noise measurements collected between April 19 and May 3, 2016. The measurements included both an Leq and Lmax. The Leq, or equivalent sound level, is the time-weighted average sound level over the 15-minute measurement period. The Lmax is the maximum sound level recorded during the 15-minute period.

Table 1: Sound Level Measurement Results

			Daytime			Nighttime		
Site Number	**Location**	**Date**	**Time**	**Leq (dBA)**	**Lmax (dB)**	**Time**	**Leq (dBA)**	**Lmax (dB)**
New SR 520 Bridge, Westbound Traffic Only								
1	Pavement West of Exp. Joints	4/19/16	11:33 A.M.	76	93	12:05 A.M.	67	90
2	Large Exp. Joint	4/19/16	11:15 A.M.	78	92	11:46 P.M.	73	92
3	Small Exp. Joint	4/19/16	10:59 A.M.	73	86	11:29 P.M.	69	88
7	Pontoon Under Large Exp. Joint	4/19/16	12:16 P.M.	72	99	1:08 A.M.	54	69
9	East Shoreline Under Bridge North Side	4/19/16	12:55 P.M.	59	71	1:50 A.M.	46	66
Old SR 520 Bridge, Eastbound Traffic Only								
4	Pavement West of Exp. Joints	4/19/16	11:37 A.M.	85	94	-	-	-
5	Large Exp. Joint	4/19/16	11:20 A.M.	84	94	-	-	-
6	Small Exp. Joint	4/19/16	11:03 A.M.	85	97	-	-	-
8	Pontoon Under Large Exp. Joint	4/19/16	12:18 P.M.	70	86	-	-	-
10	East Shoreline Under Bridge South Side	4/19/16	12:57 P.M.	63	74	-	-	-
New SR 520 Bridge, Traffic Both Directions								
1	Pavement West of Exp. Joints	5/3/16	11:11 A.M.	74	89	-	-	-
2	Large Exp. Joint	5/3/16	10:54 A.M.	79	91	-	-	-
3	Small Exp. Joint	5/3/16	10:32 A.M.	78	92	-	-	-
7	Pontoon Under Large Exp. Joint	5/3/16	11:31 A.M.	67	75	-	-	-
9	East Shoreline Under Bridge North Side	5/3/16	9:50 A.M.	66	80	-	-	-
Traffic Noise from Both Directions								
11	West end Evergreen Point Lid	4/19/16	10:18 A.M.	68	80	Westbound traffic on new bridge and eastbound traffic on old bridge		
11	West end Evergreen Point Lid	5/3/16	10:07 A.M.	65	80	All traffic on new bridge		

"-" = no data.

Table 2 documents traffic conditions during each set of measurements. During the April 19, 2016, measurements, the traffic volumes on the old bridge are approximately double what they are on the new bridge. This traffic doubling could add as much as 3 dB to the old bridge sound levels. During the second set of measurements taken only on the new bridge (both directions) on May 3, 2016, the eastbound volumes were approximately the same as before, but the westbound volume of autos more than doubled.

Table 2: Typical Traffic Volumes during measurements (vehicles per hour)

Location	Autos	Medium Trucks	Heavy Trucks
Daytime (4/19/16)			
New Bridge (WB)	792	60	12
Old Bridge (EB)	1413	53	10
Nighttime (12:50 A.M. 4/20/16)			
New Bridge (WB)	110	0	0
Old Bridge (EB)	180	0	0
Daytime (5/3/16)			
New Bridge (WB)	2196	108	36
New Bridge (EB)	1896	108	24

Table 3 shows the results of 15-minute-average measurements collected at the top of every hour between 1 p.m. and 10 a.m., while traffic is open in both directions on the highway and no construction is occurring, at Site 11 on the west side of the Evergreen Point lid and Site 2 at the large expansion joint.

Table 3: Hourly 15-minute L_{eq} and L_{max} Measurements

Site 11, West end Evergreen Point Lid				Site 2, Large Exp. Joint			
Date	**Time**	**Leq**	**Lmax**	**Date**	**Time**	**Leq**	**Lmax**
5/26/2016	1:00 P.M.	67	81	6/1/2016	1:00 P.M.	76	88
	2:00 P.M.	66	74		2:00 P.M.	76	90
	3:00 P.M.	63	77		3:00 P.M.	76	88
	4:00 P.M.	62	71		4:00 P.M.	77	90
	5:00 P.M.	63	80		5:00 P.M.	76	92
	6:00 P.M.	62	76		6:00 P.M.	72	84
	7:00 P.M.	65	84		7:00 P.M.	73	86
	8:00 P.M.	64	75		8:00 P.M.	72	87
	9:00 P.M.	62	76		9:00 P.M.	76	89
	10:00 P.M.	62	78		10:00 P.M.	75	88
	11:00 P.M.	59	74		11:00 P.M.	73	89
5/27/2016	12:00 A.M.	55	74	6/2/2016	12:00 A.M.	72	87
	1:00 A.M.	53	70		1:00 A.M.	70	89
	2:00 A.M.	54	68		2:00 A.M.	66	89
	3:00 A.M.	55	69		3:00 A.M.	67	88
	4:00 A.M.	58	73		4:00 A.M.	64	87
	5:00 A.M.	63	72		5:00 A.M.	67	88
	6:00 A.M.	67	73		6:00 A.M.	69	88
	7:00 A.M.	68	80		7:00 A.M.	75	89
	8:00 A.M.	65	75		8:00 A.M.	78	91
	9:00 A.M.	64	76		9:00 A.M.	75	88
	10:00 A.M.	66	74		10:00 A.M.	78	90

Comparisons of the Leq values measured on April 19, 2016, for the large and small expansion joints on the new and old bridge (see Table 1) show that the joints are 6 dB to 12 dB quieter on the new bridge, whereas the Lmax values are roughly the same. While this may seem counterintuitive, the Leq also measures the quiet periods in between cars going over the expansion joints or passing by the microphone, which lowers the time-weighted (Leq) average. Noise measurements of cars traveling over the two bridge pavements away from the expansion joints show that the pavement on the old bridge is notably louder than on the new bridge. This influences both the Leq and Lmax on the old bridge. The pavement on the old bridge is older and worn, which causes an increase in the noise produced by vehicles passing over it. The louder, older pavement is masking some of the noise from the expansion joints on the old bridge. In spite of the higher traffic volumes on May 3, 2016, in almost all cases the noise measurements on the new bridge with both lanes open are still lower than the measurements on the old bridge.

As noted in Table 1, some of the expansion-joint noise measurements collected on May 3, 2016, were in the same areas as on April 19, 2016, while others were measured from the bike path (on the north side of the new bridge) rather than from the eastbound lanes because both directions of the new bridge were open to traffic and no traffic remained on the old bridge. Comparison of the Leq values for the large and small expansion joints on the new bridge show that the large expansion joint is approximately the same noise level and the small expansion joint is about 5 dB louder than previously measured with only one direction of traffic and the Lmax values show the same trend. As noted in Table 2, May 3, 2016, traffic volumes were more than double what was measured on April 19, 2016, which would account for more than 3 dBA of the increase. There may also have been some near-field reflection from the noise wall near the small expansion joint along the bike path. This reflection may not be observed near the large expansion joint because the noise wall significantly further away from the large expansion joint than it is from the small expansion joint.

Noise measurements of cars traveling over the pavement on the new bridge away from the expansion joints, as well as measurements taken under the bridge's large expansion joint, are both slightly quieter with both directions of traffic open, despite the higher traffic volumes. This is likely a result of the absence of the traffic on the old bridge, which, by having substantially louder pavement than the new bridge, contributed to the total noise level measured on the new bridge on April 19, 2016. On the shore under the new bridge, noise was louder during the May 3, 2016, measurements because demolition was occurring on the old bridge. The measurement on the Evergreen Point lid was slightly quieter, again due to the lack of traffic on the old bridge.

Comparing the April 19, 2016, sound levels under the two bridges shows that levels are quieter under the new bridge expansion joint than the old bridge expansion joint. This result reflects the design of the new bridge joint, which is encapsulated to reduce noise escaping from underneath the bridge structure. The measured level on the pontoon on May 3, 2016 when both directions of traffic were on the new bridge but there was no nearby construction equipment, is even lower, which further demonstrates the effectiveness of the encapsulation.

Comparing the nighttime noise levels to daytime levels at the new bridge, the Leq sound levels are about 4 to 6 dB less at night than during the daytime. This is primarily due to lower traffic volumes at night. However, there was also construction equipment running nearby during the daytime, which could have elevated the noise levels slightly. On April 19, 2016 (Table 2), traffic counts at night were 86 percent lower for the new bridge and 87 percent lower for the old bridge. The day-versus-night Lmax values are approximately the same except at the pontoon level, where the daytime measurement included nearby construction equipment running.

Comparison of Old SR 520 Bridge and New SR 520 Bridge Sound Profiles

Expansion Joint and Pavement Noise

Figure 3 is a plot of overall 1/3 octave band frequencies or sound "tone" in hertz (Hz) during the measurement period for the small and large expansion joints on the old bridge. The graph compares the expansion joints side-by-side to the 1/3rd octave bands of the pavement without expansion joints. The old bridge 1/3rd octave band measurements show a maximum sound level centered at 1,000 Hz for all three measurements, with the other frequencies above and below falling off relatively rapidly. This is typical of traffic noise measurements, which are generally centered around 800 Hz to 1,000 Hz. There is also very little difference between the large and small expansion joints and the pavement, which indicates that the expansion joints on the old bridge are not distinctly different in tone from the typical roadway noise.

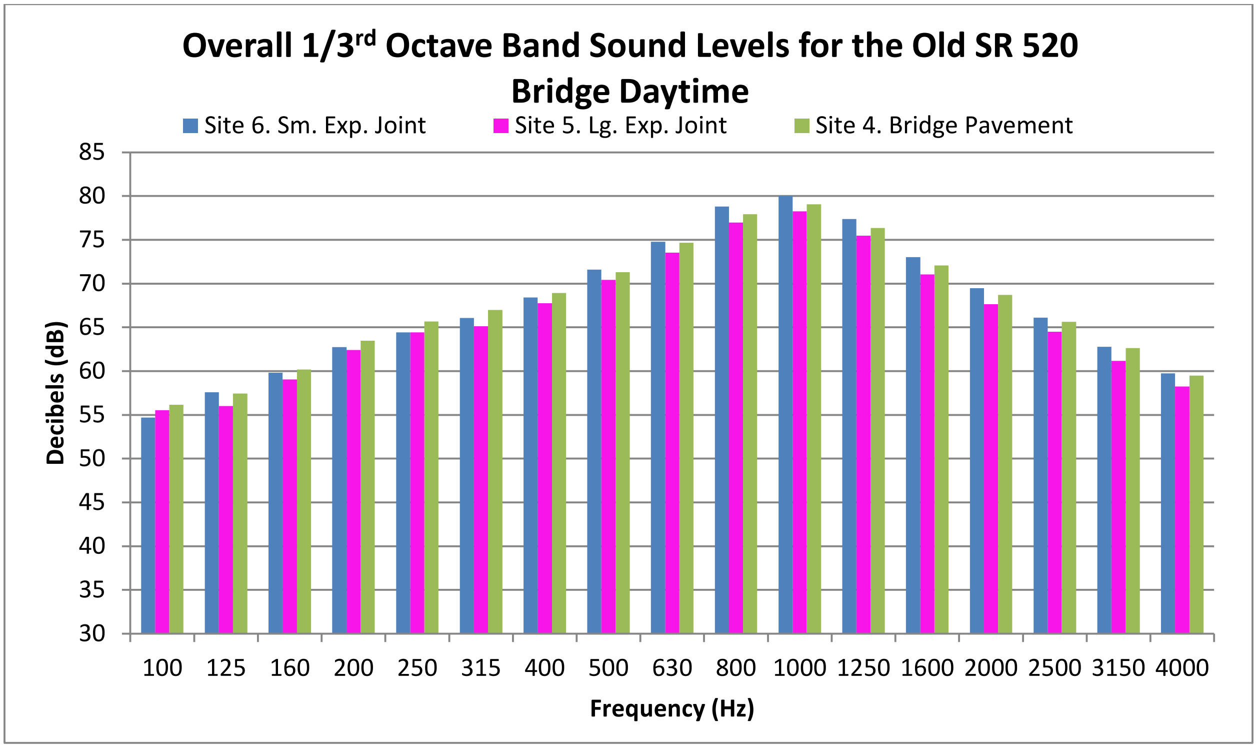

Figure 3

Figure 4 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period for the small and large expansion joints on the new bridge, and comparing these to the 1/3rd octave bands of the pavement without expansion joints. The new bridge 1/3 octave band measurements show a maximum sound level for two bands centered at 630 Hz and at 800 Hz, which is slightly lower in tone than typical traffic noise. At these relatively low frequencies, the sound will tend to travel farther, and because the wavelength is relatively long, it could bounce over large objects such as sound walls. Generally, the new expansion joints are quieter than the expansion joints on the old bridge and, as expected, the large expansion joint is louder than the smaller expansion joint on the new bridge. At the higher tones of 1,000 Hz and higher, the pavement dominates over the expansion joint noise levels on the new bridge.

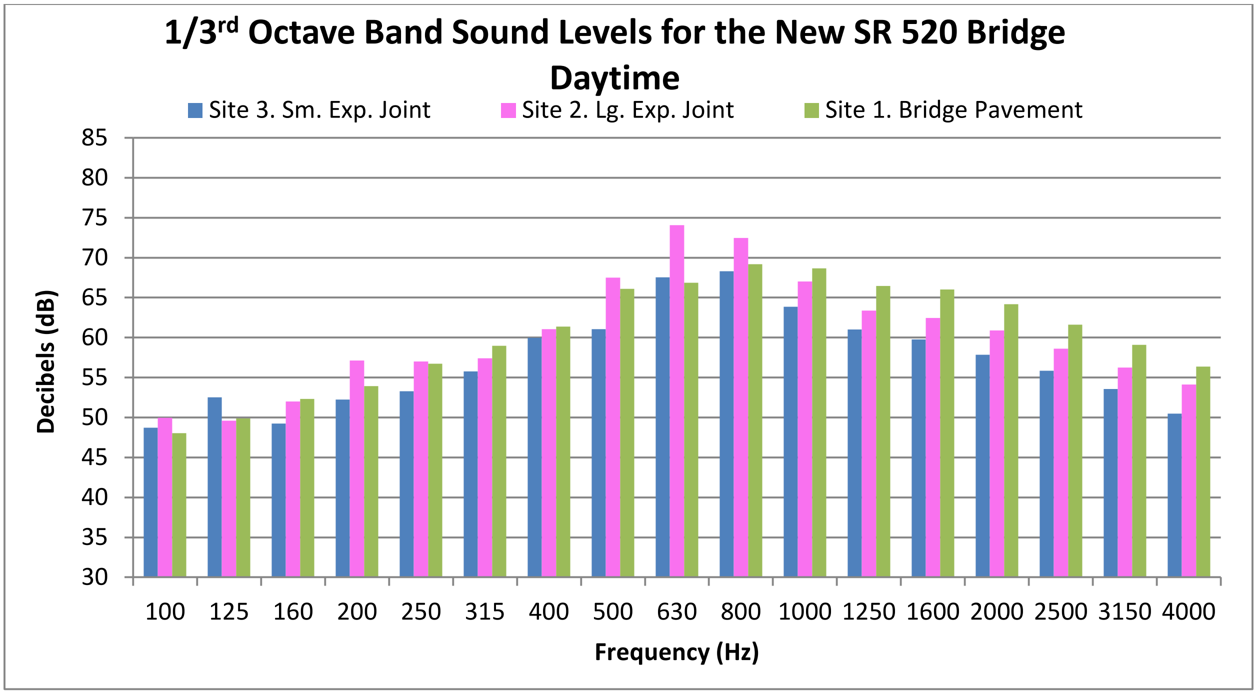

Figure 4

Figure 5 is a plot of overall 1/3 octave band sound tone in hertz (Hz) during the measurement period for the large expansion joint on the new bridge, and comparing the measurements with one direction and two directions of traffic on the new bridge with the large expansion joint on the old bridge. The 1/3 octave band measurements show very similar levels for all frequencies with a slight increase in levels when the eastbound lanes were opened to traffic because of both the greater total traffic (Table 2) and the additional eastbound cars traveling over the expansion joint. It also indicates that the large expansion joint on the old bridge was louder in all tones except for the 630 Hz tone where it was roughly the same sound level.

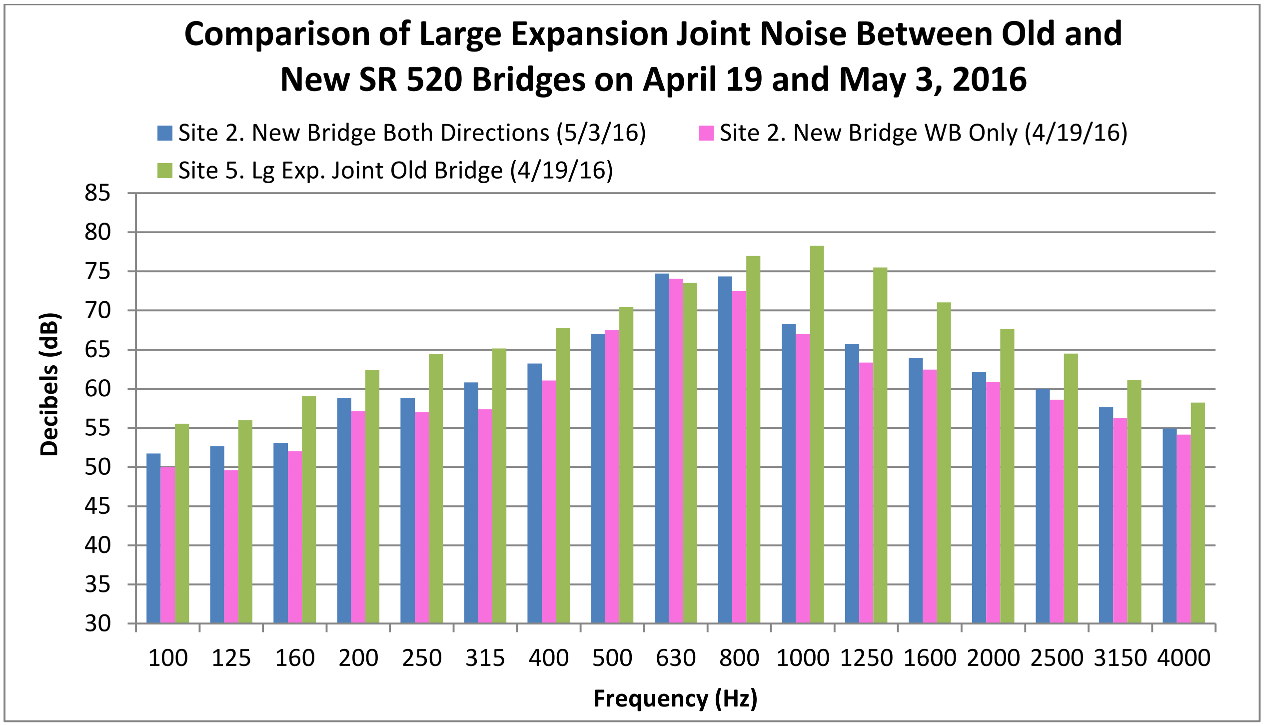

Figure 5

Figure 6 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period for the small expansion joint on the new bridge compared with the same measurement after eastbound lanes were opened to traffic and with the small expansion joint on the old bridge. The 1/3 octave band measurements show a slight increase in most of the bands with traffic in both directions on the new bridge due to increased traffic over the expansion joint. The small expansion joint on the old bridge was louder in all tones measured than the small expansion joint on the new bridge.

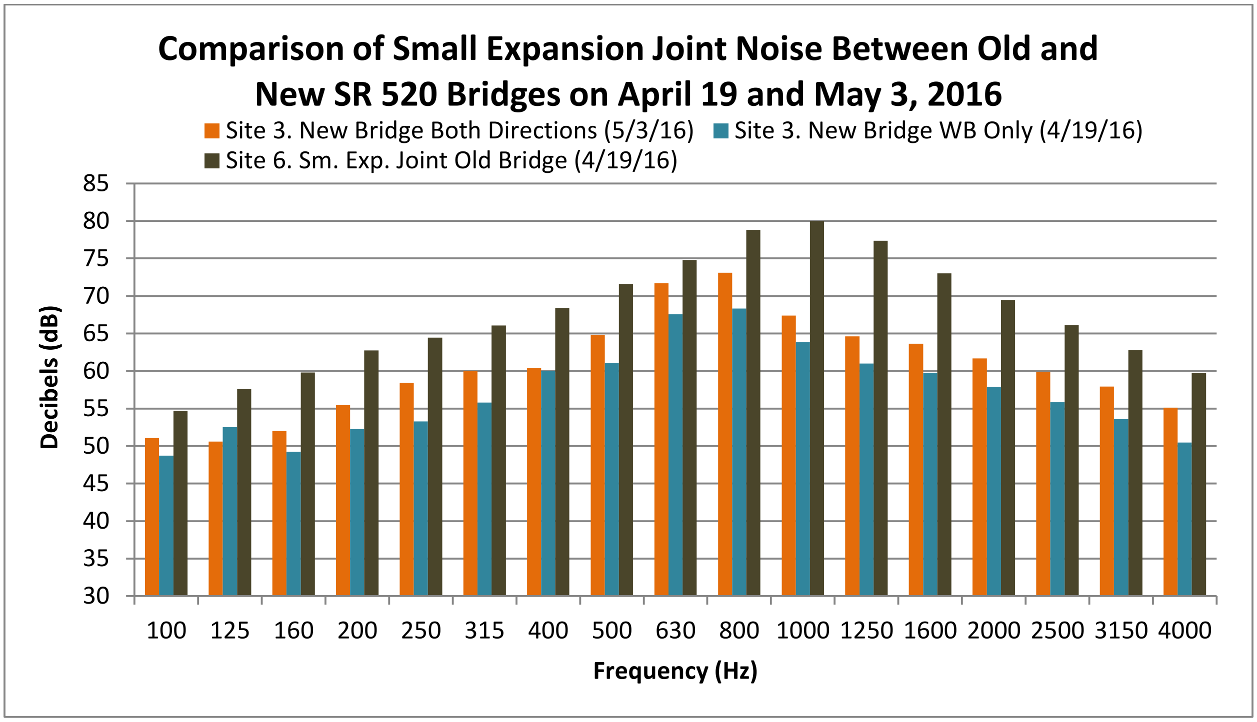

Figure 6

Figure 7 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period for the pavement only on the new bridge compared with the same measurement after eastbound lanes were opened to traffic and with the pavement measurement on the old bridge. The 1/3 octave band measurements show almost no difference in most of the bands with traffic in both directions and is 3 to 10 dB quieter than the old bridge pavement

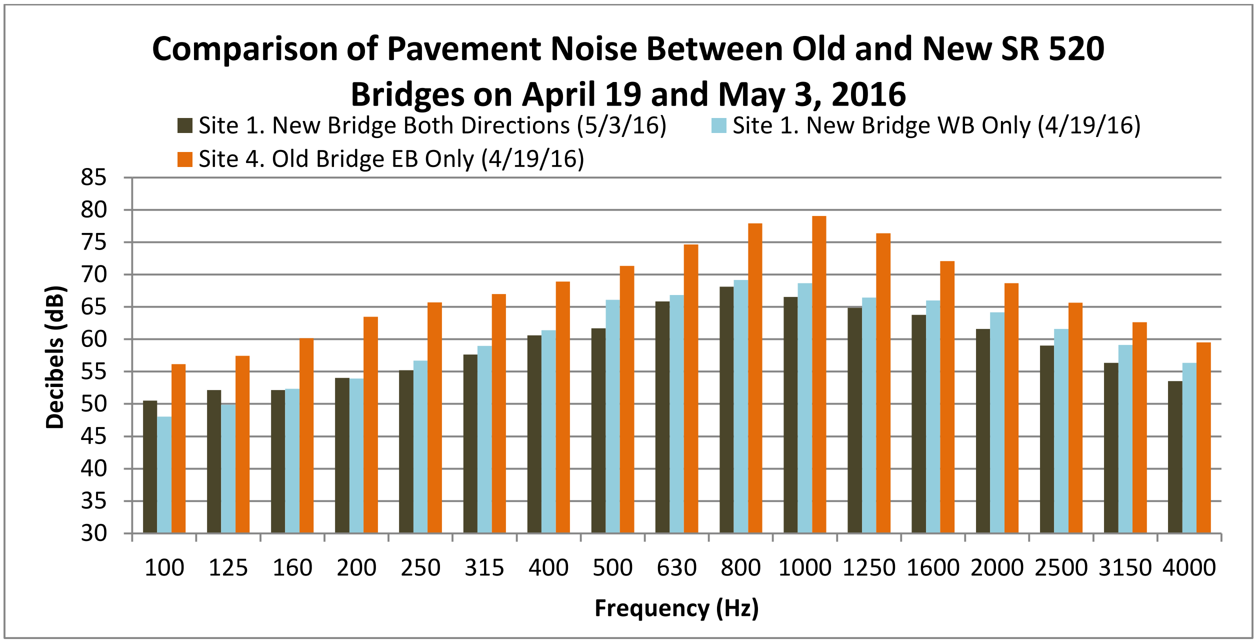

Figure 7

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Figure 8 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period at the west end of the Evergreen Point lid compared with the same measurement after eastbound lanes were opened to traffic (Table 1, Site 11 data reports the overall Leq for this location). The 1/3 octave band measurements show that shifting all traffic to the new bridge and eliminating the traffic on the old bridge is about 5 decibels quieter in most bands, despite the higher traffic volumes during the measurement period. This corresponds with the 3 dBA difference in overall Leq reported in Table 1.

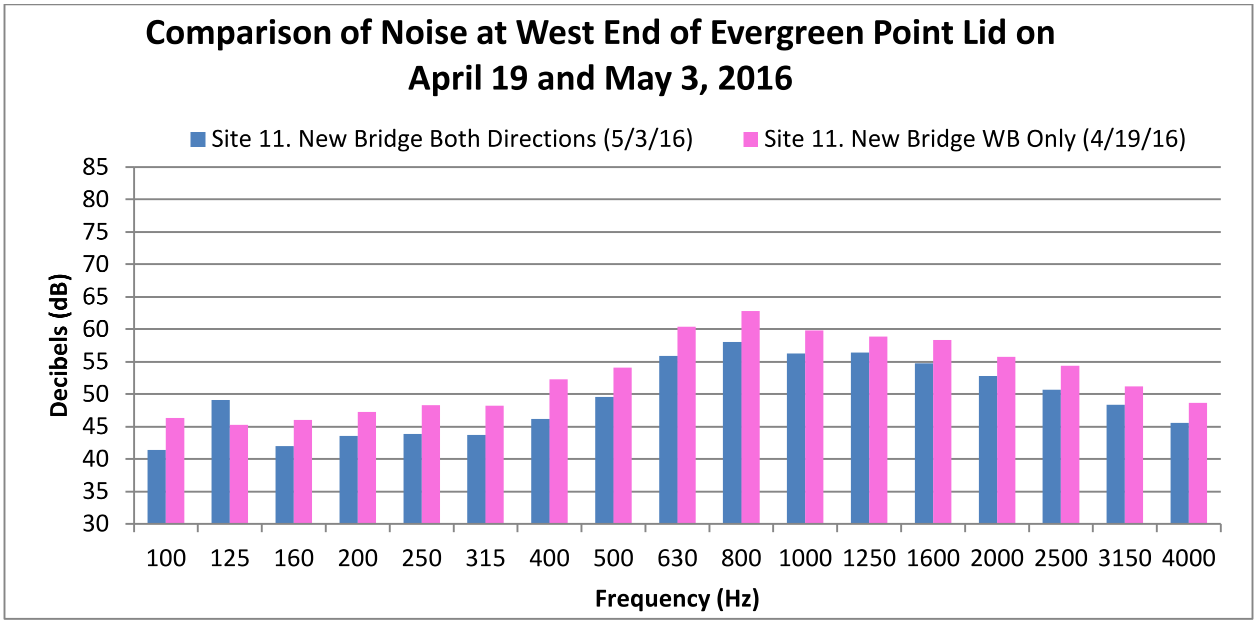

Figure 8

Noise Levels Under the SR 520 Bridges

Figures 9 and 10 compare the measurements collected during daytime operations at two locations under the old and new SR 520 bridges. As discussed previously, the measurement at the pontoon level for the new bridge on April 19, 2016, included noise from operating construction equipment. The noise levels directly under the old bridge's large expansion joint are approximately the same as noise levels under the new bridge's expansion joint, with the new expansion joint measurement showing increased levels at tones above 2,000 Hz. Comparing the levels to those in Figure 11 illustrates the effect of operating light construction equipment that was running within 100 feet of the noise meter on April 19, 2016. Under both expansion joints, the peak tone is centered around 630 Hz, is slightly dominant over the other tones, and is generally only slightly (1 dB) higher than measurements collected under the old expansion joint. In Figure 10 the sound levels are about 10 dB quieter than directly under the expansion joints and the sound levels from the old bridge are about 3 to 4 dB higher than the new bridge on the shore, where there was no nearby construction equipment.

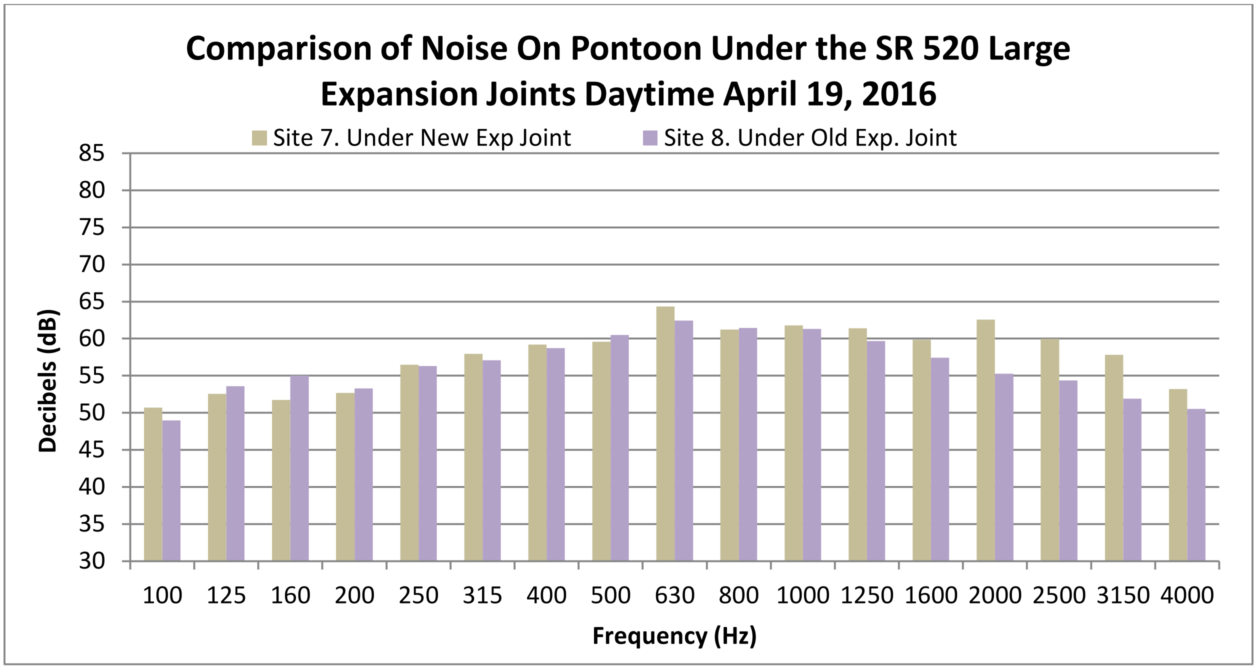

Figure 9

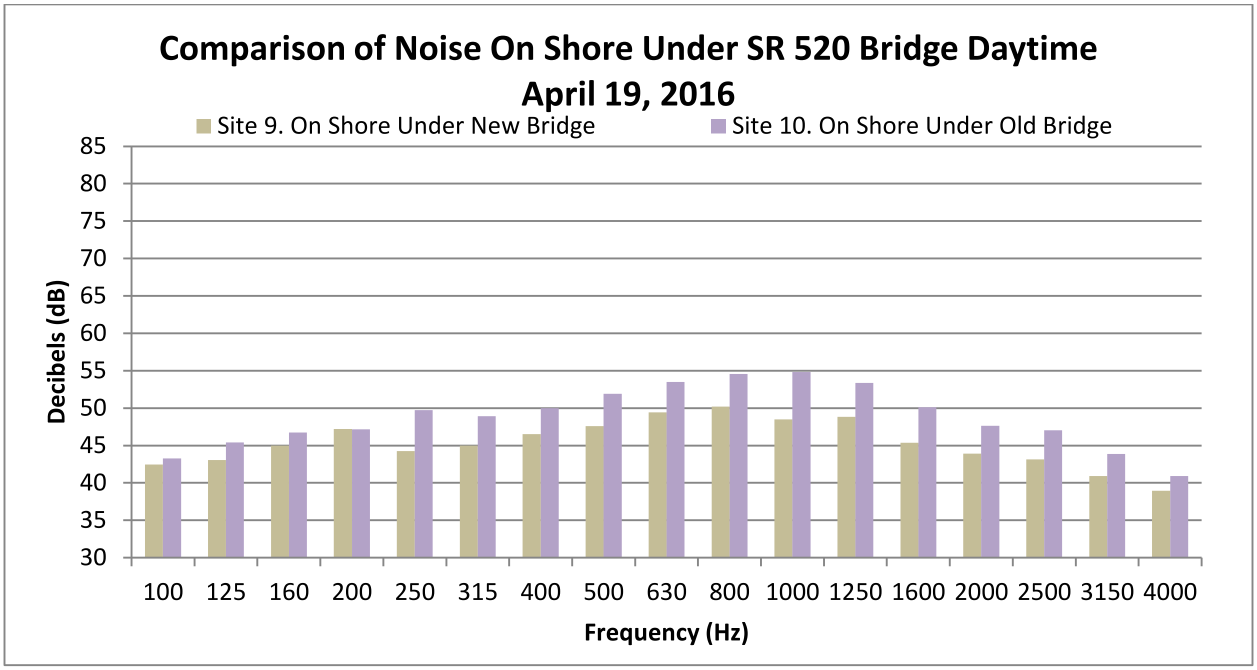

Figure 10

Figure 11 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period on the pontoon under the large expansion joint on the new bridge compared with the same measurement after eastbound lanes were opened to traffic. The 1/3 octave band measurements show that the new bridge without traffic on the old bridge is about 3 to 5 decibels quieter in all bands showing the influence of the louder old bridge in the previous measurements. It also shows a peak tone of 630 Hz from the old bridge expansion joint.

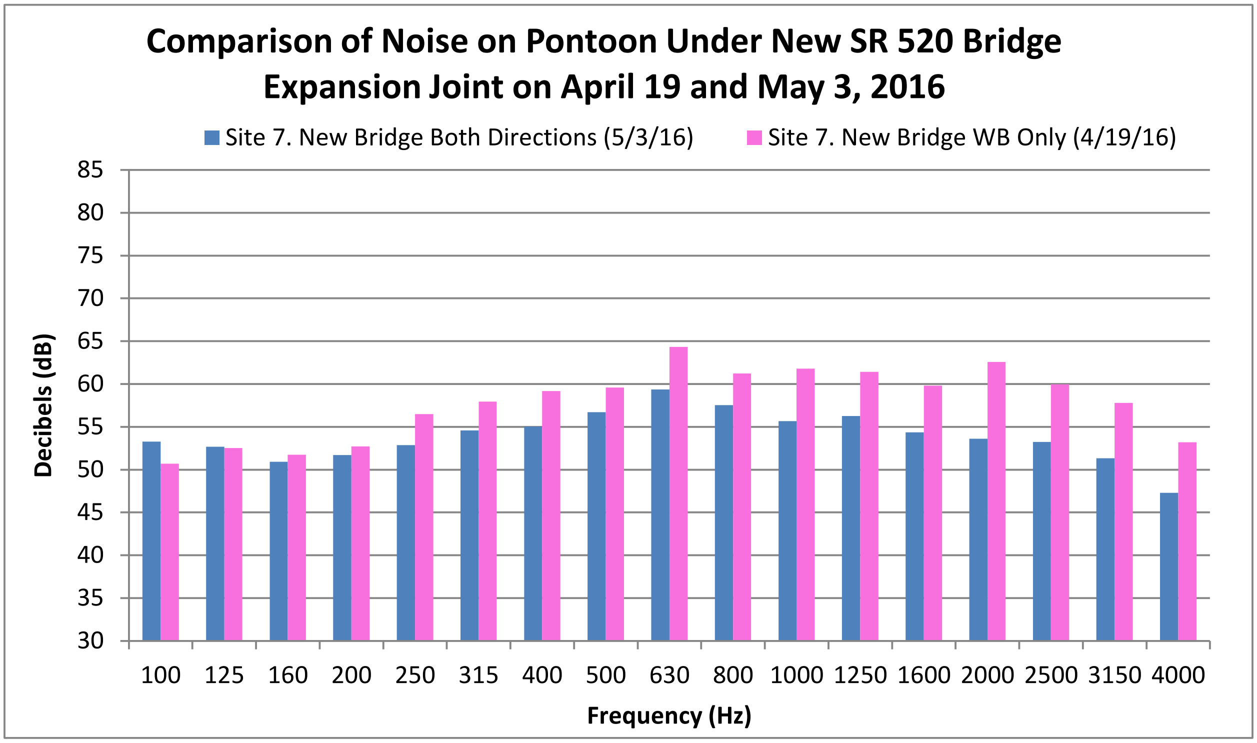

Figure 11

Figure 12 is a plot of overall 1/3 octave band tone in hertz (Hz) during the measurement period near the shoreline under the new bridge compared with the same measurement after eastbound lanes were opened to traffic, and with the measurement on the Evergreen Point lid after both directions of the new bridge were opened to traffic. The 1/3 octave band measurements show that the new bridge without traffic on the old bridge is about 3 to 6 decibels louder in all bands. This is likely due to some light construction occurring on the nearby pontoons during the measurement on May 3, 2016.

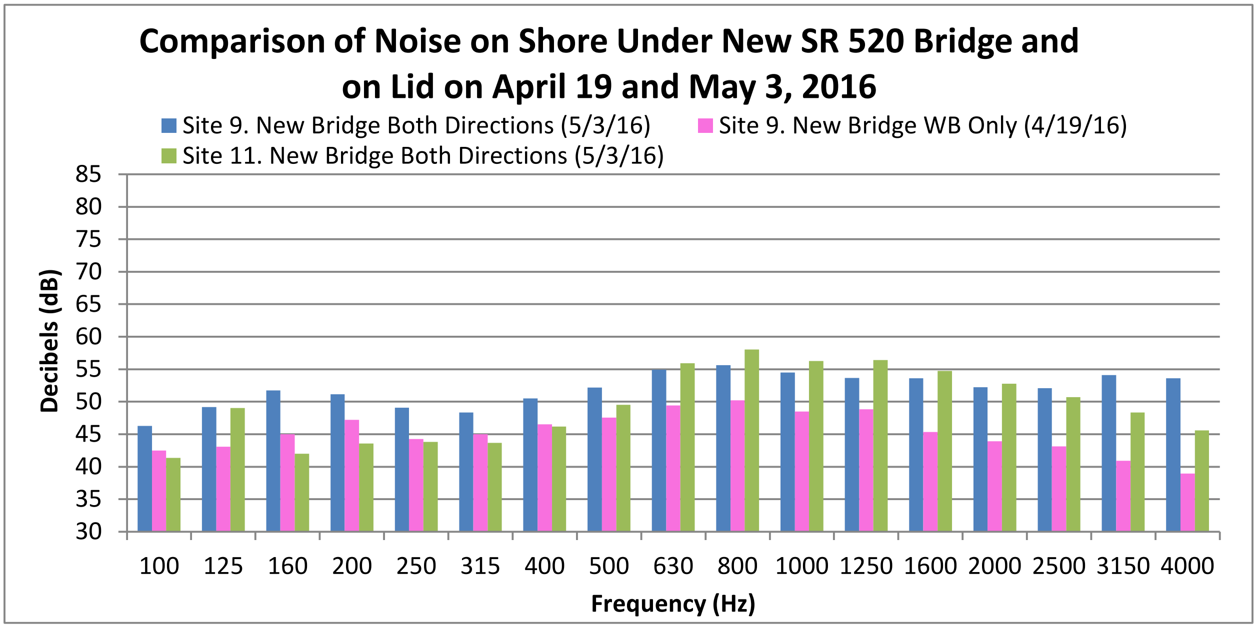

Figure 12

Nighttime Noise Levels

Figure 13 compares the same measurement locations as in Figure 4 except these were collected at night when traffic volumes, and thus sound levels, are lower overall. We see the same dominant peak levels centered around 630 and 800 Hz and roadway noise maximum centered around 800 Hz as before. The large expansion joint is generally louder than the small expansion joint and because the traffic volumes and noise levels are lower at night the difference between the expansion joints and traffic noise is slightly greater than during the daytime.

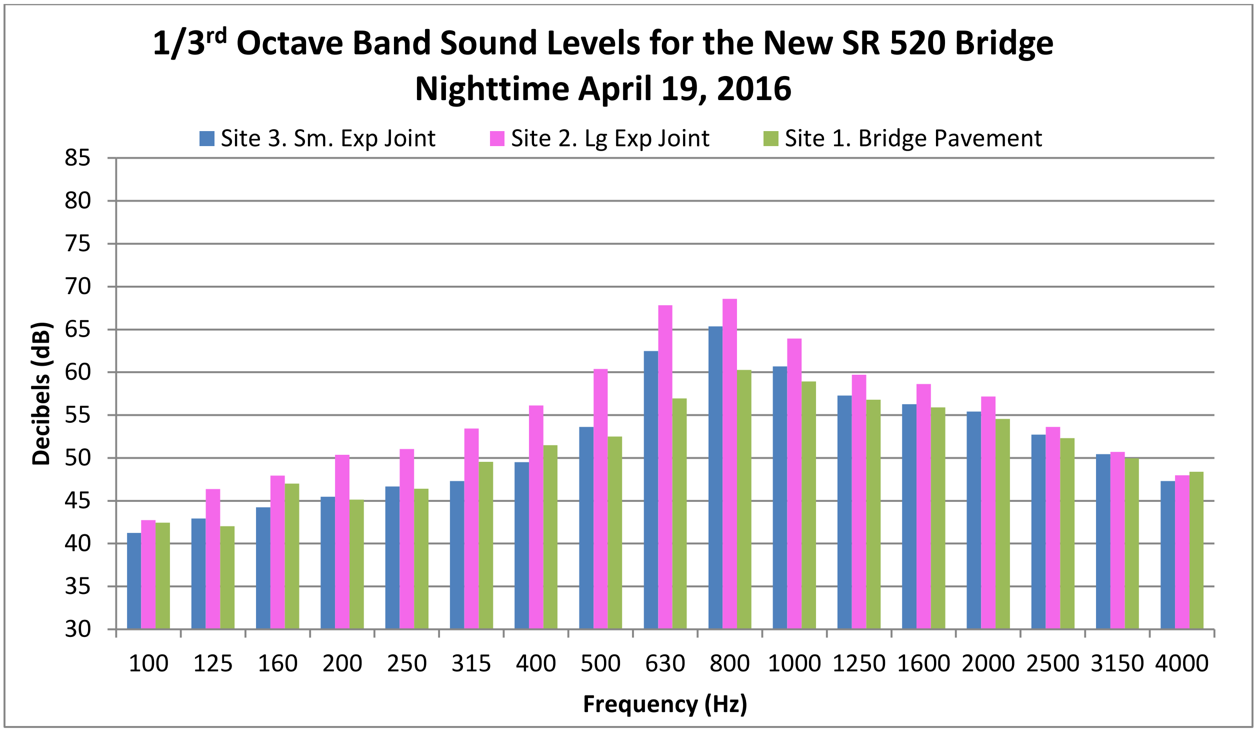

Figure 13

Figure 14 shows the difference in sound levels as measured under the new expansion joint during daytime vs. nighttime. In some cases these measurements differ by as much as 20 dB. The difference is partly due to higher traffic volumes during the day but also because of some light daytime construction under the bridge during the measurement. We see a small peak at the tone centered around 630 Hz, which is similar to the measurements above the bridge deck and suggests that the expansion joint noise is slightly noticeable under the bridge at night when all other noise levels are lower.

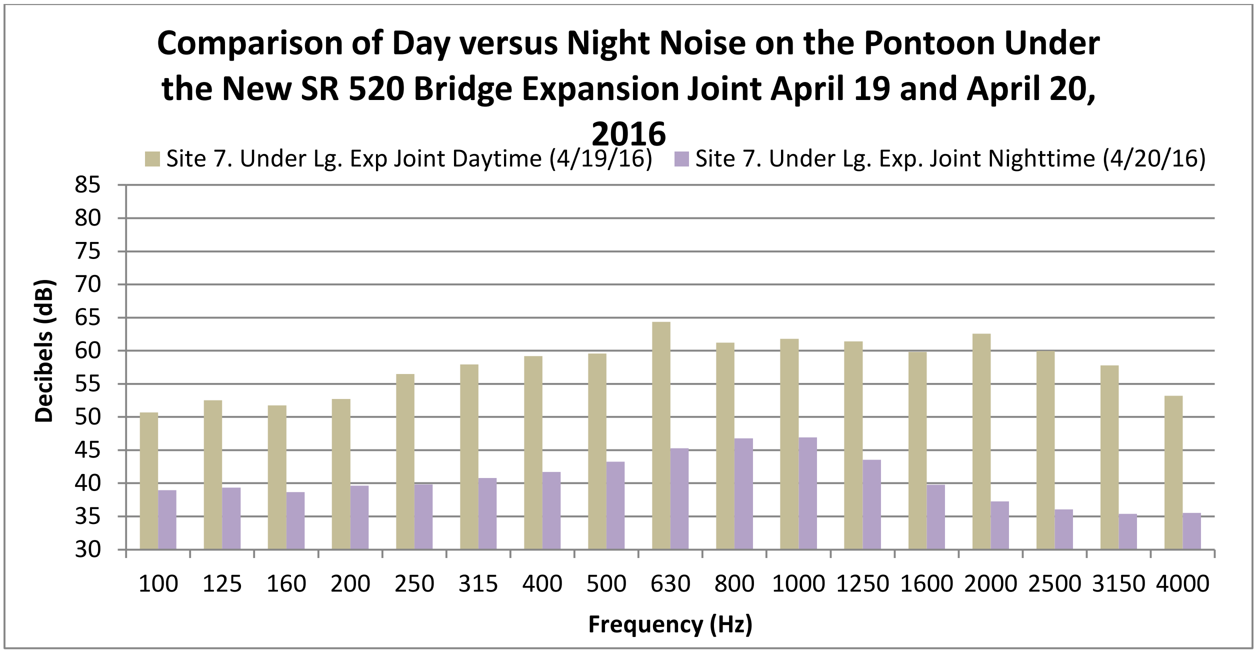

Figure 14

Figure 15 shows the results of 15-minute measurements collected at the top of every hour between 1 p.m. and 10 a.m., while construction has stopped, at Site 11 on the west side of the Evergreen Point lid. The results indicate that at this location the Leq values decrease overnight primarily due to a decrease in traffic volumes. The Leq decreases to a low point between 1 and 2 a.m., which is approximately 12 decibels less than daytime noise levels.

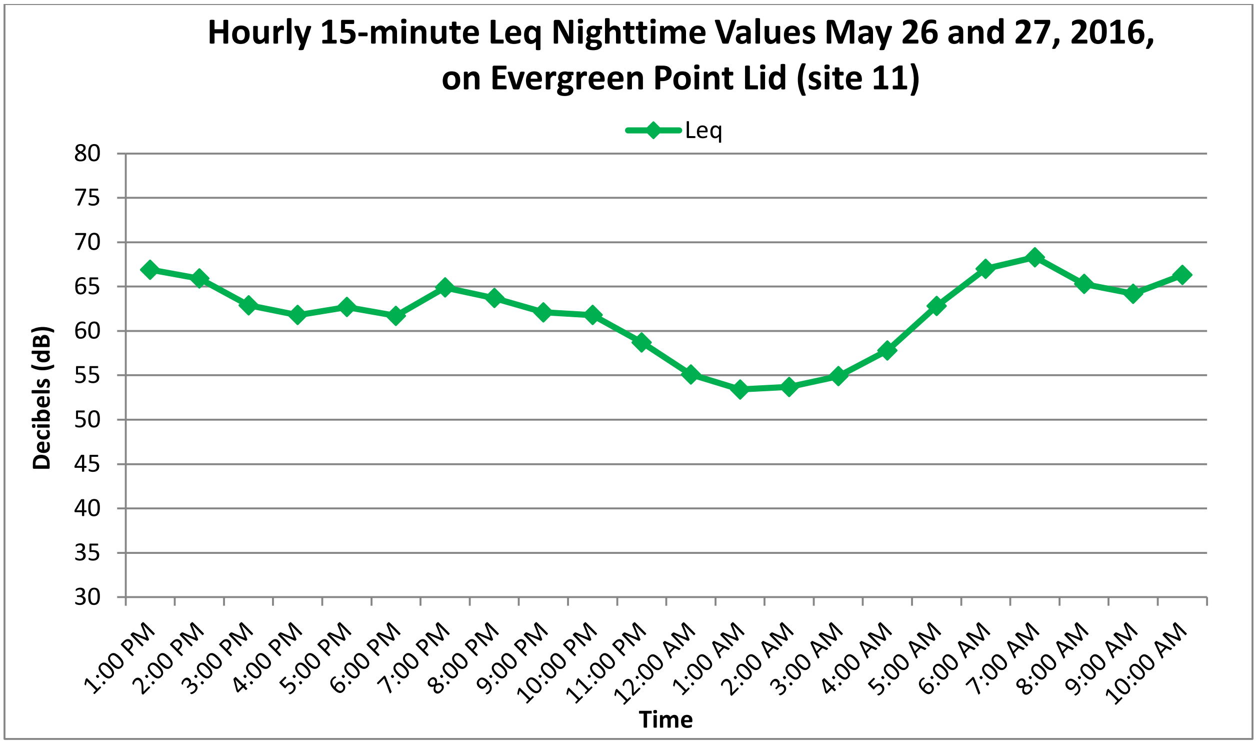

Figure 15

Figure 16, Site D, shows the results of 15-minute measurements collected at the top of every hour between 1 p.m. and 10 a.m., while construction has stopped, at Site D, north of the Evergreen Point lid near the residence at 3204 76th Ave. NE. The results indicate that at this location the Leq values decrease overnight primarily due to a decrease in traffic volumes. The Leq decreases to a low point between 2 and 3 a.m., which is approximately 19 decibels less than daytime noise levels.

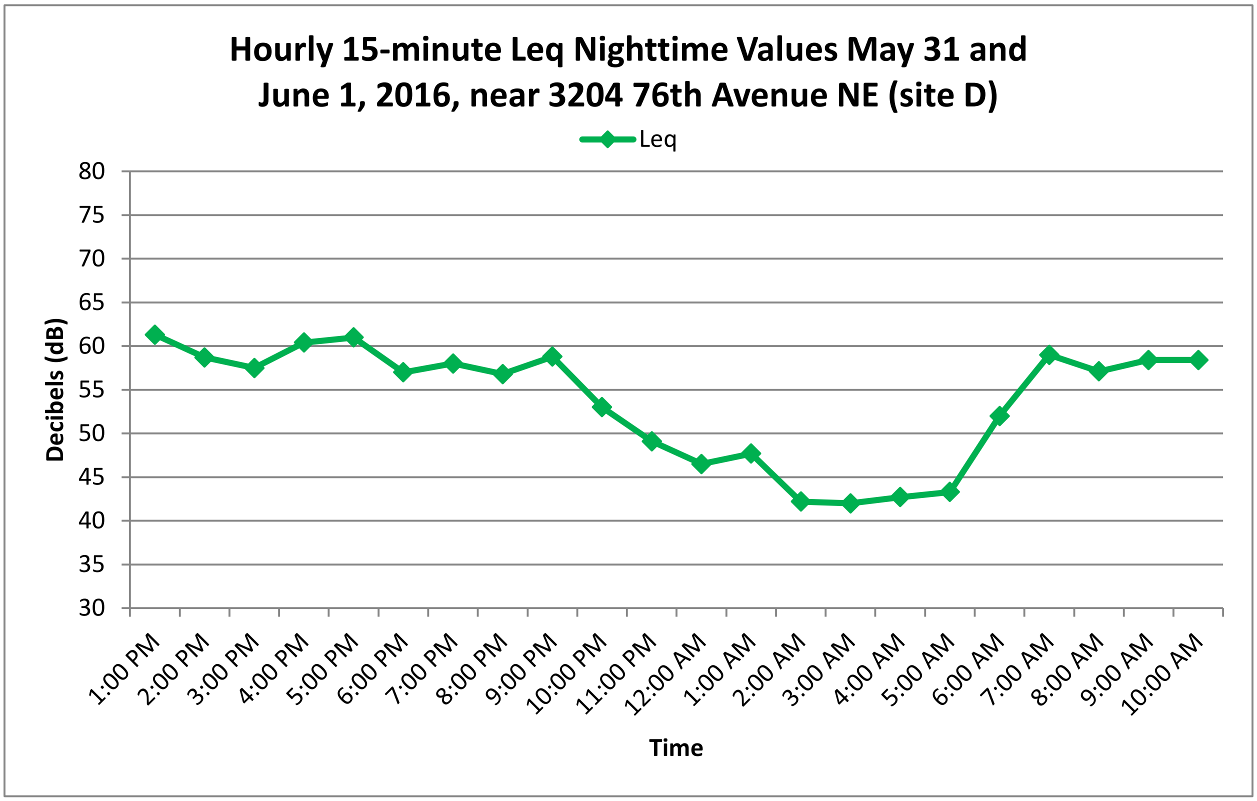

Figure 16

Figure 17, Site 2, shows the results of 15-minute measurements collected at the top of every hour between 1 p.m. and 10 a.m., while construction has stopped, at Site 2 at the bicycle and pedestrian path adjacent to the large expansion joint. The results indicate that at this location the Leq values decrease overnight primarily due to a decrease in traffic volumes. The Leq decreases to a low point at 4 a.m. which is approximately 14 decibels less than daytime noise levels.

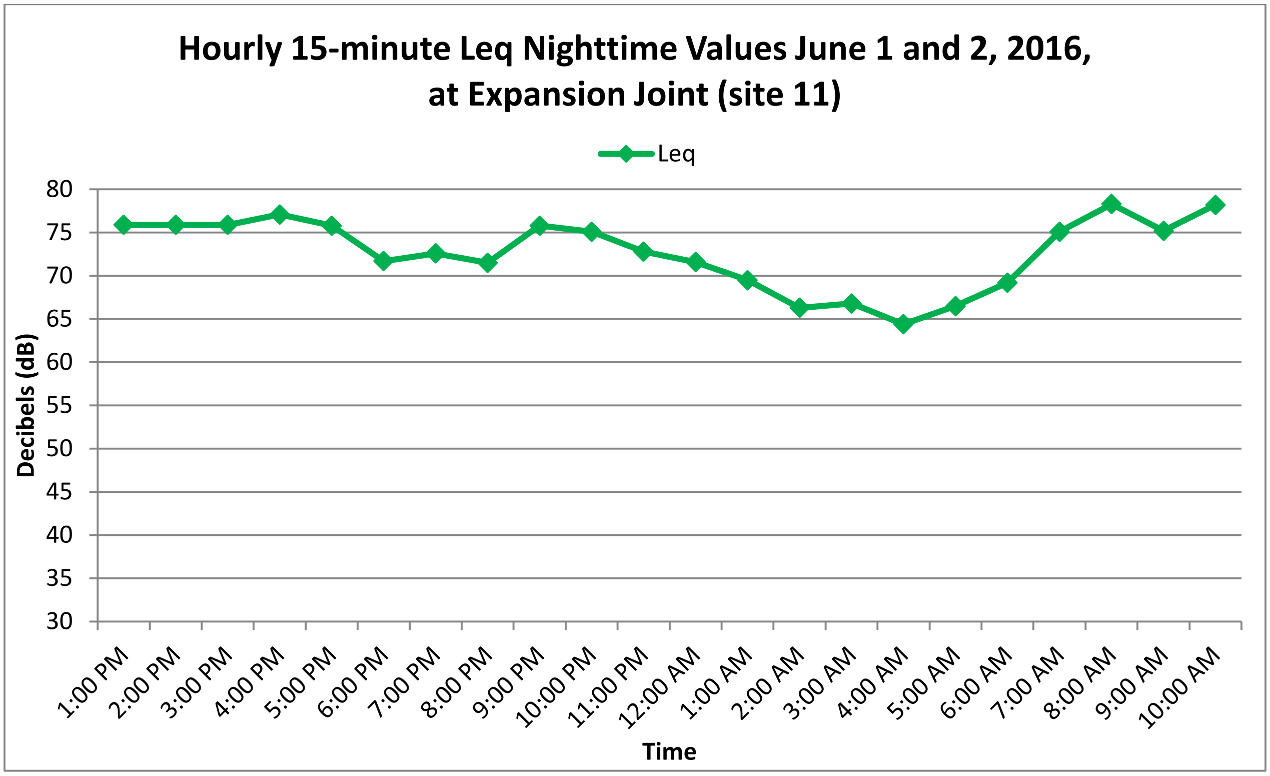

Figure 17

Residential Noise Measurements

Noise measurements were collected at seven residential locations in Medina near the bridge and at one location in Yarrow Point. Figure 18 shows the locations and Table 4 shows the results of these measurements.

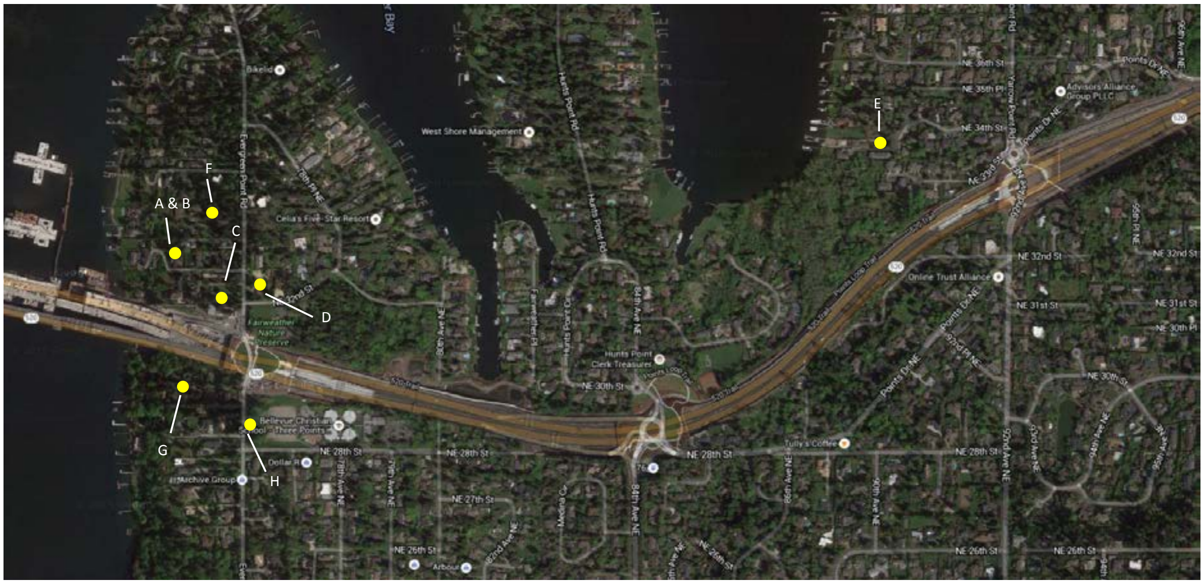

Figure 18: Residential Noise Measurement Locations

The results of the residential measurements indicate that the Leq values are below the Federal Highway Administration (FHWA) traffic noise impact threshold of 66 dBA (Table 5). These noise levels are typical of a suburban environment during daytime hours. The Lmax sound levels are also typical of a suburban environment. At those homes farther away on 76th Avenue Northeast in Medina and Yarrow Point, the peaks at 630 Hz and 800 Hz are less noticeable and traffic noise tends to dominate more. At these more distant locations, the expansion-joint noise is barely audible above the ambient noise level, and does not appear to be measurable. Table 6 shows the results of 15-minute measurements collected at the top of every hour between 1 p.m. and 10 a.m., while construction has stopped, at Site D, near the residence at 3204 76th Ave. NE, Medina.

Table 5: Results of Sound Level Measurements Collected at Nearby Residents on April 20, May 3 and May 10, 2016

Site	Address	Date	Time	Old Bridge EB Traffic?	New Bridge Both Lanes?	Leq (dBA)	Lmax (dB)
A	3223 Evergreen Point Rd, Medina (Outside house)	4/20/16	1:58 P.M.	Y	N	59	71
		5/3/2016	2:59 P.M.	N	Y	60	72
B	3223 Evergreen Point Rd, Medina (On 2nd floor balcony)	4/20/16	2:00 P.M.	Y	N	61	72
		5/3/2016	1:38 P.M.	N	Y	60	71
C	3205 Evergreen Point Road, Medina	4/20/16	2:45 P.M.	Y	N	60	75
		5/3/2016	2:17 P.M.	N	Y	59	71
D	3204 76th Ave NE, Medina	4/20/16	3:10 P.M.	Y	N	57	76
		5/3/2016	2:41 P.M.	N	Y	61	85*
E	8901 NE 34th St, Yarrow Point	4/20/16	3:40 P.M.	Y	N	54	68
		5/3/2016	1:09 P.M.	N	Y	51	70
F	3245 Evergreen Point Road, Medina	5/10/16	11:08 A.M.	N	Y	57	72
G	2839 Evergreen Point Road, Medina	6/1/16	10:12 A.M.	N	Y	58	75
H	Three Points Elementary School, Medina	6/1/16	10:38 A.M.	N	Y	60	80**

*This Lmax and Leq is higher due to multiple school buses passing by at time of measurement
**This Lmax is higher due to demolition construction occurring nearby at time of measurement

Table 6: Hourly 15-minute L_{eq} and L_{max} Measurements

Site D, 3204 76th Ave NE, Medina			
Date	**Time**	**Leq**	**Lmax**
5/31/2016	1:00 P.M.	61	87
	2:00 P.M.	59	76
	3:00 P.M.	58	73
	4:00 P.M.	60	81
	5:00 P.M.	61	81
	6:00 P.M.	57	73
	7:00 P.M.	58	77
	8:00 P.M.	57	73
	9:00 P.M.	59	78
	10:00 P.M.	53	74
	11:00 P.M.	49	69
6/1/2016	12:00 A.M.	47	65
	1:00 A.M.	48	72
	2:00 A.M.	42	52
	3:00 A.M.	42	52
	4:00 A.M.	43	64
	5:00 A.M.	43	62
	6:00 A.M.	52	71
	7:00 A.M.	59	82
	8:00 A.M.	57	75
	9:00 A.M.	58	83
	10:00 A.M.	58	80

Noise measurements collected at residential locations away from the bridge show that the homes along Evergreen Point Road in Medina are experiencing sound levels from the new expansion joint. In Figure 19 it shows that for these residents along Evergreen Point Road there is a measurable peak in the tones at 630 and 800 Hz. This peak tone of 630 and 800 Hz is unique to the new expansion joint, while the old expansion joint exhibited a peak tone of 1,000 Hz. At those homes farther away on 76th Avenue Northeast in Medina and Northeast 34th Street in Yarrow Point, it is showing more influence of traffic noise in the 1000 Hz band. To the south of the bridge a 2839 Evergreen Point Road and Three Points Elementary School, the influence is from traffic noise and the expansion joint is not audible.

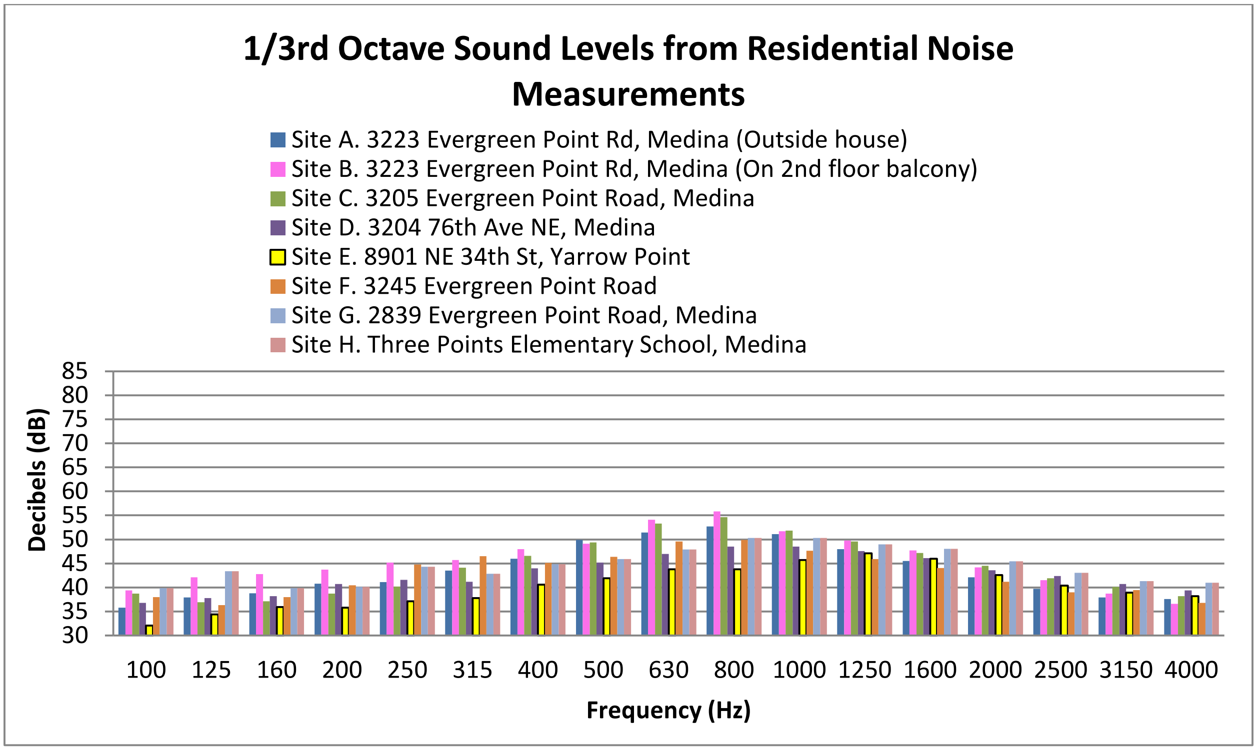

Figure 19

Noise measurements collected at residential locations on April 19, May 3, May 10, and June 1, 2016, are compared in Figure 20, with the exception of sites F, G and H which were only measured one time. In almost every case the sound levels measured after traffic was removed from the old bridge are the same or lower. The measurement at 3204 76th Ave. NE is higher on May 3 and likely is due to several school buses passing by during the measurement. Figure 20 shows that for the residents along Evergreen Point Road there is a measurable peak in the tones at 630 and 800 Hz This peak tone of 630 and 800 Hz is unique to the new expansion joint, while the old expansion joint exhibited a peak tone of 1,000 Hz. At those homes farther away on 76th Avenue Northeast in Medina and Northeast 33rd Street in Yarrow Point and to the south of the bridge, the measurements show that these locations are more influenced by traffic noise in the 1,000 Hz band.

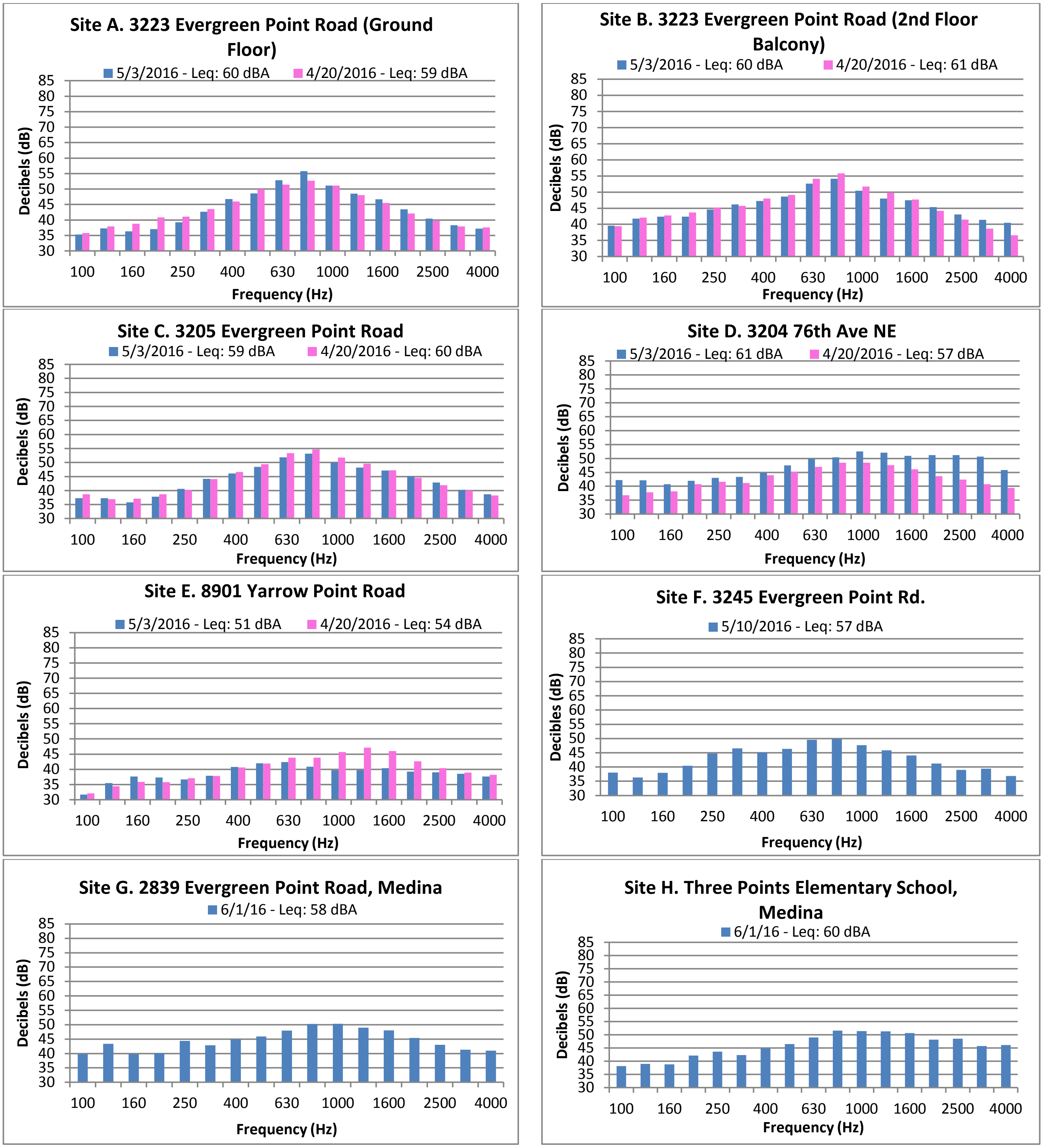
Site A. 3223 Evergreen Point Road (Ground Floor)
5/3/2016 - Leq: 60 dBA
4/20/2016 - Leq: 59 dBA
Decibels (dB)
85 80 75 70 65 60 55 50 45 40 35 30
100 160 250 400 630 1000 1600 2500 4000
Frequency (Hz)
Site B. 3223 Evergreen Point Road (2nd Floor Balcony)
5/3/2016 - Leq: 60 dBA
4/20/2016 - Leq: 61 dBA
Decibels (dB)
Frequency (Hz)
Site C. 3205 Evergreen Point Road
5/3/2016 - Leq: 59 dBA
4/20/2016 - Leq: 60 dBA
Decibels (dB)
Frequency (Hz)
Site D. 3204 76th Ave NE
5/3/2016 - Leq: 61 dBA
4/20/2016 - Leq: 57 dBA
Decibels (dB)
Frequency (Hz)
Site E. 8901 Yarrow Point Road
5/3/2016 - Leq: 51 dBA
4/20/2016 - Leq: 54 dBA
Decibels (dB)
Frequency (Hz)
Site F. 3245 Evergreen Point Rd.
5/10/2016 - Leq: 57 dBA
Decibles (dB)
Frequency (Hz)
Site G. 2839 Evergreen Point Road, Medina
6/1/16 - Leq: 58 dBA
Decibels (dB)
Frequency (Hz)
Site H. Three Points Elementary School, Medina
6/1/16 - Leq: 60 dBA
Decibels (dB)
Frequency (Hz)

Figure 20

Measurements of SR 520 from a Boat on the Water

Noise measurements were collected at four locations north of the SR 520 bridge and three locations south of the bridge parallel to the shore. Figure 21 shows the locations of where these measurements were collected and the associated Leq sound levels. The results are shown in Table 7 and in general the sound levels are lower than those measured on the pontoon or on the shore and generally decrease as you move further away from the bridge. There was some demolition of the old SR 520 bridge during the measurements so those measurements on the south side of the bridge are being influenced somewhat by those sounds causing more variability in the sound levels.

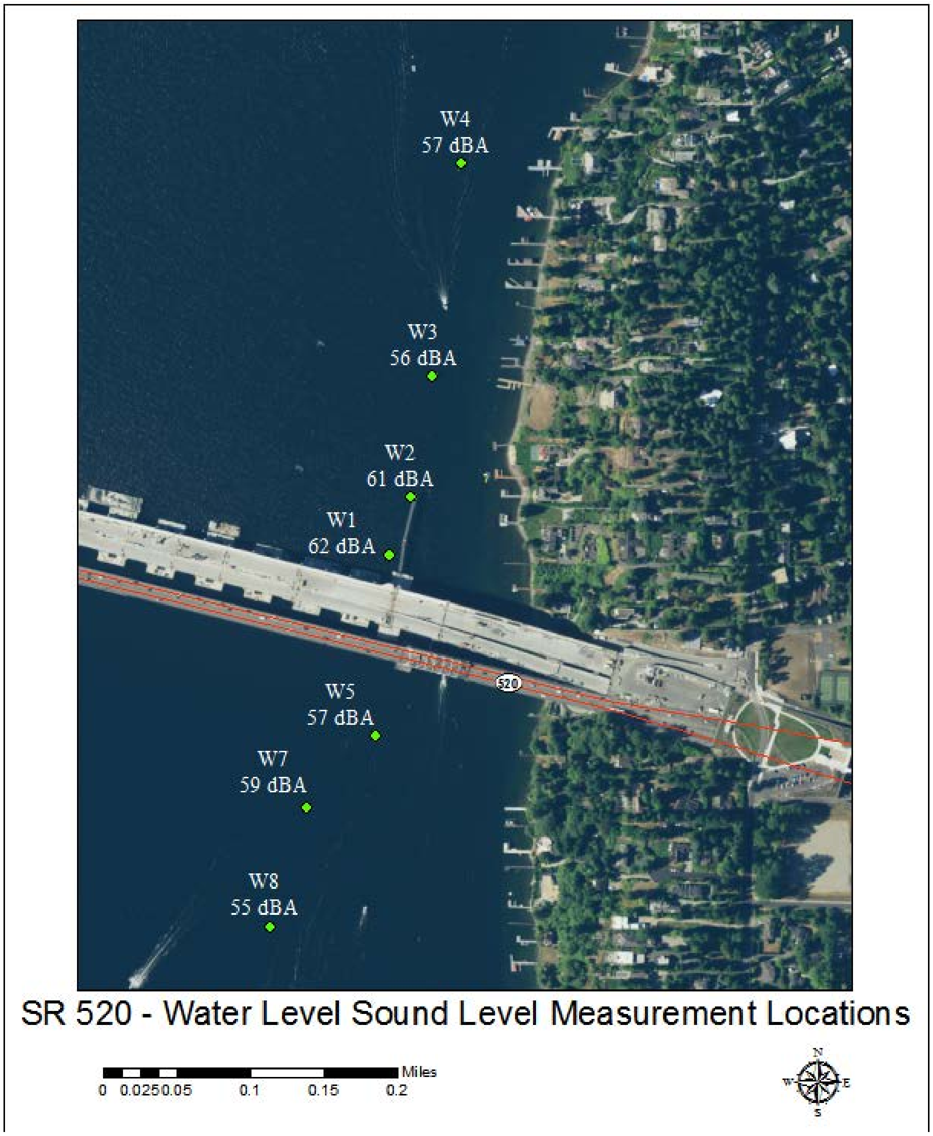

Figure 21

Table 7: Results of Sound Level Measurements Collected at Water Level

Location	Date	Time	Leq (dBA)	Lmax (dBA)	Distance from Eastern Sentinel (feet)
		North of SR 520 Bridge			
W1	May 3, 2016	2:13 PM	62	82	107
W2	May 3, 2016	2:32 PM	61	77	315
W3	May 3, 2016	12:56 PM	56	71	746
W4	May 3, 2016	1:19 PM	57	89	1,527
		South of SR 520 Bridge			
W5	May 3, 2016	1:43 PM	57	72	329
W7	May 3, 2016	2:05 PM	59	74	645
W8	May 3, 2016	2:24 PM	55	76	1,135

Figure 22 is a plot of overall 1/3 octave tones in hertz (Hz) during May 3 measurements collected at the water level at different distances from the bridge on the north and south side (see Figure 21). The plot indicates that there are peaks at 630 Hz and 800 Hz at the two locations closest to the bridge both on the north and south side of the bridge, which suggests that there is some measureable detection of the expansion joint within approximately 650 feet of the bridge. However, as you move farther away the expansion-joint tone is not measureable.

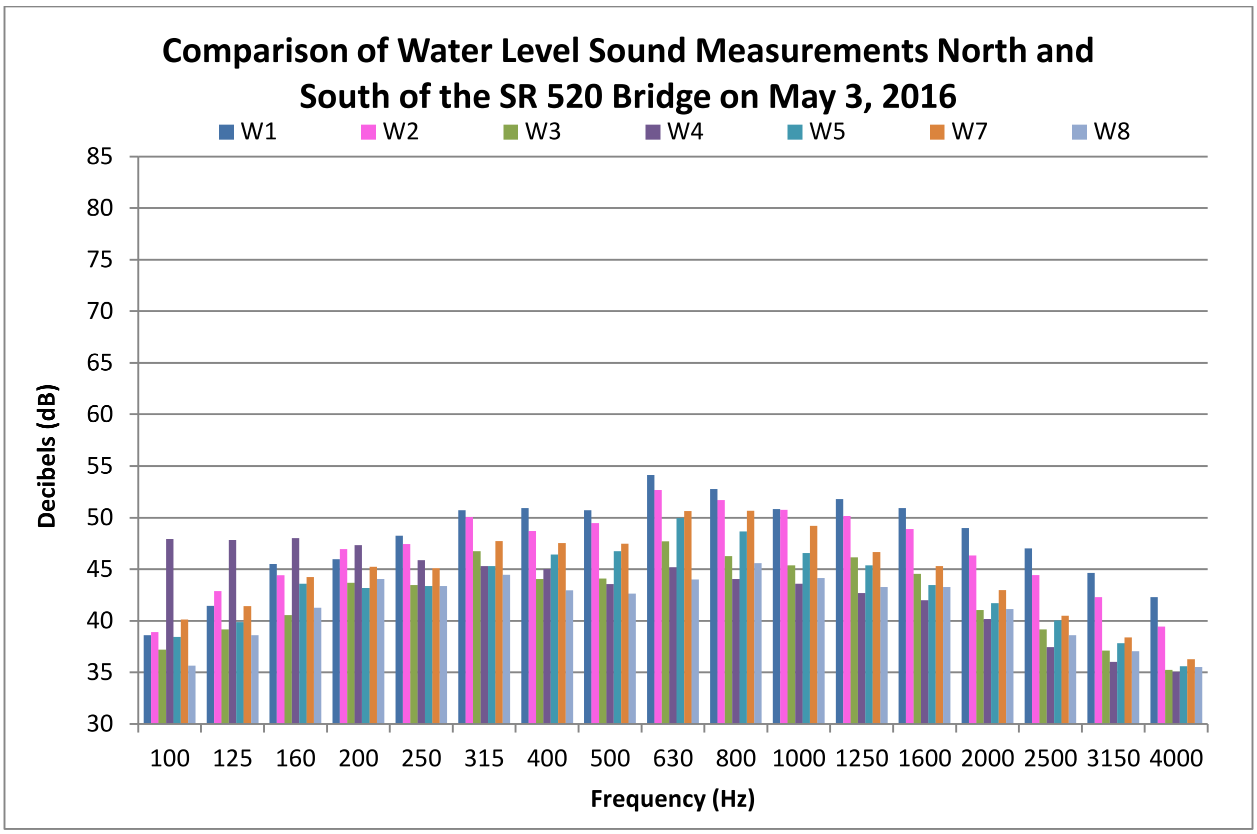

Figure 22

Comparing the New SR 520 Bridge with Other Over-Water Bridge Expansion Joints

For a comparison to other bridge expansion joints, measurements were collected at expansion joints on the west side of the I-90 floating bridge and the east side of the newer Tacoma Narrows Bridge (TNB). These bridges were selected because they are the bridges in Washington with the most similar expansion joint conditions, being major bridges with large joints over water with little to obstruct sound traveling from the joints to the nearest neighbors.

Table 8 shows the expansion joint types and manufacturer for each of the bridges. The expansion joints on all three bridges are the same basic type but the new SR 520 expansion joint has a different manufacturer and was constructed as an encapsulated expansion joint to reduce noise escaping below the bridge deck.

Table 8: Expansion Joints Used on Other Over-Water Bridges in Western Washington

Bridge	Expansion Joint Type	Expansion Joint Manufacturer
SR 520	Accordion	Mageba
I-90	Accordion	D.S. Brown
Tacoma Narrows Bridge	Accordion	D.S. Brown

Table 9 shows the results of measurements collected on the new SR 520 bridge on May 3, 2016, with both directions of traffic open; on the I-90 floating bridge on April 25, 2016, between noon and 1:20 p.m.; and on the TNB on April 25, 2016, between 1:32 p.m. and 4:18 p.m.

Table 9: Results of Sound Level Measurements Collected at Three Different Bridges

	Leq			Lmax		
Measurement Location	SR 520 Bridge (Both) (dBA)	I-90 Bridge (dBA)	Tacoma Narrows Bridge (dBA)	SR 520 Bridge (Both) (dBA)	I-90 Bridge (dBA)	Tacoma Narrows Bridge (dBA)
Large Expansion Joint	79	87	89	91	100	103
Pavement	74	84	84	89	93	96
Pontoon Under Expansion Joint	67	74	75[1]	75	80	90[1]

1 – On the ground, not on a pontoon over water

The results in Table 9 show that the expansion joint on the new SR 520 bridge is 8 to 10 decibels quieter than similar-sized expansion joints on the I-90 and TNB. An 8 to 10 decibel reduction sounds about one-half as loud to the human ear. The pavement on the new SR 520 bridge is 10 decibels quieter, or sounds about one-half as loud as the other bridges' pavements, and the noise levels measured on the pontoon under the expansion joint for SR 520 is 7 to 8 decibels quieter that similar locations on the I-90 and TNB bridges. The Lmax measurements are also quieter on the new SR 520 bridge than on the other two bridges.

Figure 23 is a plot of overall 1/3 octave tones in hertz (Hz) during the measurement period for the SR 520, I-90 and Tacoma Narrows bridges' expansion joints. The plot indicates that there is a similar peak at the 630 Hz and 800 Hz tones as noted above for the new SR 520 expansion joint. However, the sound levels of the different tones of the expansion joints on I-90 and TNB are 6 to 12 dB higher than on the new SR 520 bridge in all frequencies.

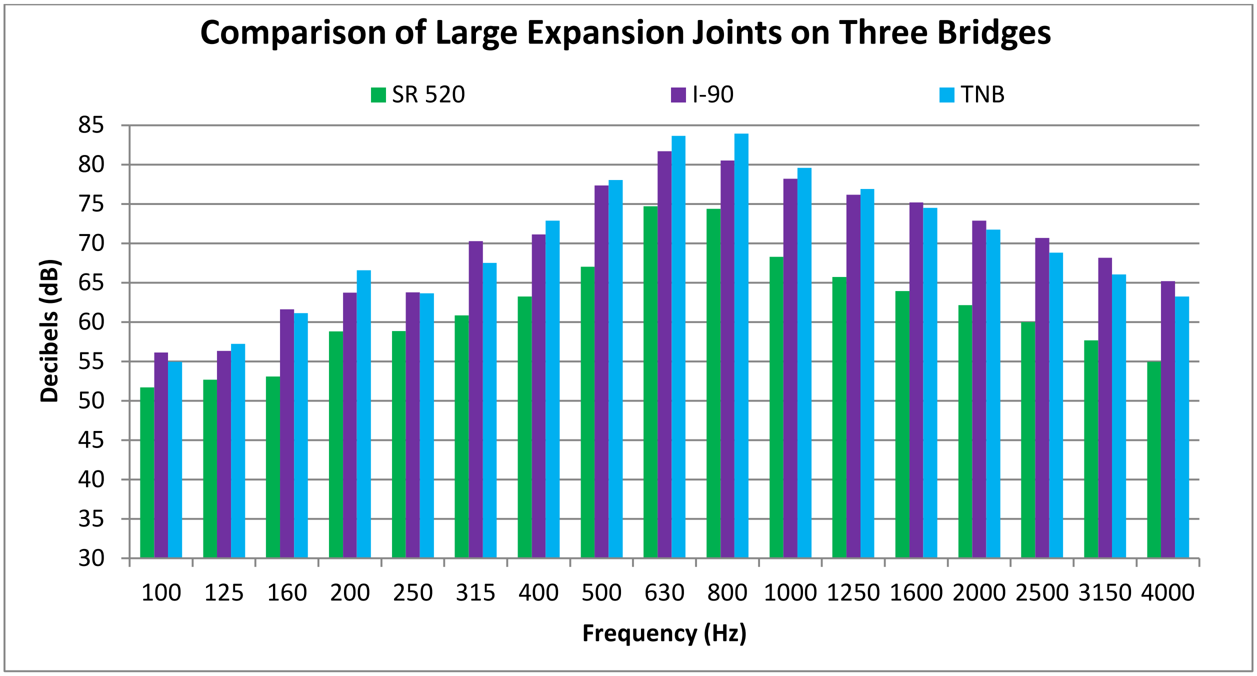

Figure 23

Figure 24 is a plot of overall 1/3 octave tones in hertz (Hz) during the measurement period for each of three bridges' expansion joints. The plot indicates that there is a similar peak at the 1,000 Hz tone as shown above for the typical pavement or traffic noise measurement. Because the I-90 and TNB pavements are older and more worn, they are louder in all frequencies by 4 to 8 decibels.

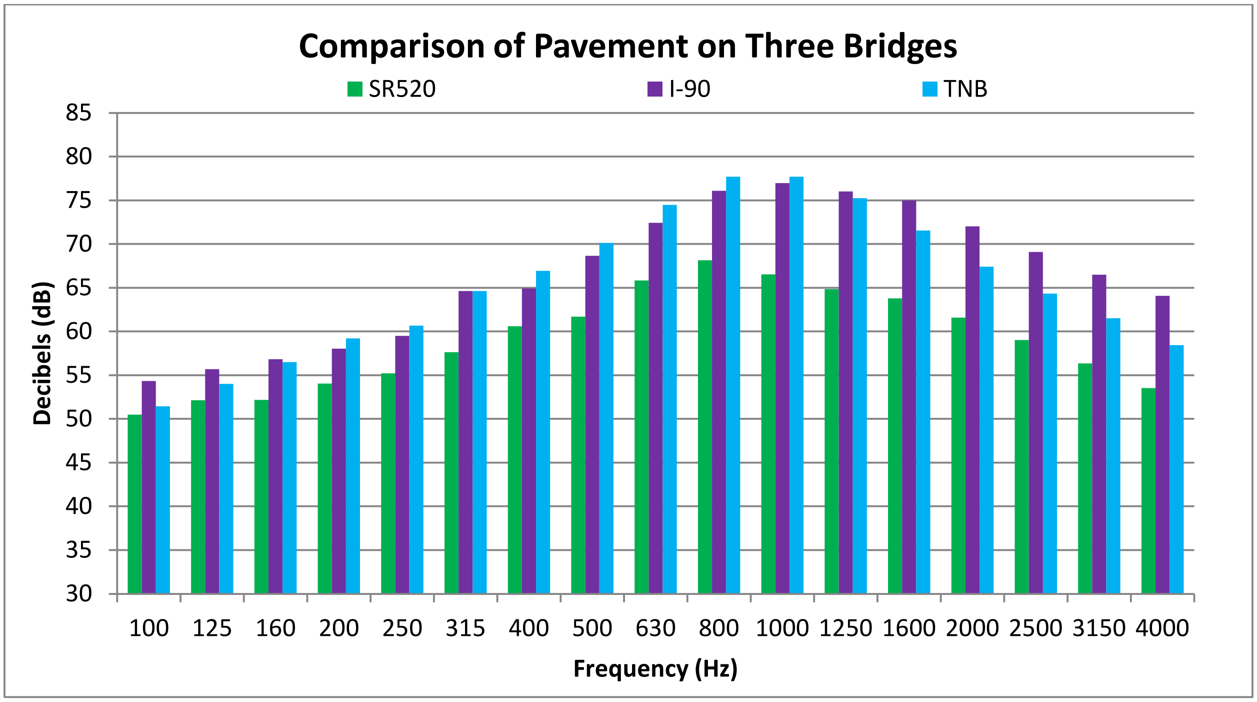

Figure 24

Figure 25 is a plot of overall 1/3 octave tones in hertz (Hz) during the measurement period for measurements collected on the pontoons under the new SR 520 and existing I-90 bridges and on the ground under the TNB expansion joint. The plot indicates that there are peaks at 630 Hz and 800 Hz, which suggest that there is some measureable detection of the expansion joint under each bridge, but it is likely more audible at the TNB and masked by the traffic noise at 1,000 Hz for the other bridges. At the I-90 pontoon, the eastbound bridge is lower in elevation than the westbound traffic and so is likely adding more traffic noise than experienced under the new SR 520 bridge.

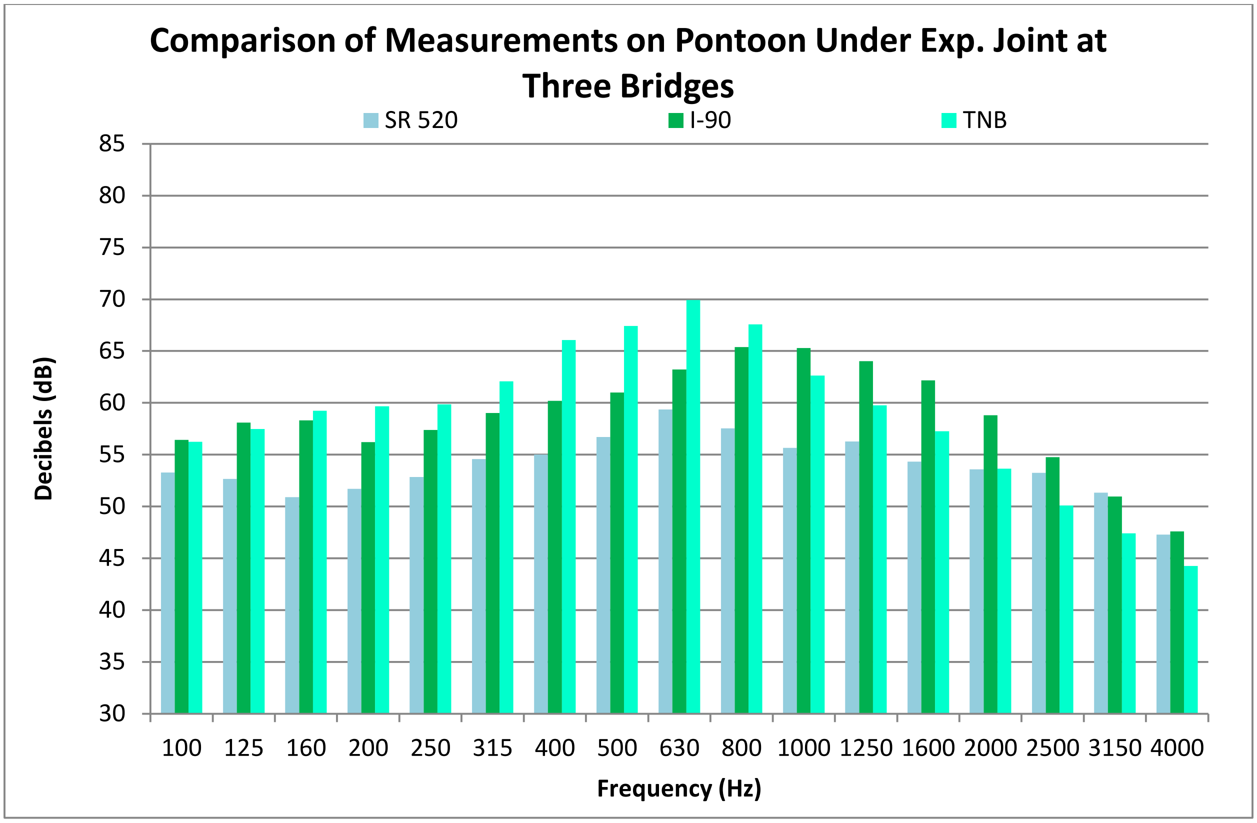

Figure 25

Summary

The results of the noise measurements indicate that the time-weighted average (Leq) sound levels for the new SR 520 bridge, including the new expansion joint, are lower than the old bridge. This reduced sound level is primarily because the pavement on the new bridge is quieter than the old bridge. The Lmax levels that represent the maximum sound level generated by a single vehicle pass-by on the new expansion joint are similar to the Lmax levels on the old bridge. The 1/3 octave frequency plots indicate that the new expansion joint has a different frequency or tonal composition than the old joints. While the new joint is quieter than on the old joint, the tone and impulsive nature of the sound from the new expansion joint can be alerting to some people. Below the bridge the sound from the new expansion joints is barely perceptible as a result of the encapsulating of the joints. The expansion-joint noise becomes more perceptible only when the elevation of nearby residences is approximately the same as the new bridge deck. Because the new bridge has introduced a new sound within a changed sound environment, it is more noticeable to nearby residents. The measurement findings can be summarized in the following points:

- All neighborhood noise measurements were below the FHWA noise abatement criteria of 67 dBA Leq.
- Total near-field SR 520 traffic noise is substantially reduced (approximately 10 dBA Leq lower) compared to the old bridge because WSDOT used quieter pavement specifications for the new bridge.
- Near-field noise from the new bridge's expansion joints is less (approximately 5 dBA Leq) than from the old bridge.
- The tone (sound frequency) of the new joints is about one-half octave lower than from the old bridge (peak sound level from the new joints is between 630 and 800 Hz, while it was around 1,000 Hz for the old bridge).
- Roadway tire noise peaks at around 1,000 Hz.
- Because the background tire noise has been substantially reduced and the peak sound tone at the new joints is lower than the peak tire tone, the noise-masking effect that occurred with the old bridge has been diminished. While the old joints were louder, the sound from the new ones can be clearly heard over the lower background pavement noise.
- The expansion joints on the new SR 520 bridge are roughly twice as quiet (by up to 10 dBA) than similar joints on other major bridges in Washington.

Next Steps

While all noise levels measured in Eastside neighborhoods near the new SR 520 floating bridge were below the FHWA noise abatement criteria, WSDOT recognizes that the sound from the new bridge joints is perceived differently because of the bridge's quieter pavement. Therefore, WSDOT is continuing to gather and analyze data, and evaluate the results. WSDOT will continue to engage with the community and discuss our findings.

Sincerely,

Jim Laughlin
Manager Acoustics, Air Quality and Energy Program
laughlj@wsdot.wa.gov
206-440-4643

Glossary

dBA – A-weighted decibels, or the relative loudness of sound as perceived by the human ear.
Decibel – In acoustics, a unit of sound pressure or sound level measured on a logarithmic scale
Hertz (Hz) – A unit of measurement equaling 1 per second. For sound, it is the frequency of sound waves emitted per second. The average adult human can hear sounds between 20 Hz and 16,000 Hz.
Leq – A time-weighted average of sound measurement, in decibels, generally taken over a 15-minute period.
Lmax - The maximum sound level, in decibels, recorded during a 15-minute period.
Tone – A qualitative description of sound relating to its pitch, quality, or strength.