Regional Connector Transit Corridor
Final Environmental Impact Statement/
Environmental Impact Report

APPENDIX 2

UPDATED LOCALLY PREFERRED ALTERNATIVE NOISE AND VIBRATION ANALYSIS

State Clearinghouse Number: 2009031043

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MEMORANDUM

DATE: 11 July 2011 Revised 12 July 2011

TO: John Prizner, Connector Partnership

FROM: Deborah Jue, Richard Carman

SUBJECT: Noise and Vibration - Preliminary Engineering Update
Walt Disney Concert Hall
Construction and Operational Vibration Impact – Updated Results
WIA#10-088

Executive Summary

This memorandum addresses the updated analysis for the Walt Disney Concert Hall (WDCH) based on field tests conducted in May 2011. Our preliminary impacts analysis for the WDCH was previously presented in a memorandum on Historic Resources[1]. Field tests have been conducted to quantify some outstanding issues identified during the FEIS/FEIR analysis. Two of the main issues were a) how would vibration propagate from the alignment tunnel depth to the WDCH building, and b) how would vibration propagate through the WDCH building into the sensitive spaces. This preliminary engineering analysis includes results from recent sound and vibration measurements conducted at and near the WDCH, and it indicates that there would be a potential noise impact for a single train passby at the Choral Hall, a performance, rehearsal and recording space, which has an unusually high level of amplification, and there would also be potential noise impact during construction in the Choral Hall and in the Main Auditorium, the audience seating area for the primary performance, rehearsal and recording space within WDCH, and in the LA Philharmonic Association (LAPA) conference room. Thus, some form of vibration mitigation such as suspension rail fasteners or isolated slab track in the tunnel would be required to eliminate the operational groundborne noise impacts, and scheduling coordination, slow tunnel train speed, use of conveyor or mitigations similar to the method listed above would be required to eliminate the effect of groundborne noise impacts during construction. The infrequent case of two trains in the tunnels would generate a noise impact at the Main Auditorium and the Choral Hall, but these impacts would be mitigated with the methods listed above. This revision includes changes to Table 5 and 6 to correct erroneously entered data and some corresponding updates in the construction impact section.

Introduction

During the FEIS/FEIR analysis, the potential for noise and vibration impacts at the WDCH was identified, based on conservative assumptions regarding a) how vibration would propagate from the alignment tunnel depth to the WDCH building, and b) how vibration would propagate

[1] Prepared for Task 6.1.4.4, revision date 7 April 2011

through the WDCH building into the sensitive spaces. Thus, in May 2011, field tests were conducted with the cooperation of the Music Center Staff and tenants. These tests were primarily done during the late night/early morning hours, so as to minimize disruption with operations and activities at the WDCH, and to minimize the effects of ambient noise and vibration on the measurement results.

A test plan document was prepared, and a copy of that document is included in Appendix A for reference. In the test plan, a matrix of potentially noise sensitive spaces was listed, as identified by Music Center staff. That matrix is reproduced below in Table 1 with a few updates.

Figure 1 illustrates a schematic cross section of the field test measurements in relation to the WDCH building. Additional drawings showing the test locations within the parking structure and WDCH are provided in the Appendix. The Track Plan and Profile drawings dated 6/29/2011 were used for this analysis. Drawings of the parking structure and WDCH construction were received on 4/13 2011. Representative plan and cross section drawings used for this analysis are included in the Appendix

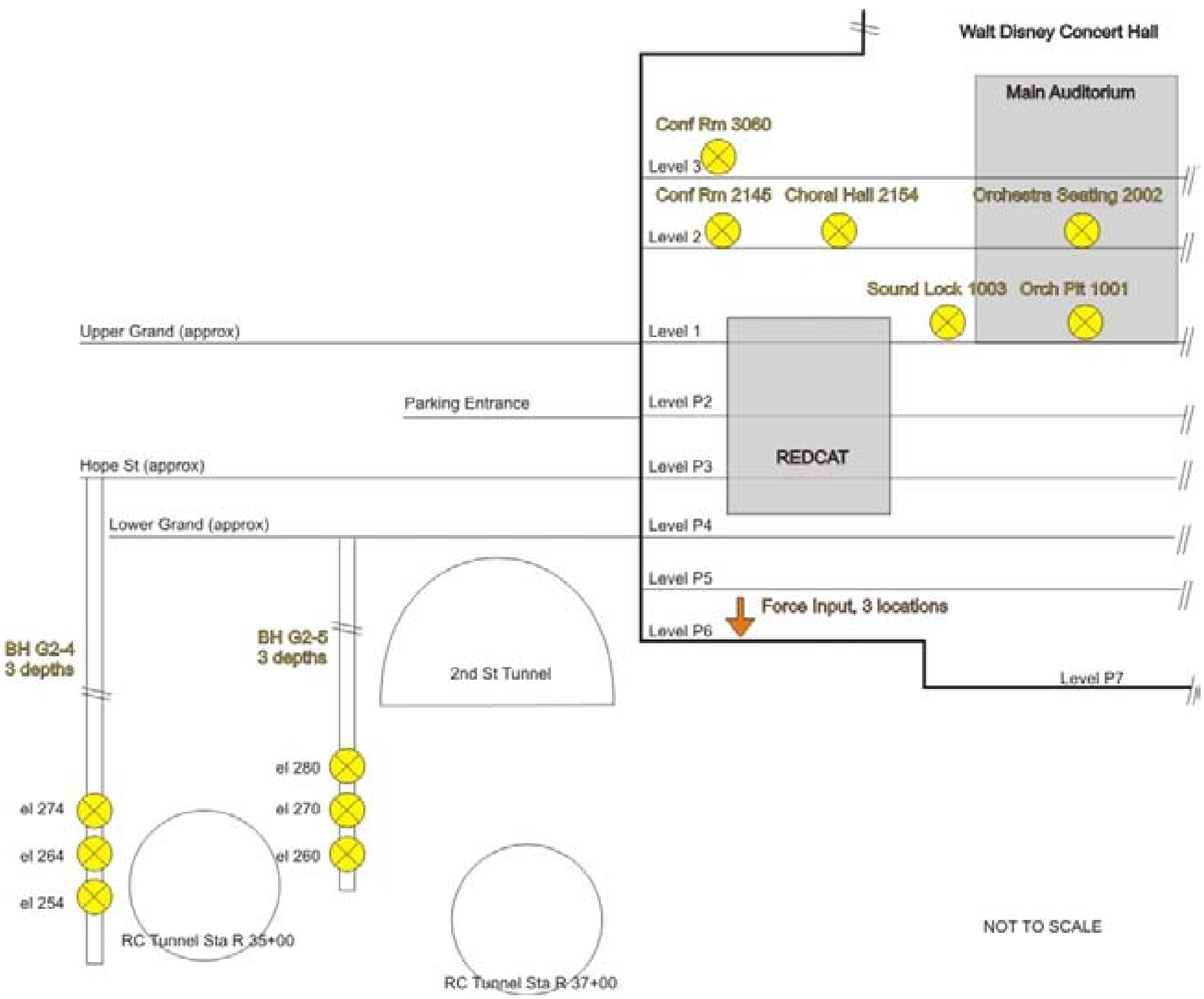

FIGURE 1 Schematic Cross Section, Field Tests Conducted May 2011

TABLE 1 Areas of Interest – Music Center and Walt Disney Concert Hall

Room	Space	Usage	Expected Level Basis	Comment
1st level	Main Entrance	Lobby	see 1001	far less sensitive than Main Auditorium
1001	Platform Pits	Stage Lift Equipment	Calculation	below stage; far less sensitive than Main Auditorium, some horizontal decoupling for final pour under lifts
1003	Sound Lock	Back of house	Calculation	Below staging areas; far less sensitive than Main Auditorium, has different response than 1001
1111	Tenant Space	Retail	see 1001	far less sensitive than Main Auditorium
1111	Tenant Space	Patina Restaurant	see 1001	far less sensitive than Main Auditorium
2nd level	Terrace	Outdoor	see 2145	Vibration only
2001	behind chorus loft	Stage/Main Aud.	see 2002	
2001	Concert platform	Stage/Main Aud.	see 2002	
2002	Orchestra Seating	Main Auditorium	Calculation	
2008	recording	control booth/Main Aud.	see 2002	
2011	Assembly Area	pre-stage	see 2002	less sensitive than Main Auditorium
2058	Dressing Room		see 2145	less sensitive than Main Auditorium
2068	Dressing Room		see 2145	less sensitive than Main Auditorium
2073	Dressing Room	Concert Master	see 2145	less sensitive than Main Auditorium
2083	Director	pre-stage	see 2145	less sensitive than Main Auditorium
2092	Stage Door Waiting	pre-stage	see 2145	less sensitive than Main Auditorium
2119	Orchestra Café	dining	see 2154	far less sensitive than Main Auditorium
2143	LAPA	Conference Room	see 2145	less sensitive than Main Auditorium
2145	LAPA	Conference Room	Calculation	less sensitive than Main Auditorium
2144	LAPA (1)	open office	see 2145	less sensitive than Main Auditorium
2144	LAPA (2)	board president	see 2145	less sensitive than Main Auditorium
2154	Choral Hall	Rehearsal, performance, some recording	Calculation	less sensitive than Main Auditorium
2170	Ante Room	Practice/warm up	see 2154	less sensitive than Main Auditorium
2178	Ante Room	Practice/warm up	see 2154	less sensitive than Main Auditorium
2190	founders room	function	see 2002	far less sensitive than Main Auditorium
3rd level	garden	outdoors	see 3060	Vibration only; less sensitive than interior spaces
3rd level	Keck Amphitheater	outdoors	see 3060	Vibration only; less sensitive than interior spaces
3001	Center Orchestra	Main Auditorium	see 2002	
3rd level	Main Auditorium wall(s)		n/a	Wall panels are installed with decoupling hardware.
3023	announce/control		see 2002	
3028	organ	Stage/Main Aud.	see 2002	
3060	LAPA	Conference Room	Calculation	less sensitive than Main Auditorium
3061	LAPA (1)	open office	less than 2144	less sensitive than Main Auditorium
3061	LAPA (2)	open office	less than 2144	less sensitive than Main Auditorium
4th level	Keck audience (2)	outdoors	less than 2144	Vibration only; far less sensitive than Main Auditorium

Operational Noise and Vibration

This analysis follows the Federal Transit Administration (FTA) methodology for "Detailed Analysis"[2] which uses the following equation for vibration:

(1) L_V(in building) = L_F (speed) + TM_{Line} (distance from track centerline) + C_{Tunnel} + C_{Build}

Where

L_V = Vibration at a specific horizontal distance from the alignment in decibels re 1 micro-inch/second

L_F = Force density or system input spectrum of the LRV on the track structure. This is a function of parameters such as

- Speed
- Wheel/Rail condition (corrugation, wear, etc.)
- Rail configuration (joints, special trackwork, tangent, curved, etc.)
- Track structure (direct fixation on invert, ballasted track, resilient fasteners, floating slab, etc.)

TM_{Line} = Transfer mobility of the intervening ground or subsurface layers for a line input of a specified length (typically the length of a train consist) as measured at the receiver.

C_{Tunnel} = Although this factor is not explicitly called out in the FTA methodology, it is used to account for coupling loss between the tunnel structure and the surrounding soil.

C_{Build} = Adjustments to account for ground-to-building coupling losses, floor to floor attenuation and room surfaces structural response to vibration

Groundborne noise is determined by the groundborne vibration level, and it is calculated as follows:

(2) $L_A = L_V + K_{rad} + K_{A\text{-}wt}$

Where

L_A = A-weighted noise level in dB re 20 micro-inch/second

K_{rad} = Adjustment for conversion of vibration velocity to sound pressure, taking into account the acoustical absorption in the room and the sound radiating characteristics of the room surfaces

$K_{A\text{-}wt}$ = A-weighting adjustment curve

The following parameters were used for this analysis:

- LRV
    - 3-car train
    - 15 mph maximum speed (limited by design speed of curves and nearby station)
    - Direct fixation (resilient fasteners on the order of 140,000 lb/in dynamic stiffness)
    - L_F in this case is taken from an energy-average of various similar LRV operating on direct fixation fasteners including LA Metro Blue Line (Nippon-Sharyo P865), LA Metro Goldline (Siemens P2000 or Breda P2550) and Sound Transit (Kinki-Sharyo). The Sound Transit L_F dominates the average in the 50 and 63 Hz 1/3 octave bands and includes the effect of a curve. The assumed L_F spectrum is shown in Figure 2.
    - One train or two trains passing in the tunnel structure.

[2] Originally developed in 1986 by WIA, this method has been incorporated into the FTA Guidance Manual.

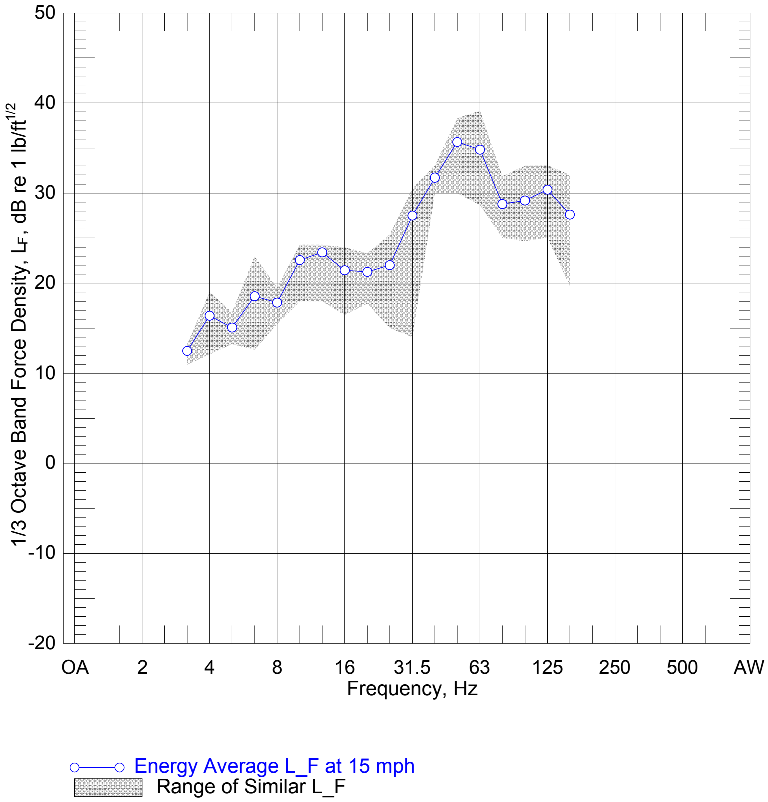

FIGURE 2 **Range of Applicable Force Density (L_F) Spectra**
15 mph Direct Fixation Fasteners

- Potential Mitigation Measures
  - High compliance fastener such as a Cologne Egg or HA-LVT (50kips/in static stiffness with a dynamic to static stiffness ratio of 1.2)
  - Rail suspension fastener systems such as Delta DFF manufactured by Advanced Track Products or Panguard manufactured by Pandrol (14 to 16kips/in static stiffness with a dynamic to static stiffness ratio of 1.4 or less)
  - Isolated slab trackbed using a 1" resilient mat between the tunnel invert and the concrete trackbed such as the Sylomer mat manufactured by Getzner e.g., 64 lb/in^2 dynamic stiffness modulus)
  - For optimal performance, the dynamic/static stiffness ratio (k_d/k_s) a bonded DF fastener should ideally fall within the range of 1.0 to 1.3 for natural rubbers; synthetic rubber, the optimal ratio is typically within the range of 1.4 to 1.8. The above ratios indicated are obtainable from manufacturers.
  - The expected performance for these systems in shown in Figure 3.
- Tunnel
  - Bored tunnel – the analysis assumes no coupling loss with the Fernando Formation
  - At station R 34+40 the top-of-rail is near 250 ft elevation and at station T2 37+00 the top-of-rail is near 240 ft elevation.
  - Thus, the top-of-rail at R 37+00 is about 115 ft below Lower Grand Avenue.

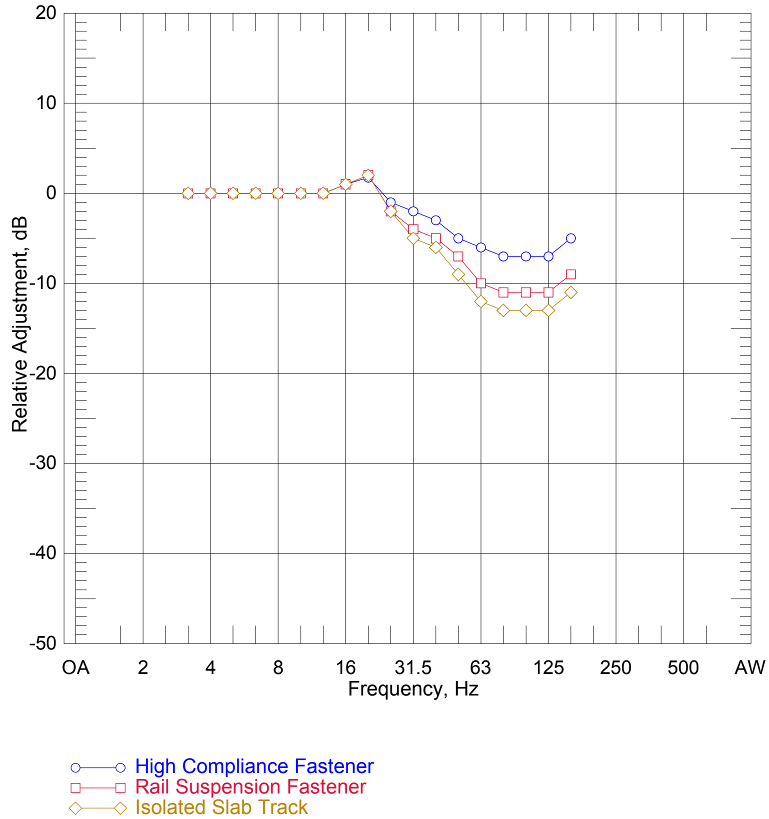

FIGURE 3 Mitigation Options – Relative Vibration Performance

- Subsurface conditions
  - The geotechnical studies indicate that the alignment tunnel would be founded in Fernando Formation in this area[3]
  - Fernando Formation is exposed at the ground surface of nearby Broad building site
  - Transfer mobility derived from field tests conducted in May 2011 from tunnel depths to P6 level within WDCH.
  - See Figure 4 for the transfer mobilities derived from the WDCH measurements.
    - TM at 30 ft horizontal distance used for worst case condition with train centered at southwest corner of WDCH, near Sta R 37+00 and top-of-rail about 84 ft below P6 level.
    - TM at 95 ft horizontal distance used for worst case condition at Choral Hall with train centered south of the WDCH, near Sta R 34+40 and top of rail about 74 ft below P6 level.
  - A comparison of field test results with previous Transfer Mobility models is contained in the Appendix.

[3] Preliminary geologic profiles (1/5/11) prepared by MACTEC Engineering and Consulting, and updated geologic plan and profile from field borings (6/29/11)

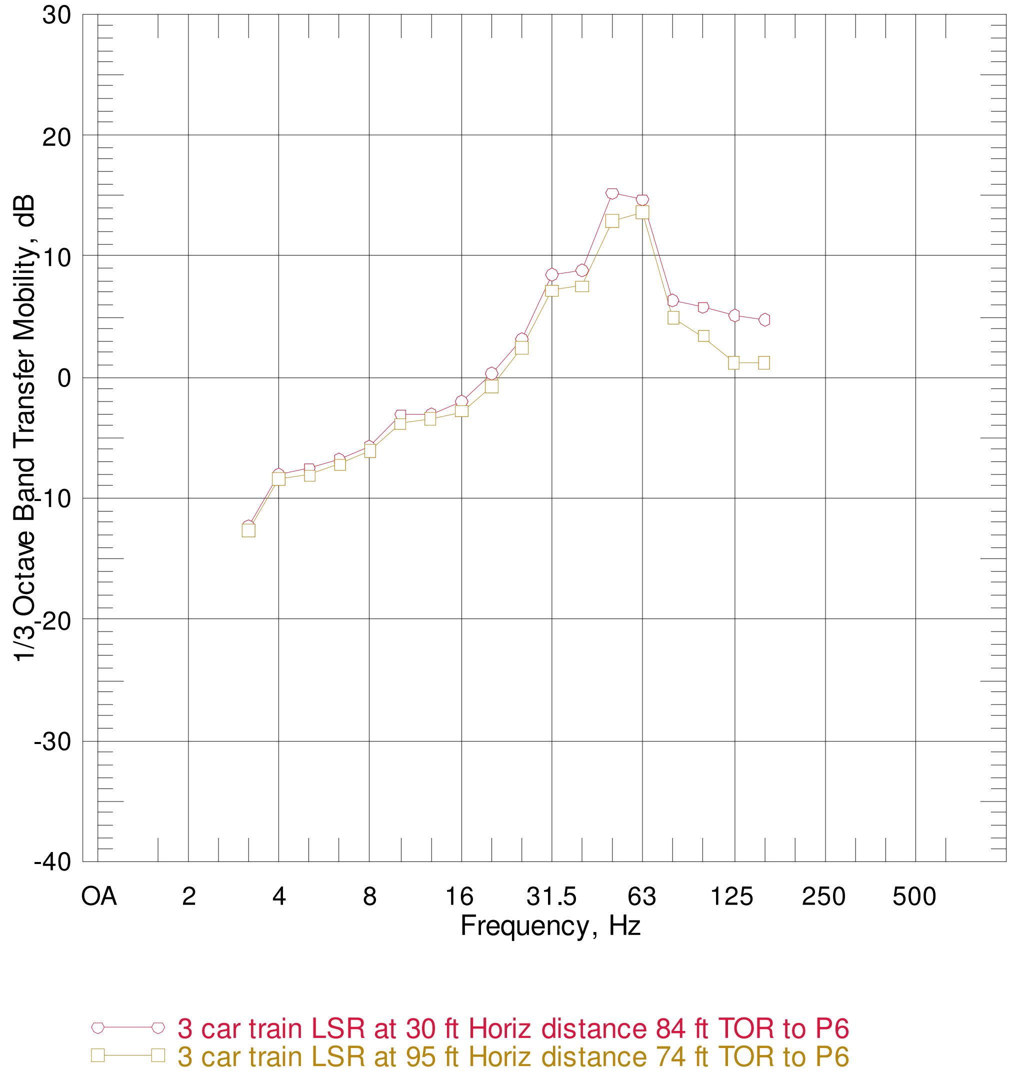

FIGURE 4 Transfer Mobility for Line Source – Fernando Formation

- Walt Disney Concert Hall
  - Along the 2nd Street, the original seven-level parking structure was founded on piles at the 6th level (P6) for the south perimeter. However, the 7th level does not extend as far south and appears to have a slab-on-grade foundation, ending around column line 5.3, as shown schematically in Figure 1.
  - The elevation of P6 is approximately 318 ft, so that the Project tunnel would be about 68 to 78 ft below P6.
  - Portions of the upper floors of the parking structure were demolished for construction of the WDCH and the Roy and Edna Disney/CalArts Theater (REDCAT)
  - Correction Factors included in C_{Build}:
    - Measured loss from P6 parking level to representative spaces within WDCH. (Figure 5)
      - The maximum response was used for each location
      - In most cases the range response was well clustered, regardless of P6 impact location. See Appendix.

- At the Choral Hall, a significantly higher response was measured when the source impact was done at the southwest corner of P6. This response was used with 95 ft horizontal distance transfer mobility, as discussed above.

▪ Room response factor assumes only minor acoustical absorption in the spaces (Figure 6); were unable to generate a sufficient level of vibration to measure the actual relationship between groundborne vibration and groundborne noise within the Main Auditorium, so this (conservative) factor has been retained from the preliminary analysis.

▪ Measured insertion loss between structure and REDCAT auditorium, across the isolation joint (Figure 7)

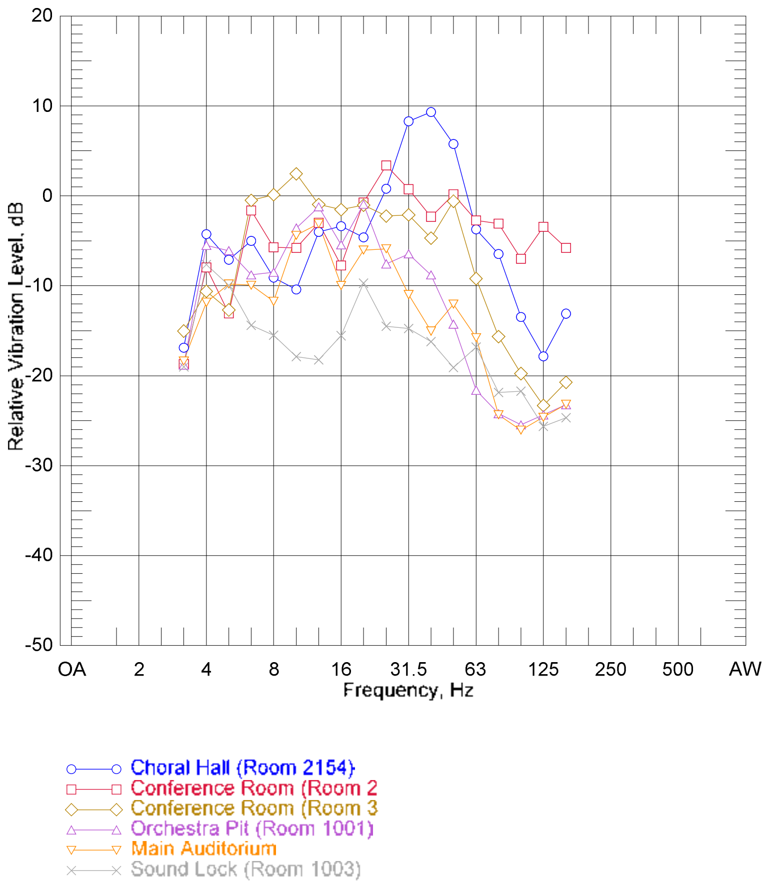

FIGURE 5 Building Response Factors WDCH

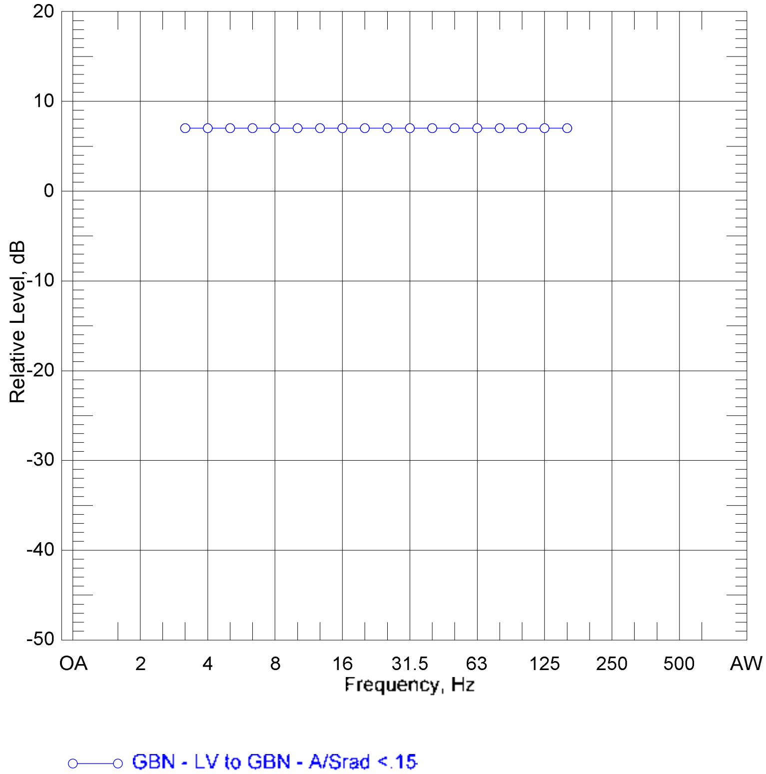

FIGURE 6 Vibration to Noise Conversion Factor

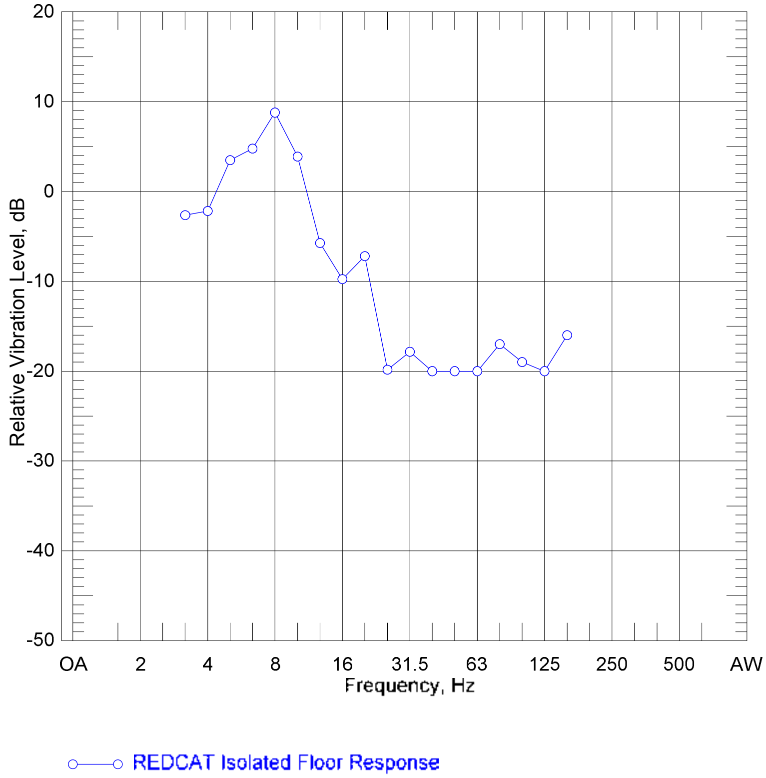

FIGURE 7 Vibration Isolation, REDCAT

- Criteria (FTA)
  - FTA Criteria were developed to address the typical needs and expectations within different categories of buildings. The specific categories and criteria applicable to WDCH are indicated below.
  - Frequent Events (greater than 70 events per day)
    - Default: FTA Category 3 (Institutional)
      - 75 VdB for groundborne vibration
      - 40 dBA for groundborne noise
      - For reference, a 35 dBA level would be just noticeable to the careful listener, a 30 dBA level would generally not be audible in a live performance setting, and a 25 dBA level could be measured, but would not be audible to the naked ear.
    - REDCAT
      - FTA Special Buildings (Theater):
        - 72 VdB for groundborne vibration
        - 35 dBA for groundborne noise
    - Choral Hall
      - FTA Special Buildings (Auditoriums)
        - 72 VdB for groundborne vibration
        - 30 dBA for groundborne noise
        - This space is used for rehearsals with some recitals/chamber performances and archival recordings
    - Main Auditorium
      - FTA Special Buildings (Concert Halls and Recording):
        - 65 VdB for groundborne vibration
        - 25 dBA for groundborne noise
        - This space is used for rehearsals, performances, archival recordings and some commercial recordings.
        - This is the most sensitive space within the WDCH complex, due to number of performances and performer and audience expectations
  - Occasional Events (from 30 to 70 event per day)
    - FTA Category 3: 78 VdB and 43 dBA
    - FTA Special Building (Theater): 80 VdB and 43 dBA
    - FTA Special Building (Auditorium): 80 VdB and 38 dBA
    - FTA Special Building (Concert Hall and Recording): 65 VdB and 25 dBA
  - Other information
    - Table 2 summarizes the ambient conditions and the corresponding NC levels.
    - The ambient noise results are included in the Appendix.
- Miscellaneous
  - The engineering design factor is shown in Figure 8. This curve is based on the estimated net uncertainty in derivation of L_F ,TM and other factors used in calculating groundborne noise and vibration
    - Based on our experience, the typical variability in the L_F for a given fleet of vehicles is small for reasonably well-maintained rails and wheels.

    - Since the L_F in this analysis is based on measured data for both the Gold Line and Blue Line vehicles, we expect the actual L_F value to be within 1 or 3 dB of the curve shown in Figure 2 to account for differences in vehicle speeds, track conditions and fasteners.
    - The typical variability in the field measured TM and coupling loss parameters also adds another 2 to 4 dB uncertainty for data between 12 and 160 Hz.
    - The validity of using this design factor and the accuracy of the FTA prediction model has been examined in a paper presented by WIA to the American Public Transit Association in 1995[4].
- Further, some additional conservatism has been included:
    - In the effect of the curve on the L_F which could be overstated in Figure 2; this effect primarily influences the 50 and 63 Hz 1/3-octave bands which dominate the groundborne noise calculations.
    - In the groundborne noise prediction by assuming that the vibration of the wall and ceiling surfaces is the same level as the floor vibration. Typically there should be some loss from floor to ceiling and from horizontal plane (floor) to the vertical plane (walls).
    - In the groundborne noise prediction since it does not include the effect of resilient supports for the wall panels in the Main Auditorium; thus the conversion from vibration to noise could be less than predicted.
    - In the groundborne noise prediction by assuming only minor acoustical absorption as mentioned above.
- This model assumes reasonably well-maintained rails and wheels, and thus does not include the effects of occasional moderate flat wheels or poorly maintained rail.
- This model assumes that the potentially high variability in high frequency vibration would be controlled through regular rail grinding and wheel maintenance programs.

[4] Carman, Richard, "Rail Transit – Groundborne Noise and Prediction Models, A Comparison of Predicted and Measured Data," June 1995.

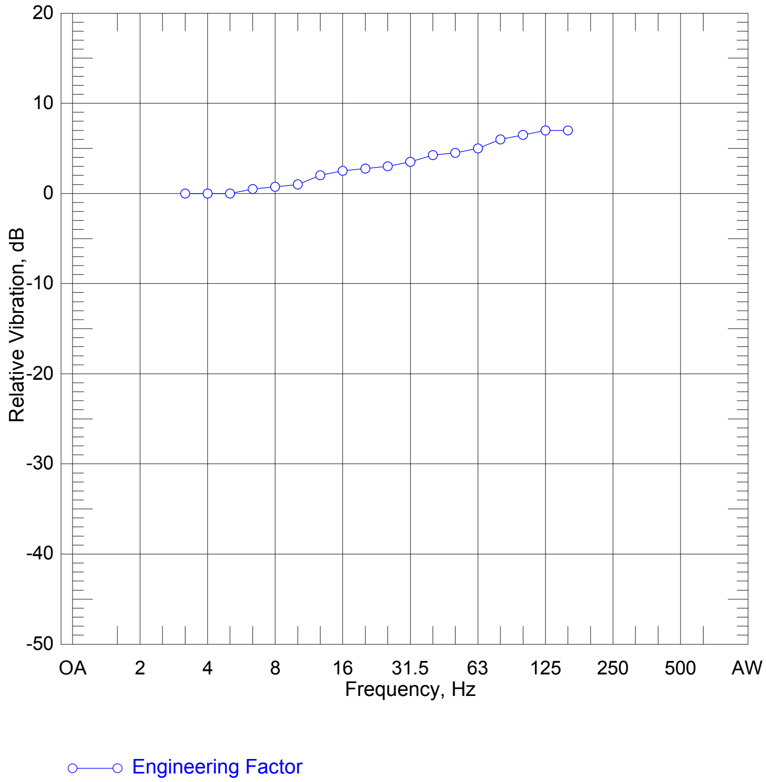

FIGURE 8 Engineering Design Factor
Groundborne Vibration Calculation

The predicted results for groundborne vibration at different spaces within the WDCH for a single train passby are shown in Figure 9, and the corresponding results for groundborne noise are shown in Figure 10. Results for the REDCAT have also been updated, and they are shown in Figures 11 and 12.

As shown in the left axis of Figure 9 and Figure 11, all groundborne vibration is expected to be less than 65 VdB.

The groundborne vibration calculations were converted to groundborne noise (Figure 10 and Figure 12), applying the highest vibration to noise conversion factor to the vibration estimate. As shown in the right axis, the groundborne noise range is expected to range from 22 dBA at the REDCAT to 37 dBA at the Choral Hall.

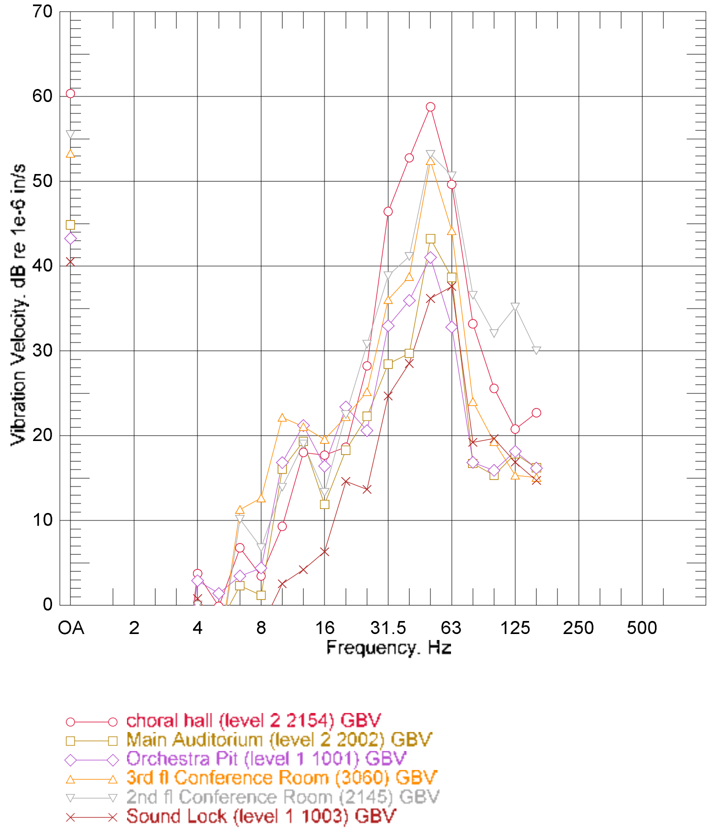

FIGURE 9 Predicted Groundborne Vibration at WDCH

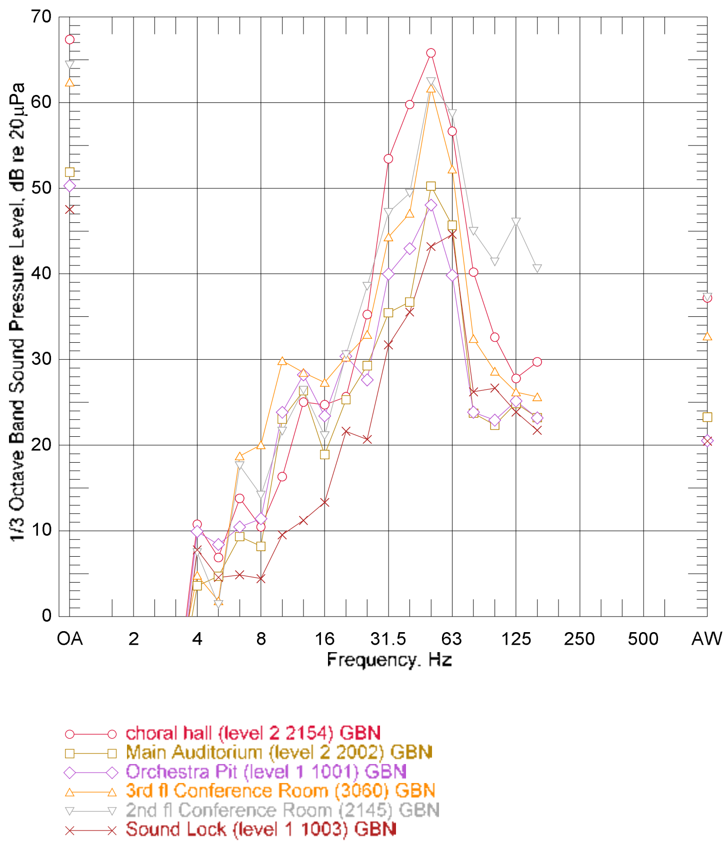

FIGURE 10 Predicted Groundborne Noise at WDCH

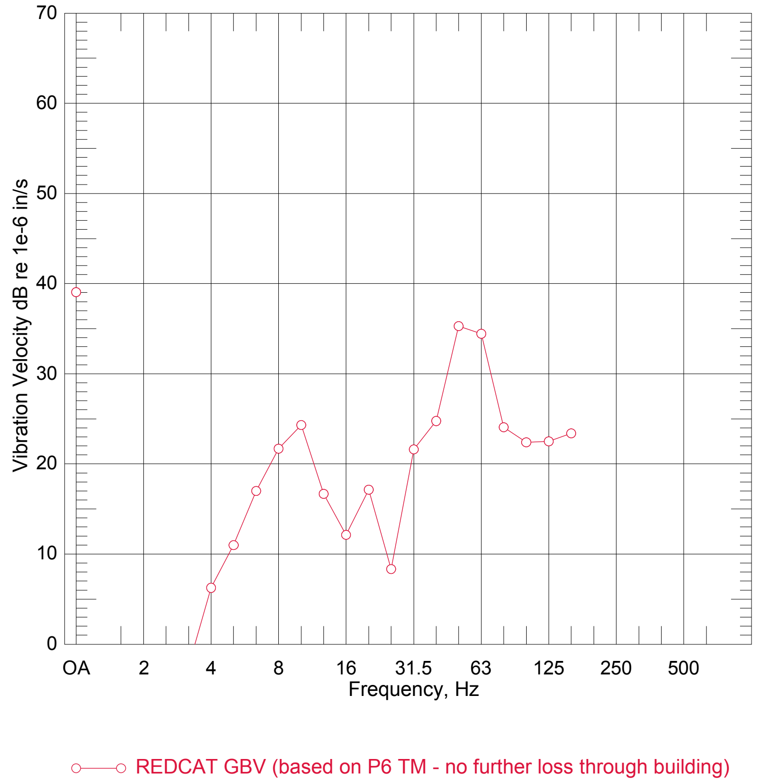

FIGURE 11 Predicted Groundborne Vibration at WDCH – REDCAT

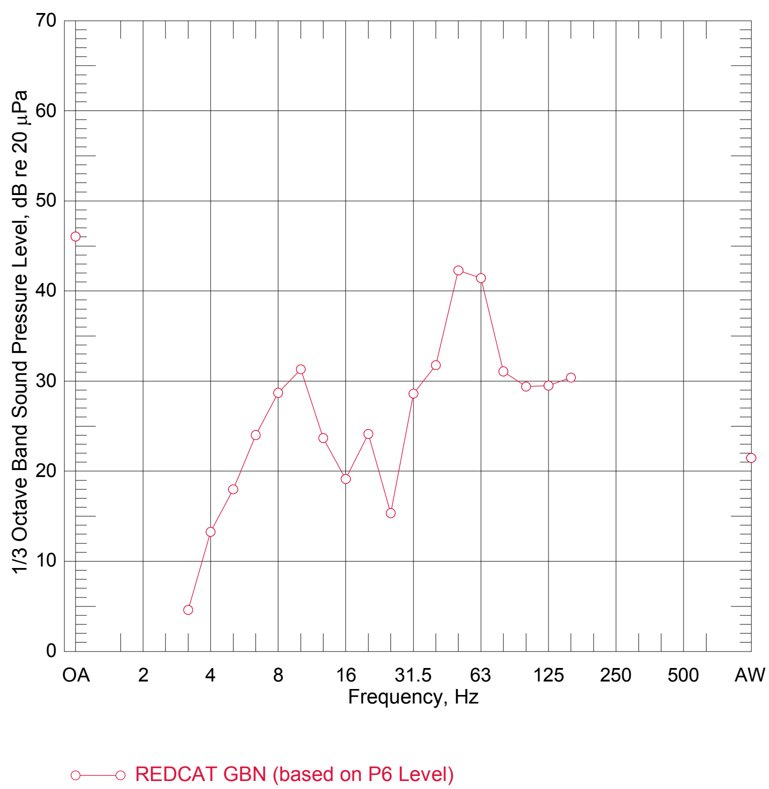

FIGURE 12 Predicted Groundborne Noise at WDCH - REDCAT

Figure 13 and Table 4 present the estimated results for the Choral Hall with the various mitigation options considered. As shown, the groundborne noise in the Choral Hall would be less than the 30 dBA criterion with several of these measures. Thus, for groundborne noise, the predicted result with mitigation measures such as a rail suspension system or an isolated slab track would comply with the applicable FTA criteria. The use of high compliance fasteners appears to be inadequate to mitigate the groundborne noise at the Choral Hall.

There would be occasions where two trains are in the tunnels (one westbound and the other eastbound). During these events, the vibration would increase by up to 3 VdB, and the groundborne noise would increase by up to 3 dBA. However, since such dual train passbys would typically occur *at this area* 70 times or fewer per day, higher criteria would apply for the institutional spaces within WDCH. For institutional buildings (office use), the FTA criteria for occasional events are 78 VdB and 43 dBA. Thus, there would be no net change in impact compared to the single train passby. For the Choral Hall, the criteria for occasional events are higher, but with mitigation the groundborne noise would be less than the 38 dBA criterion and there would be no impact for this condition. The Main Auditorium criteria remain unchanged regardless of the frequency of events. As shown in Figure 14 and Table 4, with any of the considered mitigation options, the increased levels from two trains in the tunnel comply with the criterion in the Main Auditorium.

The baseline sound and vibration measurements are noted in Table 2 below along with the FTA criteria[5] for operational groundborne vibration and noise.

Table 2 FTA Criteria and Baseline Conditions

Space	FTA Category	Criteria						Ambient	
		Groundborne Vibration			Groundborne Noise			Vibration	Noise
		Freq.	*Occas.*	*Infreq.*	*Freq.*	*Occas.*	*Infreq.*		
REDCAT	Special Buildings (Theaters)	72 VdB	80 VdB		35 dBA	43 dBA		50 VdB	28 dBA (1) NC 19
WDCH Main Auditorium (Room 2002)	Special Building (Concert Halls and recording Studios)	65 VdB			25 dBA			46 VdB	26 dBA NC 18
WDCH Orchestra Pit (Room 1001)	Separated from performing space by stage floor							45 VdB	**
WDCH Sound Lock, Level 1 (Room 1003)	Apply Calculation to other Level 1 spaces, Category 3	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	35 VdB	**
WDCH Choral Hall (Room 2154)	Special Building (Auditoriums)	72 VdB	80 VdB		30 dBA	38 dBA		44 VdB	30 dBA (2) NC 26
WDCH/LAPA Conference room 2nd Floor (Room 2145)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	52 VdB	27 dBA NC 18
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	52 VdB	**
Board of Directors Office (Room 2144)	3: Institutional	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA	**	27 dBA NC 18

Notes:
1. Measured in March 2011
2. HVAC appears to be on.

** not measured

[5] FTA criteria were cited in the Draft EIS/EIR. Concert halls and theaters are generally designed to meet Noise Criteria (NC) curves, and the baseline measured levels are indicated in this memo.

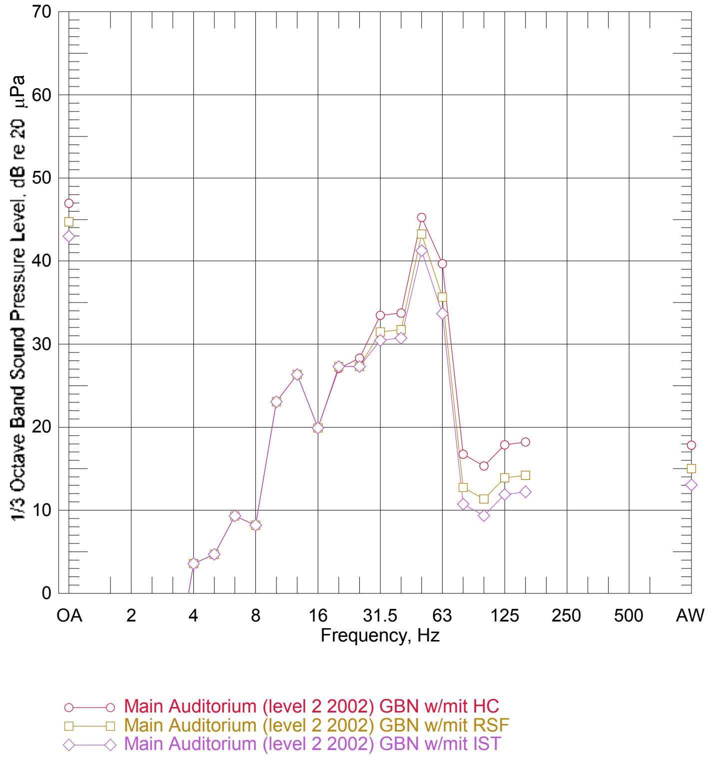

FIGURE 13 Predicted Groundborne Noise at WDCH – Main Auditorium With Mitigation Options

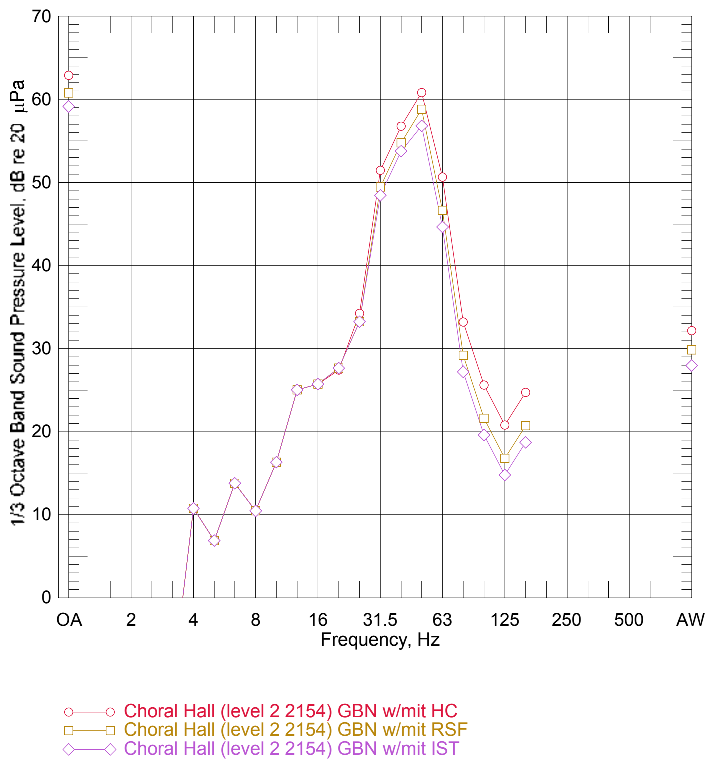

FIGURE 14 Predicted Groundborne Noise at WDCH – Choral Hall with Mitigation Options

Tables 3 and 4 summarize the updated effects from operations and the effectiveness of different measures to mitigate these effects below significance.

Table 3 Operational Effects from LA Metro Regional Connector Project – No Mitigation

Space	Criteria				Single 3-car Train (Frequent)		Two 3-car Trains (Occasional or Infrequent)		Impact?
	Groundborne Vibration		Groundborne Noise						
	Freq.	*Occas./ Infreq.*	*Freq.*	*Occas./ Infreq.*	Vibration	Noise	Vibration	Noise	
REDCAT	72 VdB	80 VdB	35 dBA	43 dBA	39 VdB	22 dBA	42 VdB	25 dBA	No
WDCH Main Auditorium (Room 2002)	65 VdB		25 dBA		45 VdB	23 dBA	48 VdB	**26** dBA	Yes: Two trains
WDCH Orchestra Pit (Room 1001)					43 VdB	21 dBA	46 VdB	24 dBA	No
WDCH Sound Lock, Level 1 (Room 1003)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	41 VdB	21 dBA	44 VdB	24 dBA	No
WDCH Choral Hall (Room 2154)	72 VdB	80 VdB	30 dBA	38 dBA	60 VdB	**37** dBA	63 VdB	**40** dBA	Yes: One and Two trains
WDCH/LAPA Conference room 2nd Floor (Room 2145)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	57 VdB	37 dBA	60 VdB	40 dBA	No
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	75 VdB	78/ 83 VdB	40 dBA	43/48 dBA	55 VdB	33 dBA	58 VdB	36 dBA	No
Bold entries exceed criteria									

Table 4 Operational Effects from LA Metro Regional Connector Project – Groundborne Noise with Mitigation for Affected Spaces

Space	Groundborne Noise Criteria		Groundborne Noise without Mitigation		Mitigation Options Considered	Groundborne Noise with Mitigation (dBA)		Impact after Mitigation?
	Freq.	*Occas./ Infreq.*	Single Train	Two Trains		Single Train	Two Trains	
WDCH Main Auditorium (Room 2002)	25 dBA		23 dBA	**26** dBA	HC RSF IST	18 15 13	21 18 16	No: all mitigation options would be effective
WDCH Choral Hall (Room 2154)	30 dBA	38 dBA	**37** dBA	**40** dBA	HC RSF IST	**32** 30 28	35 33 31	No: Only RSF and IST options would be effective

Notes:
Bold entries exceed criteria
HC: High Compliance Fasteners (e.g., Cologne Egg or High Attenuation LVT)
RSF: Resiliently Supported Fasteners
IST: Isolated Slab Track

Construction Impacts

Building damage criteria and impacts were previously discussed in the 7 April 2011 memorandum where the potential for building damage impacts from cut and cover activities were indicated.

The FTA also provides criteria for short-term impacts (or annoyance) during construction, with the criteria equivalent to the same criteria provided for operational groundborne vibration and noise discussed above.

For tunneling vibration, the EIS/EIR indicates that tunnel boring machines (TBM) can generate vibration as high as 0.055 in/sec peak particle velocity (PPV) at a distance of 33 feet from the TBM source. Since the alignment refinements have not brought the alignment closer than 40 feet to historic resources, no new construction vibration impacts are expected due to the change in tunnel depth. No new mitigation measures would be required.

Thus, TBM vibration of 0.018 in/sec PPV at 70 ft[6] would result in an RMS vibration level of approximately 73 VdB at the lowest parking level. The corresponding groundborne noise could be on the order of 40 to 53 dBA. Taking into account building isolation and losses through the parking structure, the short-duration noise and vibration from TBM at Walt Disney Concert Hall and at the REDCAT, are indicated in Table 5 and would potentially exceed the criteria for groundborne noise at the Main Auditorium during performances and recording sessions and at the LAPA conference room on the 2nd floor (Room 2145). It is possible that some of the other 2nd floor LAPA office spaces would experience the same effects as Room 2145. The duration of impact would be on the order of 10 days assuming 35 ft per day progress.

Groundborne noise and vibration would also be generated by delivery trains in the tunnel during construction assuming delivery trains are the method selected to move soil from tunnel to surface. These slow moving trains have greater groundborne noise and vibration effects than the trains used for operations due to the presence of wheel flats or jointed construction rails, and even with a correction for the slower tunnel train speed (5 to 10 mph) it is estimated that the vibration would be on the order of 0 to 5 dB greater than that generated by the LA Metro operations. Thus, at WDCH Main Auditorium this would result in groundborne vibration on the order of 50 VdB and groundborne noise of 23 to 28 dBA, potentially exceeding the groundborne noise criterion. At the Choral Hall the tunnel train would generate groundborne noise of 37 to 42 dBA, which potentially exceeds the groundborne noise criterion. Groundborne vibration from the tunnel train would comply with criteria.

Table 5 summarizes the short-term effects from construction, and Table 6 indicates the anticipated effects of mitigation on the potential impacts at the Main Auditorium and the Choral Hall.

The following mitigation measures were considered for construction impacts:

- Tunnel Boring Machine
    - Maintenance and Operation: minimize vibration from jacking or pressing operations (if applicable, perhaps the action could smoothed out to avoid a sharp push), and maintain machinery in good working order.
    - Coordination and Notification: There would be times when the Main Auditorium is vacant or not used for a noise-sensitive activity, thereby eliminating any noise impact from TBM. Similarly, there would be times at the LAPA Conference Room (and offices) when activities are not particularly noise sensitive. Close coordination with the WDCH would ensure that the noise-generating parts of TBM operations would be conducted to avoid noise sensitive periods.

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[6] Scaled for distance as $PPV(distance) = PPVref(ref\_dist/dist)^{1.5}$, per FTA Guidance Manual

- Tunnel Train
  - Speed: Limiting the speed of the tunnel train to 5 mph in the vicinity of the WDCH would reduce the groundborne noise to the lower range, or 5 dBA from the maximum range.
  - Resilient Mat: A resilient system to support and fasten the tunnel train tracks would reduce the groundborne noise at least 4 dBA. Such as system would include a) resilient mat under the tracks and b) a resilient grommet or bushing under the heads of any track fasteners (assuming some kind of anchor or bolt system). The hardness of the resilient mat should be in the 40 to 50 durometer range, and be about 1 to 2" thick, depending on how heavily loaded the cars would be. The contractor would need to select the mat thickness so that the rail doesn't bottom out during a car passby.
  - Conveyor: The tunnel train could be replaced with a conveyor system to transport materials in the tunnel.
  - Coordination and Notification: There would be times when the Main Auditorium and Choral Hall are vacant or not used for noise-sensitive activities, thereby eliminating any noise impact from the tunnel train. Close coordination with the WDCH would ensure that the tunnel train passbys would be conducted to avoid noise sensitive periods.

Table 5 Construction Short-Term (Annoyance) Effects – No Mitigation

Space	Criteria (Occasional)		TBM		Tunnel Train		Impact?
	Vibration	Noise	Vibration	Noise	Vibration	Noise	
REDCAT	80 VdB	43 dBA	53 VdB	18 to 33 dBA	44 VdB	21 to 26 dBA	No
WDCH Main Auditorium (Room 2002)	65 VdB	25 dBA	53 VdB	18 to **33 dBA**	50 VdB	23 to **28 dBA**	Yes, groundborne noise
WDCH Orchestra Pit (Room 1001)	**	**	53 VdB	18 to 33 dBA	48 VdB	21 to 26 dBA	No
WDCH Sound Lock, Level 1 (Room 1003)	78 VdB	43 dBA	53 VdB	18 to 33 dBA	46 VdB	20 to 25 dBA	No
WDCH Choral Hall (Room 2154)	80 VdB	38 dBA	58 VdB	23 to 38 dBA	65 VdB	37 to **42 dBA**	Yes, tunnel train groundborne noise
WDCH/LAPA Conference room 2nd Floor (Room 2145)	78 VdB	43 dBA	68 VdB	33 to **48** dBA	62 VdB	37 to 42 dBA	Yes, TBM groundborne noise
WDCH/LAPA Conference Room 3rd Floor (Room 3060)	78 VdB	43 dBA	53 VdB	18 to 33 dBA	60 VdB	33 to 38 dBA	No

Bold entries exceed criteria

Table 6 Construction Short-Term (Annoyance) Effects – Groundborne Noise with Mitigation for Affected Spaces

Space	Groundborne Noise Criteria (Occasional)	Groundborne Noise without Mitigation (dBA)		Mitigation Options Considered	Groundborne Noise with Mitigation (dBA)		Impact after Mitigation?
		TBM	Tunnel Train		TBM	Tunnel Train	
WDCH Main Auditorium (Room 2002)	25 dBA	18 to **33**	23 to **28**	Speed Mat Conveyor Maint Coord	n/a n/a n/a 18 to **33** 18 to **33**	23 19 to 24 <25 n/a 23 to **28**	No, LA Metro will use one or more of the mitigation options to meet FTA criteria
WDCH Choral Hall (Room 2154)	38 dBA	23 to 38	37 to **42**	Speed Mat Conveyor Maint Coord	Not req.	37 33 to 38 <38 n/a 37 to **42**	No, LA Metro will use one or more of the mitigation options to meet FTA criteria
WDCH/LAPA Conference room 2nd Floor (Room 2145)	43 dBA	33 to **48**	37 to 42	Speed Mat Conveyor Maint Coord	n/a n/a n/a 33 to **48** 33 to **48**	Not req.	No, LA Metro will use one or more of the mitigation options to meet FTA criteria

Notes:
Bold entries exceed criteria
Speed: Speed reduction – near 5 mph near WDCH
Mat: Resilient mat – 40 to 50 durometer hardness, 1 to 2” thick with resilient grommet or bushing under the track fastener heads (assuming an anchor or bolt fastening system)
Conveyor: Use conveyor instead of tunnel train to transport materials through the tunnel
Maint: Maintenance and operation of the equipment to minimize vibration. TBM: minimize vibration from jacking or pressing operations, and maintain machinery in good working order.
Coord: Coordination with WDCH to conduct these construction activities around noise sensitive activities in the affected spaces; the groundborne noise level would not be lessened, but there would be no sensitive activity to impact

APPENDICES

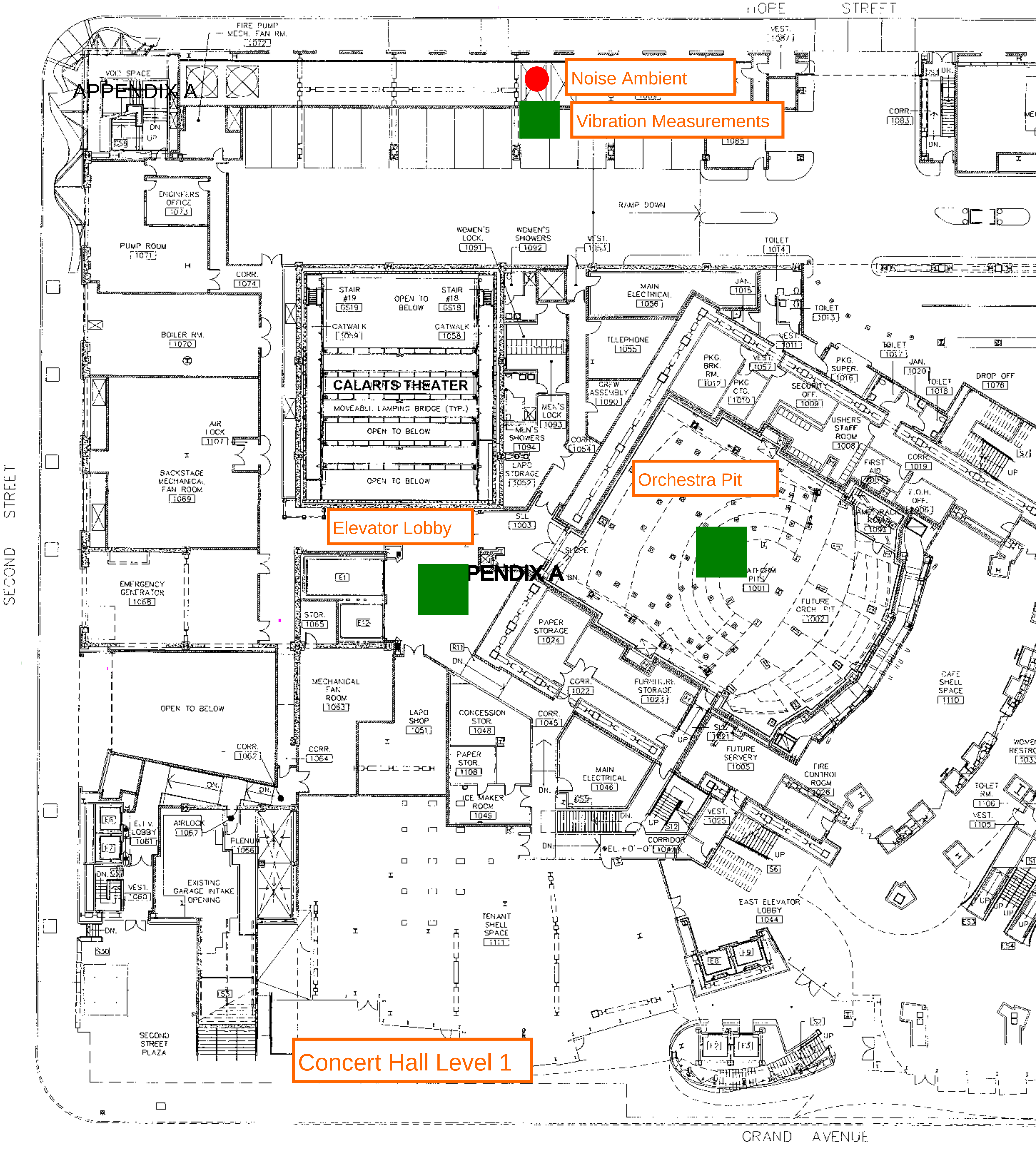
A. Field setup WDCH and parking garage (PDF)

B. Plan and Profile Drawings (marked up from June 29 Draft Submittal, Drawing T104)

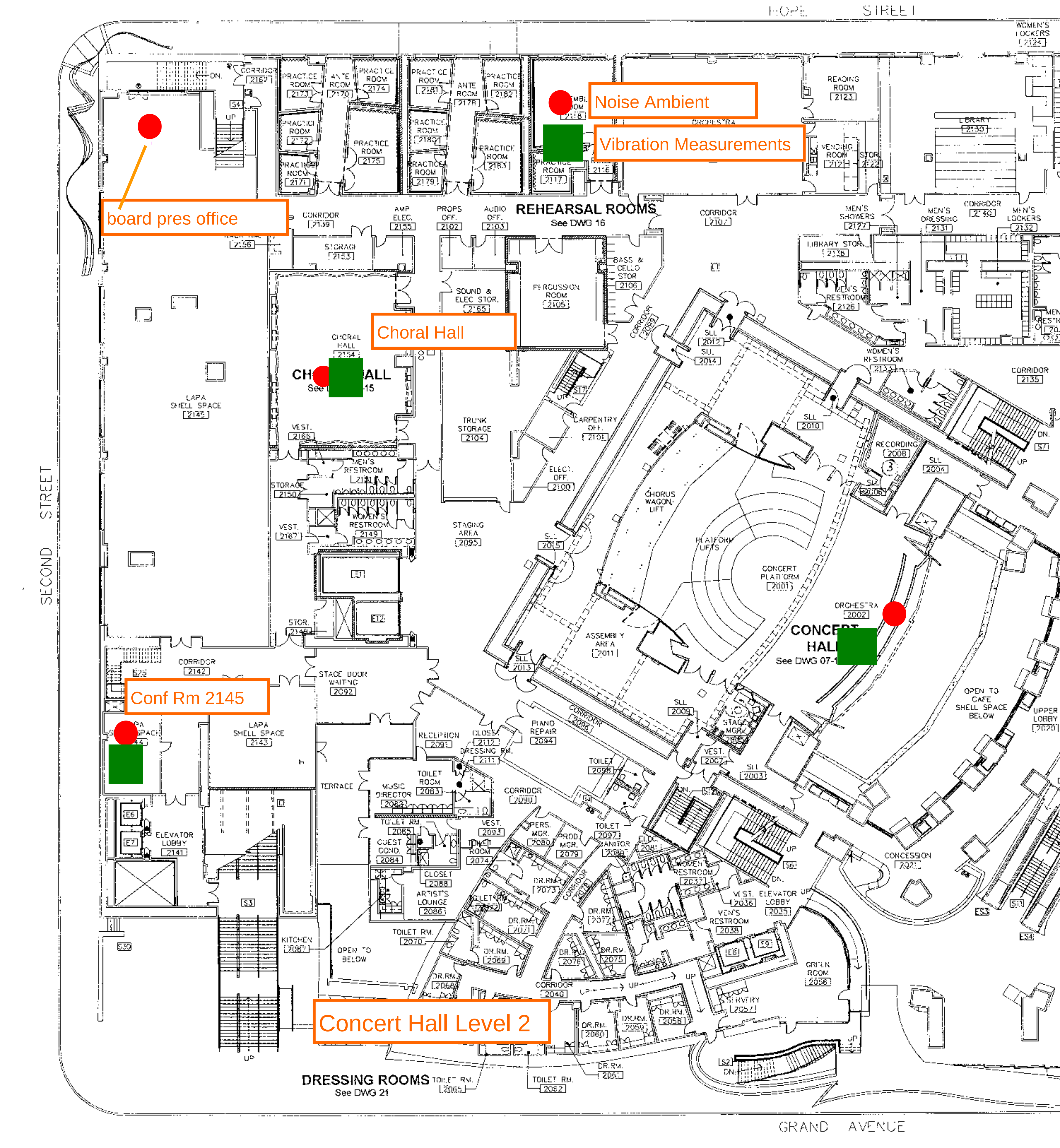
C. Ambient measurement results

D. Building response data ranges

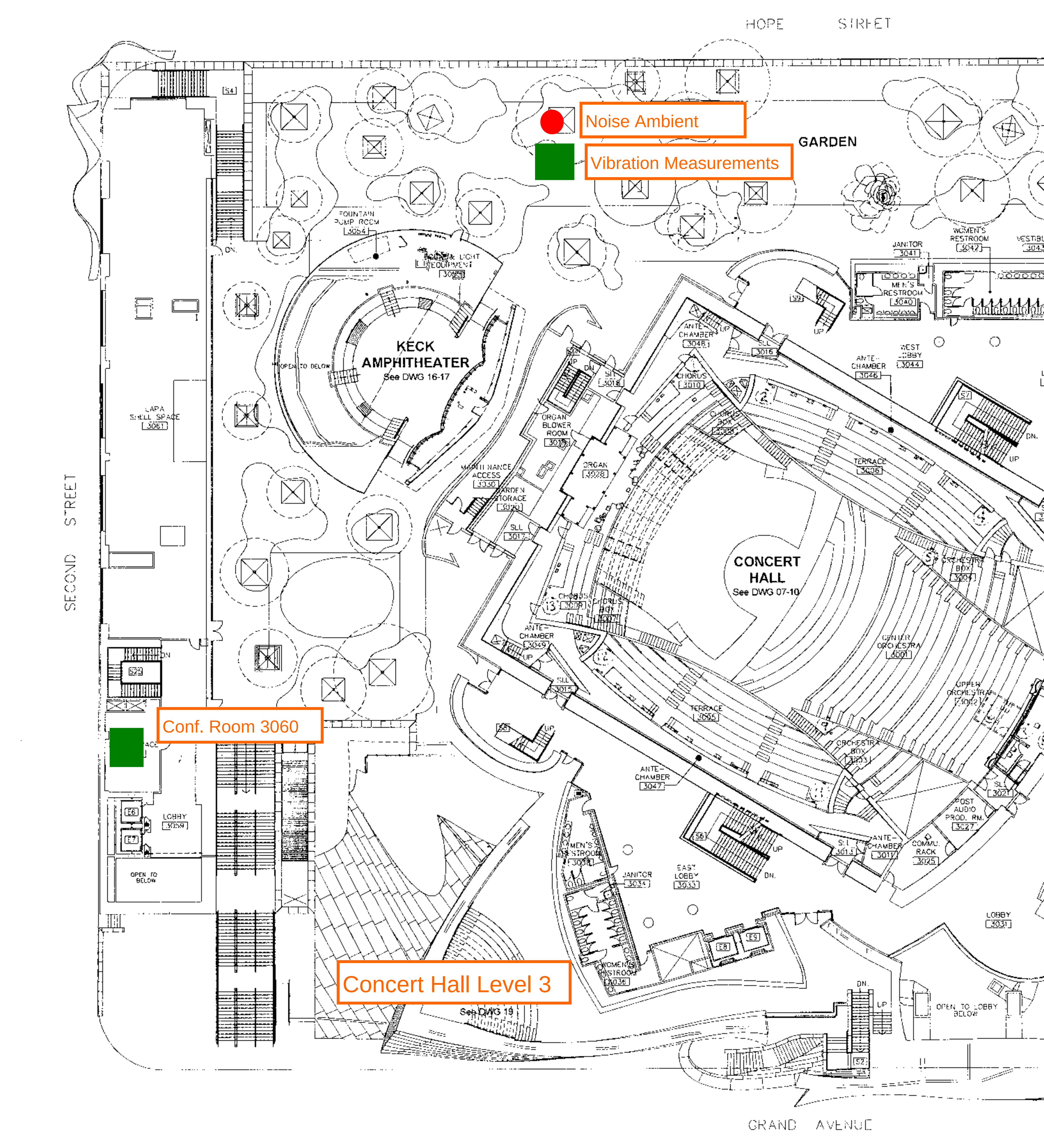
E. Compare TM with previous

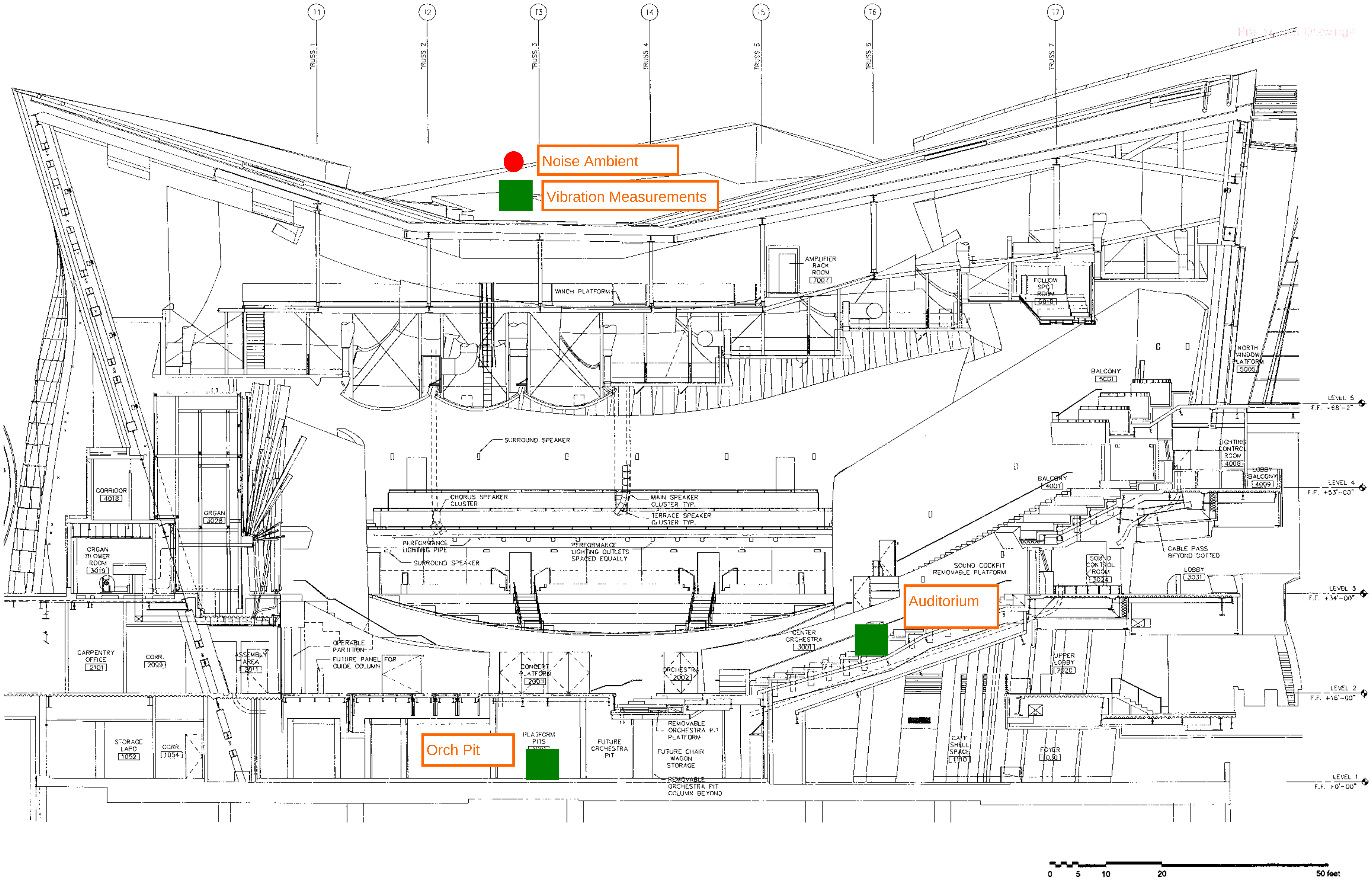


APPENDIX A
Noise Ambient
Vibration Measurements
CALARTS THEATER
Orchestra Pit
Elevator Lobby
PENDIX A
Concert Hall Level 1
HOPE STREET
SECOND STREET
GRAND AVENUE



HOPE STREET
Noise Ambient
Vibration Measurements
board pres office
REHEARSAL ROOMS
See DWG 16
Choral Hall
CHORAL HALL
LAPA SHELL SPACE 2145
SECOND STREET
CONCERT PLATFORM 2001
ORCHESTRA 2002
CONCERT HALL
Conf Rm 2145
Concert Hall Level 2
DRESSING ROOMS
See DWG 21
GRAND AVENUE


HOPE STREET
Noise Ambient
Vibration Measurements
GARDEN
FOUNTAIN PUMP ROOM 3054
KECK AMPHITHEATER
See DWG 16-17
OPEN TO BELOW
JANITOR 3041
WOMEN'S RESTROOM 3042
MEN'S RESTROOM 3040
ANTE-CHAMBER 3048
ANTE-CHAMBER 3046
WEST LOBBY 3044
CHORUS 3010
ORGAN BLOWER ROOM 3035
ORGAN 3028
MAINTENANCE ACCESS 3050
GARDEN STORAGE 3020
TERRACE 3006
CONCERT HALL
See DWG 07-10
CENTER ORCHESTRA 3001
UPPER ORCHESTRA 3002
ORCHESTRA BOX 3004
CHORUS 3009
CHORUS BOX 3007
ANTE-CHAMBER 3049
TERRACE 3005
ORCHESTRA BOX 3003
ANTE-CHAMBER 3047
ANTE-CHAMBER 3011
POST AUDIO PROD. RM. 3027
COMMU. RACK 3025
MEN'S RESTROOM 3038
JANITOR 3034
EAST LOBBY 3033
WOMEN'S RESTROOM 3036
LOBBY 3031
OPEN TO LOBBY BELOW
SECOND STREET
LAPA SHELL SPACE 3061
Conf. Room 3060
LOBBY 3059
OPEN TO BELOW
Concert Hall Level 3
See DWG 19
GRAND AVENUE

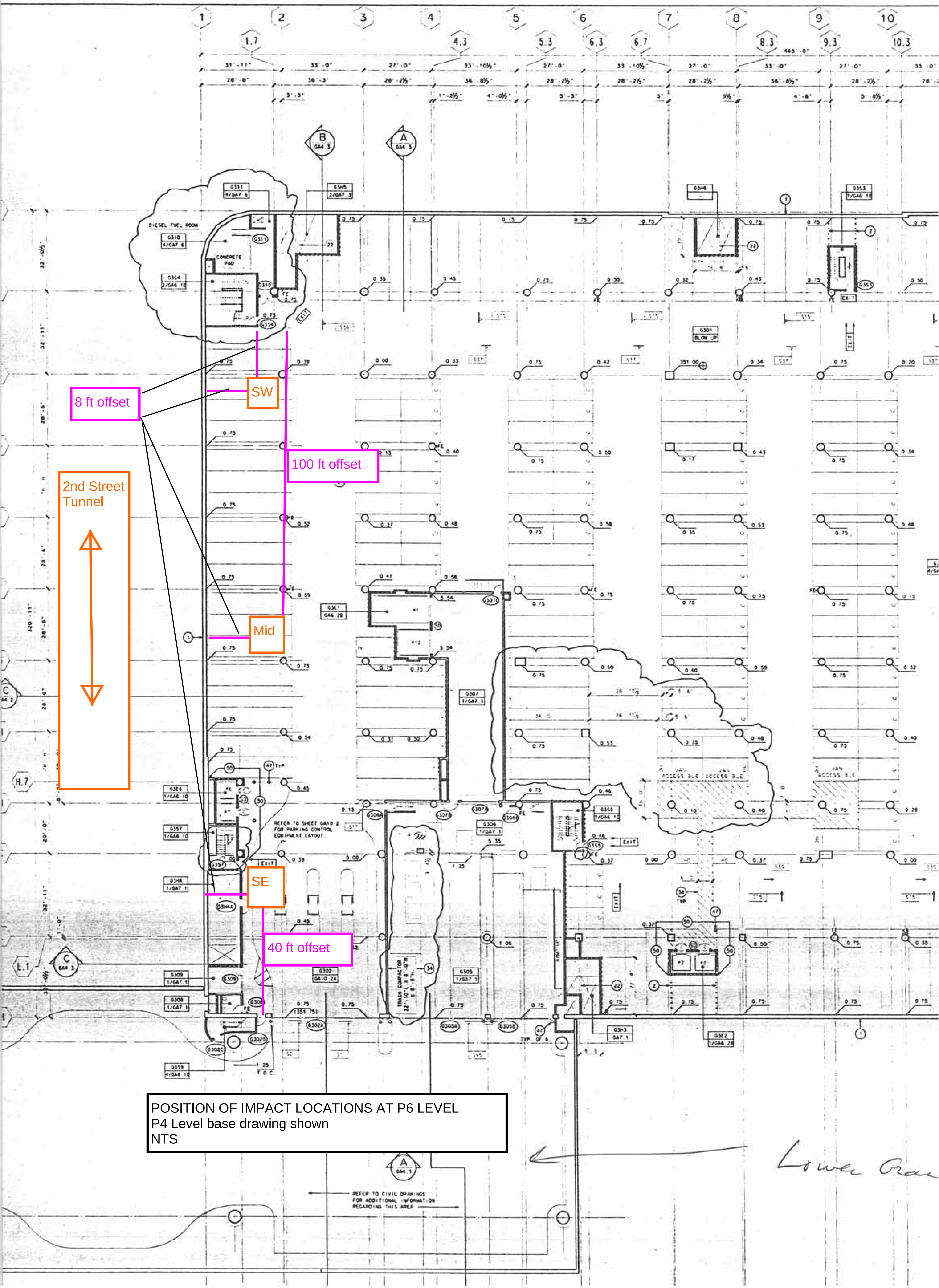


WALT DISNEY CONCERT HALL

Concert Hall • CL Section

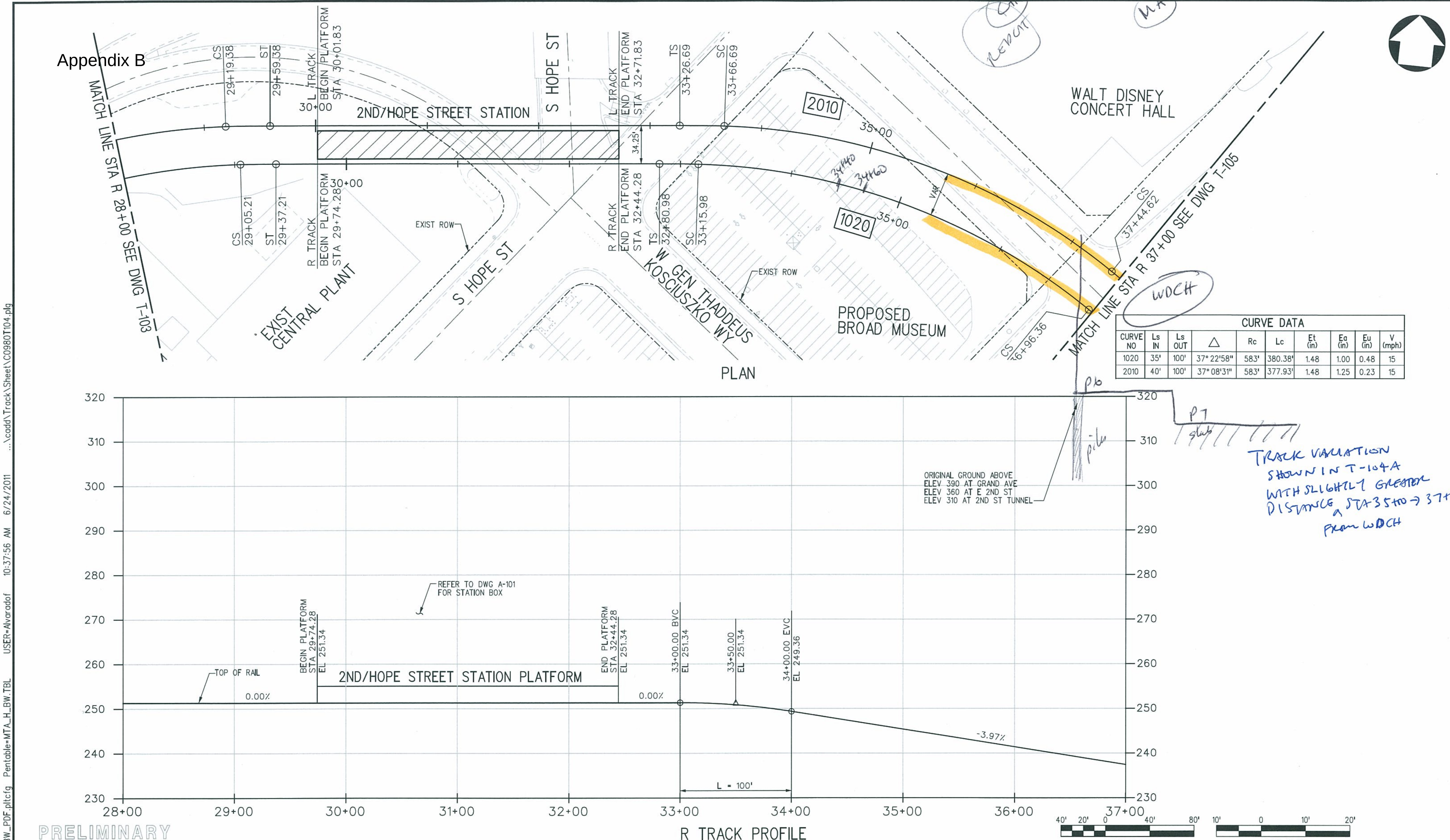
Scale: 1/16" = 1'-0"

Page: DWG 09



POSITION OF IMPACT LOCATIONS AT P6 LEVEL
P4 Level base drawing shown
NTS

Appendix B



CURVE DATA

CURVE NO	Ls IN	Ls OUT	△	Rc	Lc	Et (in)	Ea (in)	Eu (in)	V (mph)
1020	35'	100'	37° 22'58"	583'	380.38'	1.48	1.00	0.48	15
2010	40'	100'	37° 08'31"	583'	377.93'	1.48	1.25	0.23	15

PRELIMINARY

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA.

REV	DATE	BY	APP	REG NO	EXPIRES	SEAL HOLDER	DESCRIPTION

DESIGNED BY J. SUSILO
DRAWN BY M. AL-MASHAT
CHECKED BY
IN CHARGE
DATE 06/29/2011

LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

Metro

The Connector Partnership
777 S. FIGUEROA STREET 10TH FLOOR LOS ANGELES, CA 90017 T 213-312-3100 F 213-312-3114

SUBMITTED

APPROVED

REGIONAL CONNECTOR TRANSIT CORRIDOR
PRELIMINARY ENGINEERING
TRACK ALIGNMENT
PLAN AND PROFILE
STA R 28+00 TO STA R 37+00

CONTRACT NO C0980
DRAWING NO T-104
REV
SCALE HORZ: 1" = 40' VERT: 1" = 10'
SHEET NO

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APPENDIX C Ambient measurements

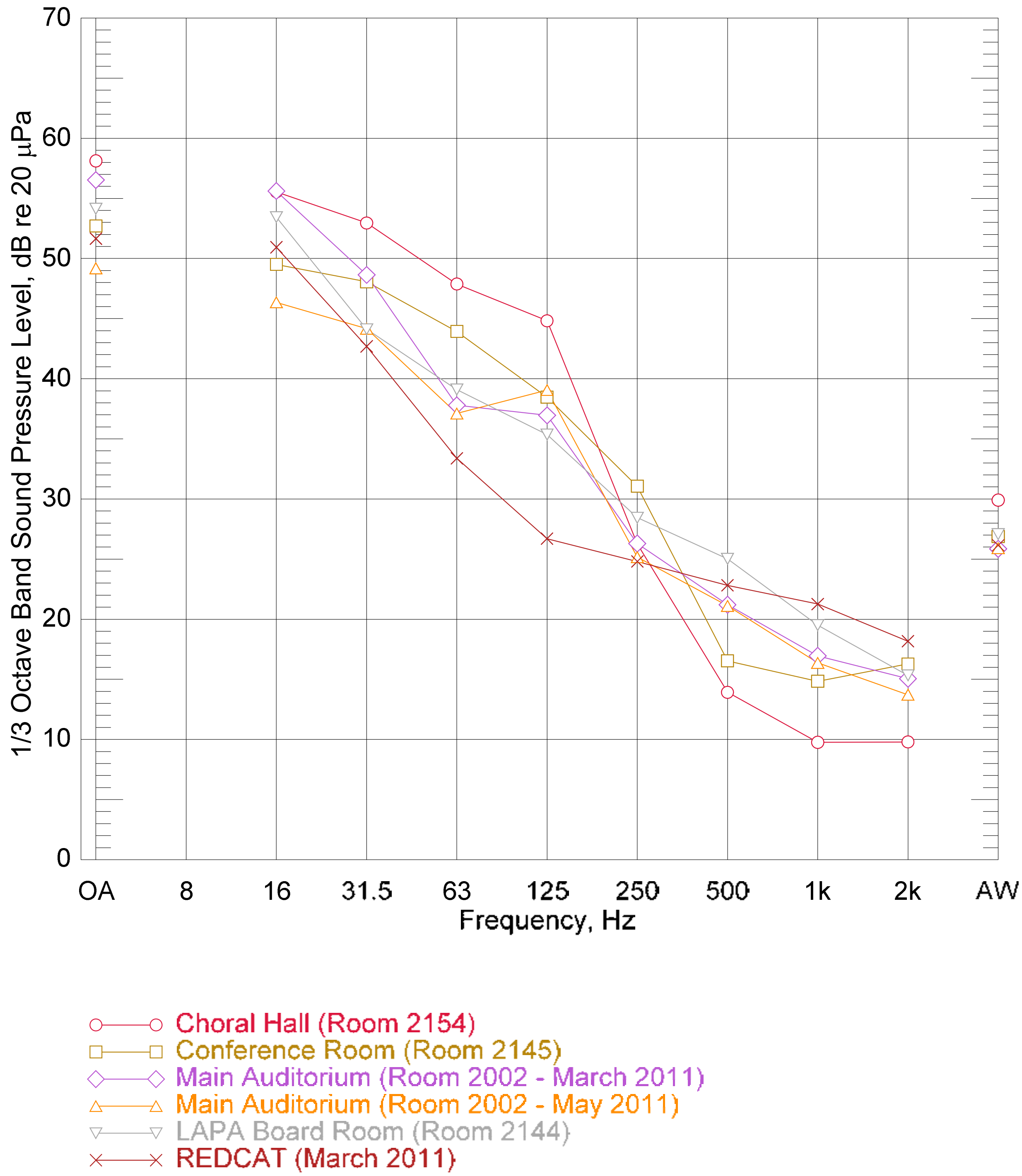


Figure C1 Ambient Noise Measurements – Octave Bands

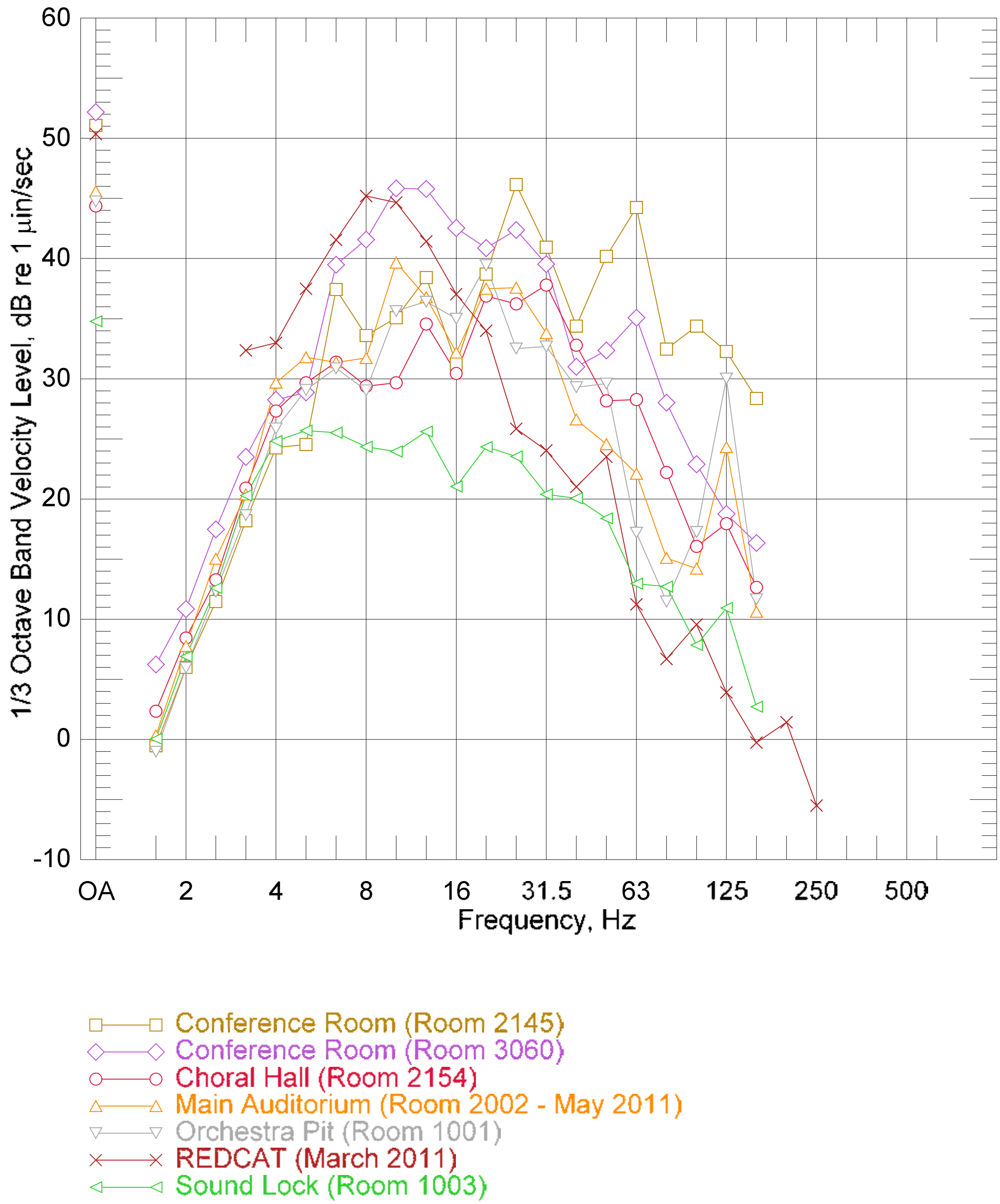


Figure C2 Ambient Vibration Measurements

APPENDIX D Building Response Data

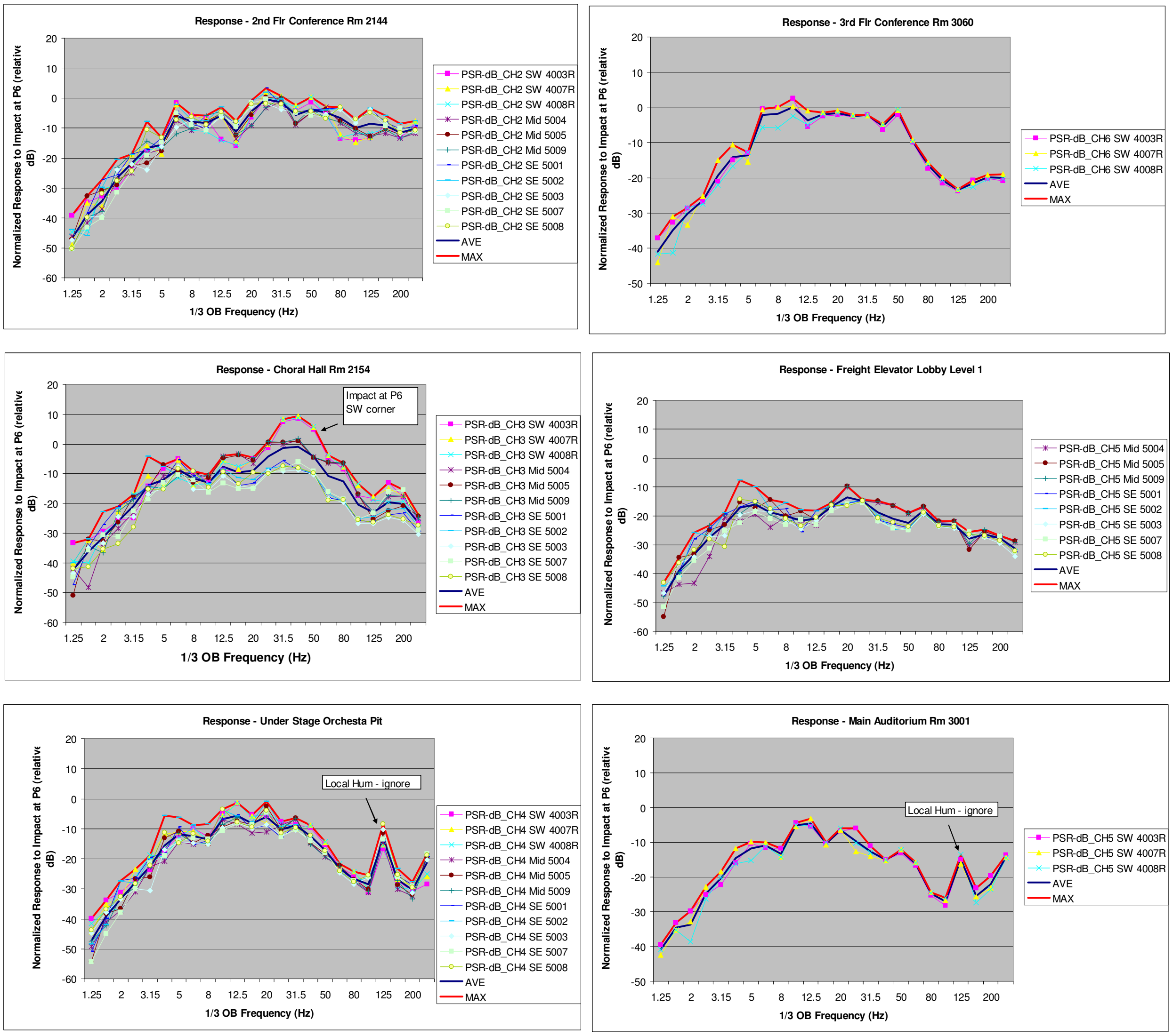
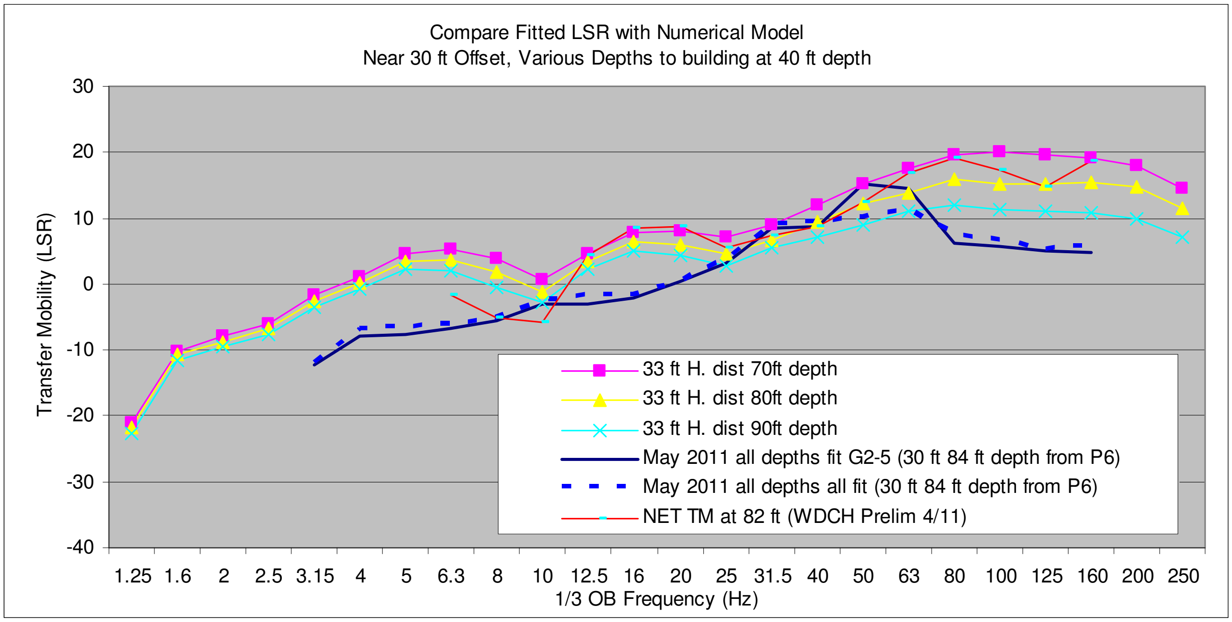
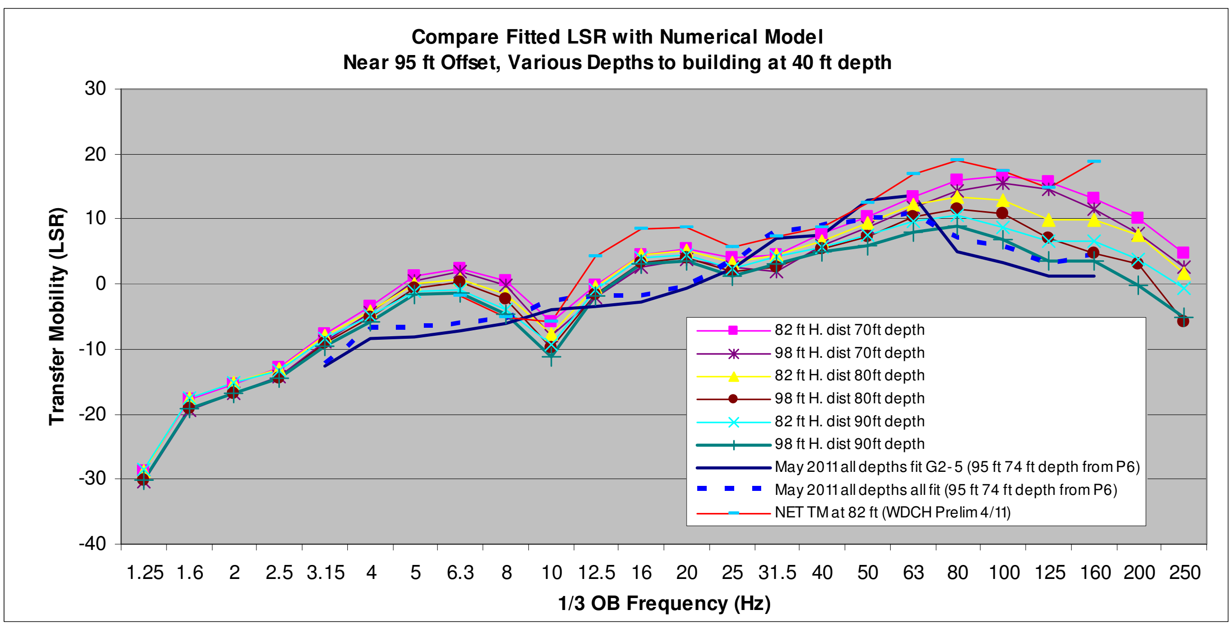


Figure D1 Building Response Data

APPENDIX E Compare TM with Previous





Compare TM (line source – LSR)

- Numerical Model at different horizontal offsets and depths. Numerical Model does not include effect of building coupling at P6.
- May 2011 field data
- NET adjusted TM used for previous WDCH analysis (FEIS April 2011)