WESTSIDE SUBWAY EXTENSION PROJECT

Noise and Vibration Study

Metro

August 2011

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1.0 INTRODUCTION

This study presents the results of additional analysis and testing of the Locally Preferred Alternative (LPA) selected by the Metro Board for further study on October 28, 2010, and further refined during the Advanced Conceptual Engineering/Preliminary Engineering phase of project development for the Westside Subway Extension Project. The study results have been incorporated into the Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR).

The analyses supplement the results of the Westside Subway Extension Project Noise and Vibration Technical Report (the Report) dated August 2010, which analyzed potential impacts from noise and vibration generated by operation of the proposed Westside Subway Extension Project for the Draft EIS/EIR. Noise and vibration resulting from construction of the Project are addressed separately in the Westside Subway Extension Construction and Mitigation Technical Report (Metro 2010b). Unless stated otherwise in this study, all descriptions in the Report also apply to this study. In instances where this study differs from the Report (or any previous addenda to the Report), the information in this study supersedes that of the Report (and any previous addenda to the Report).

The purpose of this study is to further analyze those locations where refinements in the design, operations, or alignments were made; where vibration impacts were predicted using the previous analysis; and in response to comments and concerns by the public.

2.0 PROJECT DESCRIPTION

The LPA as defined by the Metro Board is described in the following sections.

2.1 Station Locations

Changes to the station locations or components of the stations are as follows:

- The Wilshire/Crenshaw Station was eliminated from further consideration.
- The Wilshire/La Brea Station was shifted east under Wilshire Boulevard and located between Detroit Avenue and Orange Drive. Crossover tracks were shifted to the east end of the station. There is a double crossover east of this station.
- The Wilshire/Fairfax Station East Option was selected, which is located under Wilshire Boulevard, from just west of Fairfax Avenue to just east of Orange Grove Avenue. There is no crossover at this station.
- The Wilshire/La Cienega Station East Option was selected, which is located under Wilshire Boulevard from just west of La Cienega Boulevard to Tower Drive. There is a double crossover east of this station.
- The Wilshire/Rodeo Station was shifted to the east under the Wilshire Boulevard and Beverly Drive intersection extending between El Camino Drive and South Reeves Drive. A traction power substation (TPSS) is to be located at the station's entrance. There is a double crossover east of this station.
- The location of the Century City Constellation Station is the same as described in the Draft EIS/EIR, centered along the intersection of Avenue of the Stars with Constellation Boulevard. There is a double crossover east of this station.
- The Century City Santa Monica Station was shifted to the east to avoid the Santa Monica Fault; the station now extends from Century Park east to west of Moreno Drive. There is a double crossover east of this station.
- Two options are being considered for the Westwood/UCLA Station: (1) an off-street location underneath Parking Lot 36, north of Wilshire Boulevard between Gayley Avenue and Veteran Avenue with a TPSS near the corner of Wilshire Boulevard and the Gayley Avenue station entrance; and (2) an on-street location under Wilshire Boulevard extending from west of Gayley Avenue to Westwood Boulevard. There is no crossover at this station.
- Two options are being considered for the VA Hospital Station: (1) south of Wilshire Boulevard beginning at the northern tip of the cloverleaf for the I-405 southbound on/off-ramp at Wilshire Boulevard; and (2) north of Wilshire Boulevard, extending west and east of Bonsall Avenue (the same location as described in the Draft EIS/EIR). There are double crossovers east and west of this station.

2.2 Alignment Options

2.2.1 Between Wilshire/Rodeo Station and Century City Station

Two alignment options linking the Wilshire/Rodeo Station and the Century City Station options at Constellation Boulevard and Santa Monica Boulevard, were recommended for further study in the Final EIS/EIR. The Constellation South alignment option was dropped from further consideration.

The Constellation North alignment option extends west to near Linden Drive then curves southwesterly at Linden Drive to Lasky Drive and continues under Lasky Drive to just north of Young Drive. From there it turns southwesterly and runs under Constellation Boulevard to the Constellation Boulevard Station located at Avenue of the Stars.

The Santa Monica Boulevard alignment option extends westerly beneath Wilshire Boulevard to the Wilshire Boulevard/Santa Monica Boulevard intersection, then curves southwesterly to Santa Monica Boulevard and to the Century City Station located on Santa Monica Boulevard between Century Park East and Moreno Drive.

2.2.2 Between Century City Station and Westwood Station

Between the Century City and Westwood Stations, the East alignment option was recommended to be carried forward while the Central and West alignment options were dropped from further consideration. From the Century City (Santa Monica Boulevard) Station, the East alignment option extends west under Santa Monica Boulevard from the station location. The alignment then turns north at Avenue of the Stars and continues northwesterly until Wilshire Boulevard, where it travels westerly to connect to either the Westwood/UCLA Off-Street or On-Street Station. From the Century City Constellation Station, the East alignment option turns northwesterly under Westfield Century City Mall and continues to the north, crossing under Santa Monica Boulevard and continuing northwesterly to Wilshire Boulevard. At Wilshire Boulevard, the alignment continues westerly to connect to either the UCLA Off-Street or On-Street Station.

2.3 Emergency Generators and Traction Power Substations

- Emergency generators are located at two stations: The Wilshire/La Brea and Westwood/VA Hospital Stations (either the north or south location) within the station.
- The traction power substations (TPSS) that power the trains by converting the AC current to DC are located at every station except the Wilshire/Fairfax Station.

2.4 Trackwork Crossovers

- Wilshire/La Brea—double crossover east of station (see Figure 4-2)
- Wilshire/La Cienega—double crossover east of station (see Figure 4-4)
- Wilshire/Rodeo—double crossover east of station (see Figure 4-5)
- Century City (Constellation)—double crossover east of station (see Figure 4-6)
- Century City (Santa Monica)—double crossover east of station

- Westwood/VA Hospital South Option —double crossover west of station and another double crossover approximately 2,600 feet to the east of the station (see Figure 4-8)
- Westwood/VA Hospital North Option —double crossover west and east of station (see Figure 4-9)

3.0 STANDARDS AND REGULATIONS

All standards and regulations cited in the 2010 report remain the same. These include the noise and vibration criteria defined by the Federal Transit Administration (FTA) in the Transit Noise and Vibration Impact Assessment, May 2006.

4.0 AFFECTED ENVIRONMENT/EXISTING CONDITIONS

4.1 Existing Conditions—Noise Environment

Noise-sensitive land uses, such as residences, parks, schools, hospitals, places of worship, and theaters, were identified in the vicinity of each station location and near any proposed project at-grade facilities, such as emergency generators. These locations are considered in this study because of the potential for different sources of operations noise at street level. These sources include ventilation fans and train noise transmitted through the ventilation shafts to the open gratings at street level. The other sources are the periodic testing of the two emergency generators at the Wilshire/La Brea and Westwood/VA Hospital Stations and the testing of the emergency ventilation fans located at each of the stations. Land uses along the LPA directly above the subway tunnel and between stations will not be affected by noise. Ground vibration effects from train operations through the subway tunnel are analyzed at these locations.

New noise monitoring was conducted to reflect the change in station locations adopted as part of the LPA. The existing conditions of the noise environment at these sensitive land uses adjoining the stations were based on long-term (24-hour) and short-term (15-minute) measurements. These measurements were conducted following the Draft EIS/EIR at eight sites primarily in areas near sensitive uses, including residences and other buildings where people normally sleep, such as hospitals and hotels/motels. All noise measurements were conducted in a manner consistent with applicable American National Standards Institute (ANSI) procedures for community noise measurements.

The existing environmental noise levels at the LPA stations are typical of an urban environment, with 24-hour day/night (L_{dn}) levels ranging from 60 to 74 dBA. Measured noise levels are presented in

Table 4-1. The measurements were taken at residences, a hospital, and a theater directly adjoining the stations and station options as shown in Figure 4-1 through Figure 4-9. The measurements were performed at the stations because that is where potential surface noise from the Project may be expected to cause a noise impact. Measurements were not conducted above potential tunnel sections of the LPA because noise from subway operations in the tunnels will be underground and inaudible at the surface. Thus, there will be no potential for causing a noise impact. The existing noise environment is described in the following sections organized by station location.

Table 4-1: Existing 24-Hour Noise Levels

Measurement Site	Station	Address	Land Use	L_{dn}	Peak Hour Noise L_{eq}(h)	Time of Peak Hour Noise	Figure
N1	Wilshire/La Brea	5353 Wilshire Blvd	Residential	67	67	6:00 p.m.	4-2
N2	Wilshire/Fairfax	6122 Wilshire Blvd	Residential	68	65	7:00 a.m.	4-3
N3	Wilshire/La Cienega	8601 Wilshire Blvd	Residential	71	78	1:00 p.m.	4-4

N4	Wilshire/Rodeo	120 Canon Dr	Residential	64	66	3:00 p.m.	4-5
N5	Century City (Constellation)	Future residence at Avenue of the Stars and Constellation Blvd	Residential	74	78	4:00 p.m.	4-6
--	Century City (Santa Monica) Station	No noise sensitive receivers located near this station					
N6	Westwood/UCLA (Off-Street and On-Street)	Veteran Ave and Wilshire Blvd	Residential	74	79	3:00 p.m.	4-7
N7	Westwood/VA Hospital South of Wilshire	VA Hospital	Residential	60	64	3:00 p.m.	4-8
N8	Westwood/VA Hospital North of Wilshire	Wadsworth Theatre	Residential	72	70	7:00 a.m.	4-9

Note: 1. Ldn is also known as the average day-night noise level. This represents the cumulative 24-hour day-night noise level and accounts for the greater sensitivity to noise at night when people are sleeping by applying a 10 decibel penalty to nighttime noise.

2. Leq(h) is the Leq for a one-hour period. For land uses involving daytime and evening use only, the noise impact analysis uses Leq(h) representing the noisiest hour of transit-related activity during which human activities occur at noise sensitive locations.

Figure 4-1: Key Map of Noise Measurement Sites

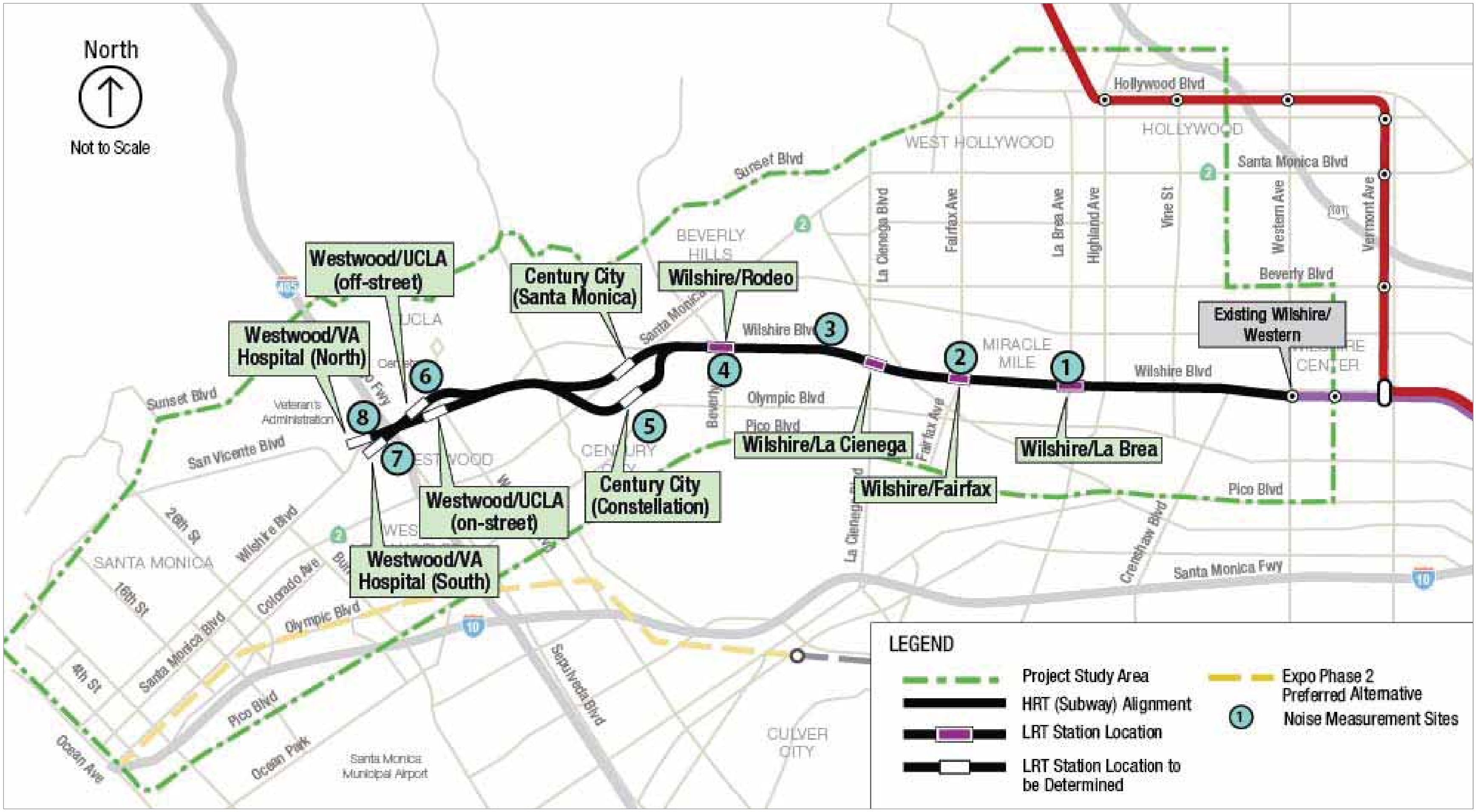


Figure 4-2: Measurement Site N1 near Wilshire/La Brea Station

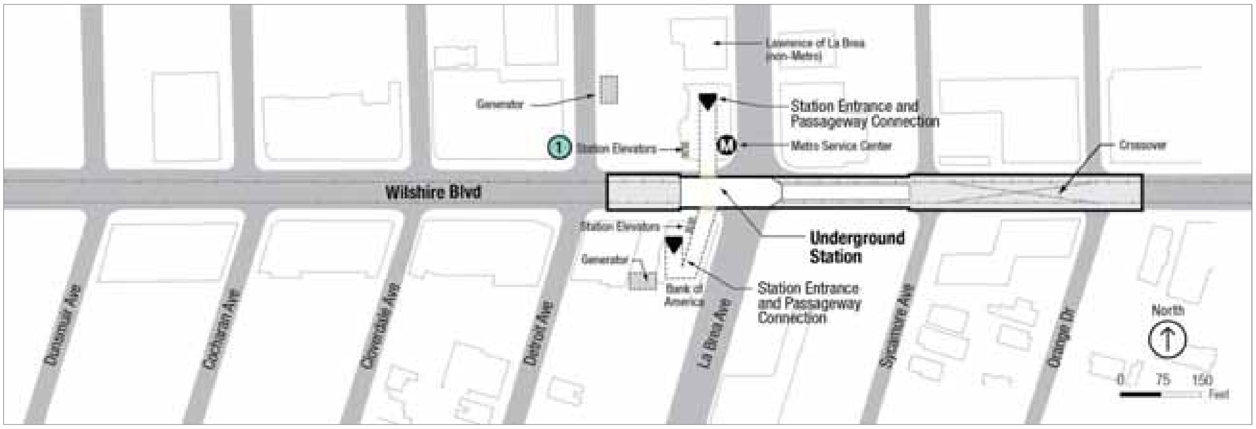


Figure 4-3: Measurement Site N2 near Wilshire/Fairfax Station

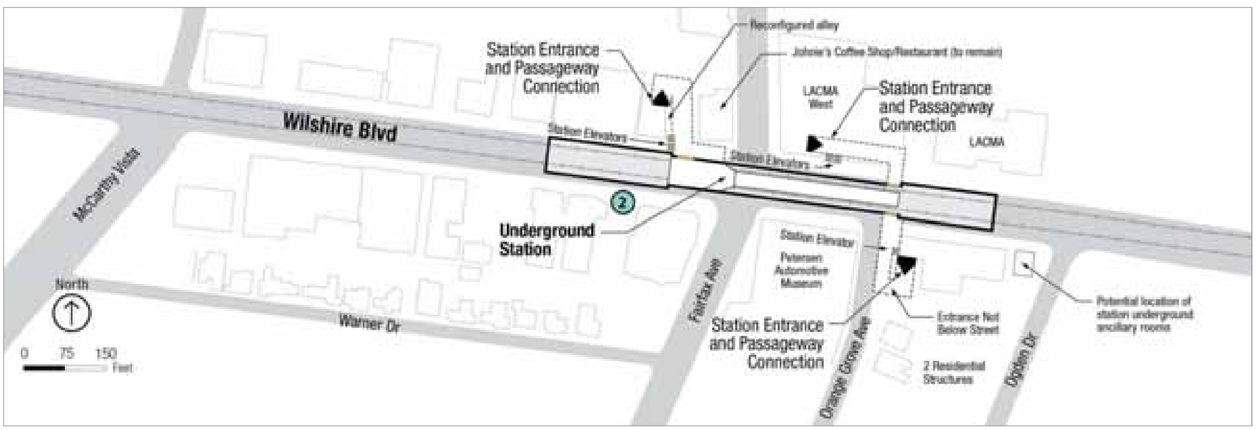


Figure 4-4: Measurement Site N3 near Wilshire/La Cienega Station

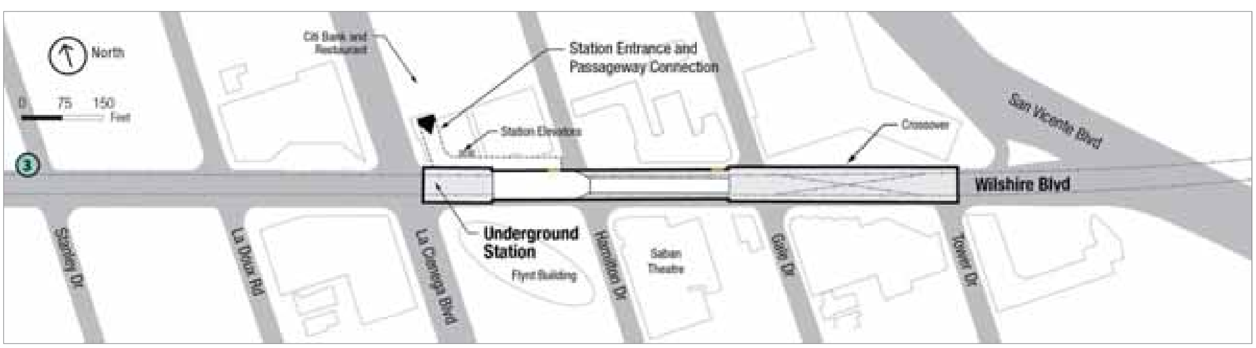


Figure 4-5: Measurement Site N4 near Wilshire/Rodeo Station

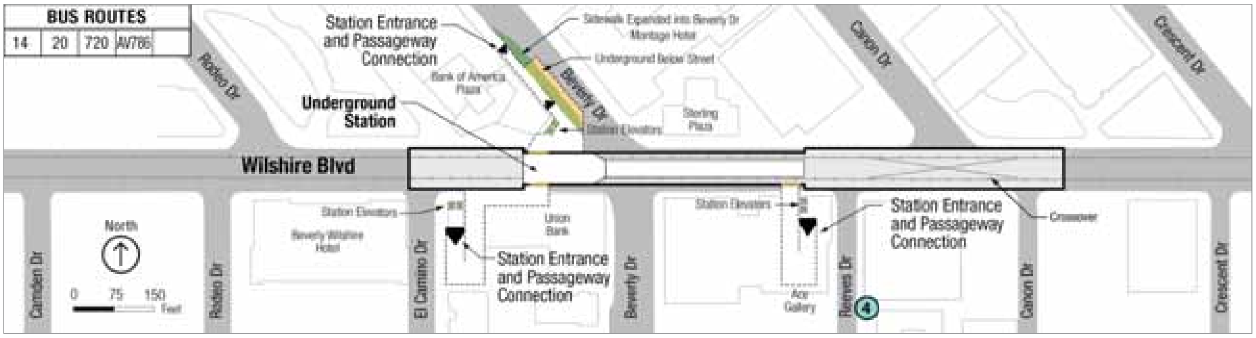


Figure 4-6: Measurement Site N5 near Century City (Constellation) Station

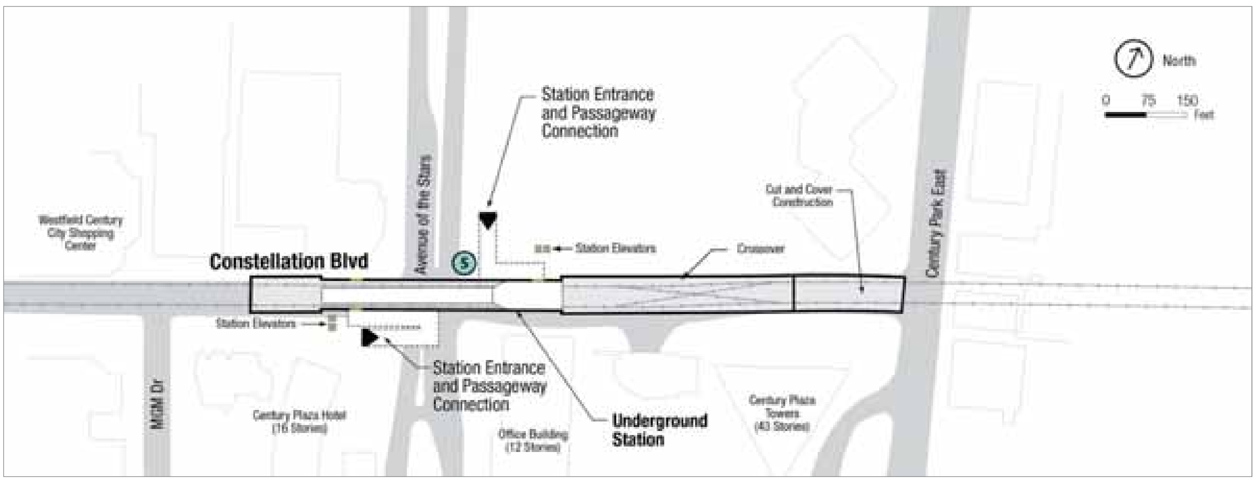


Figure 4-7: Measurement Site N6 near Westwood/UCLA Station Options

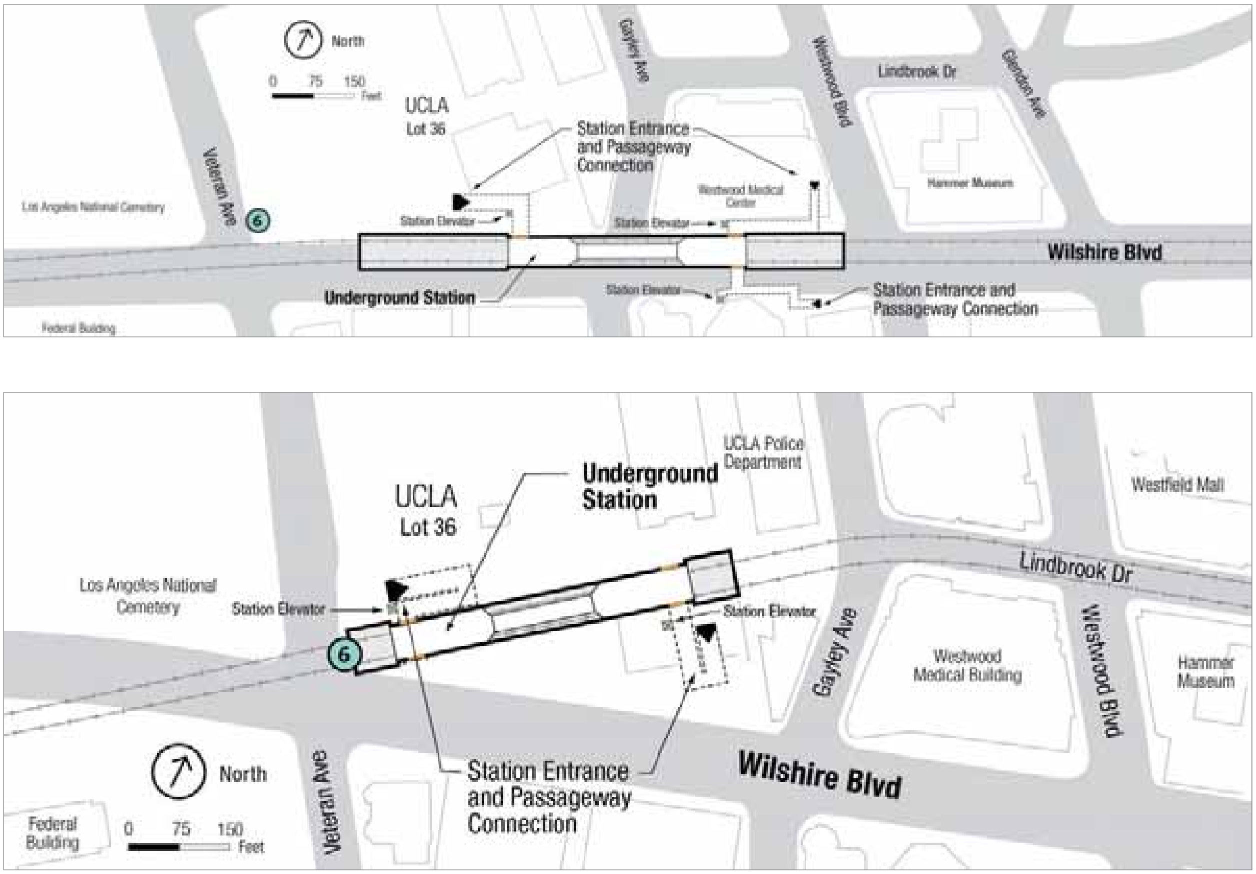


Figure 4-8: Measurement Site N7 near Westwood/VA Hospital Station South Option

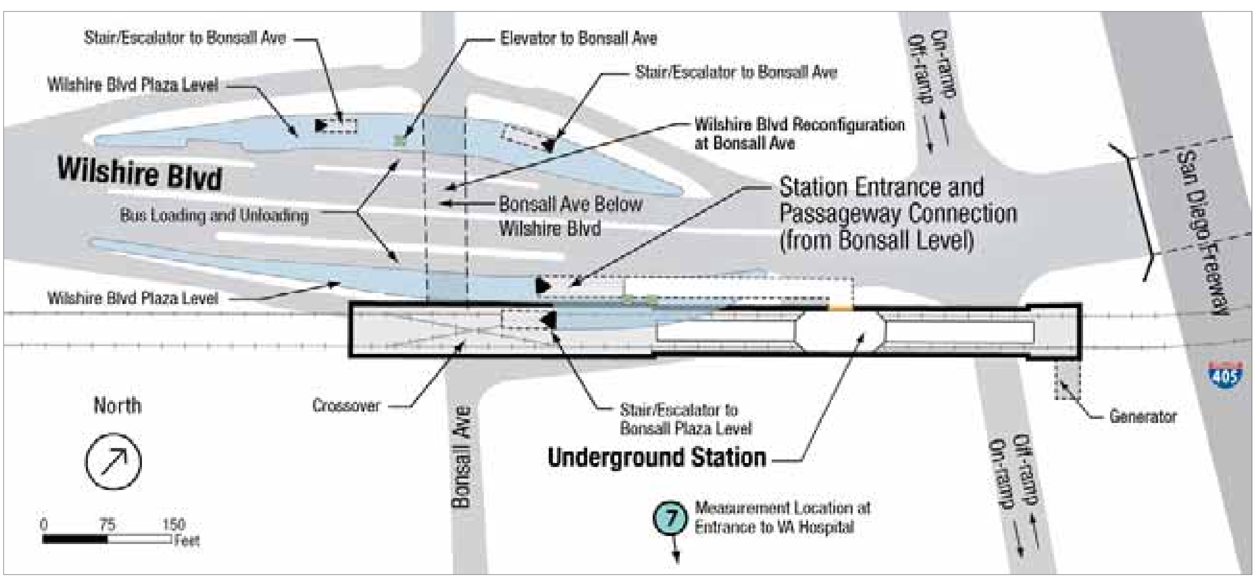
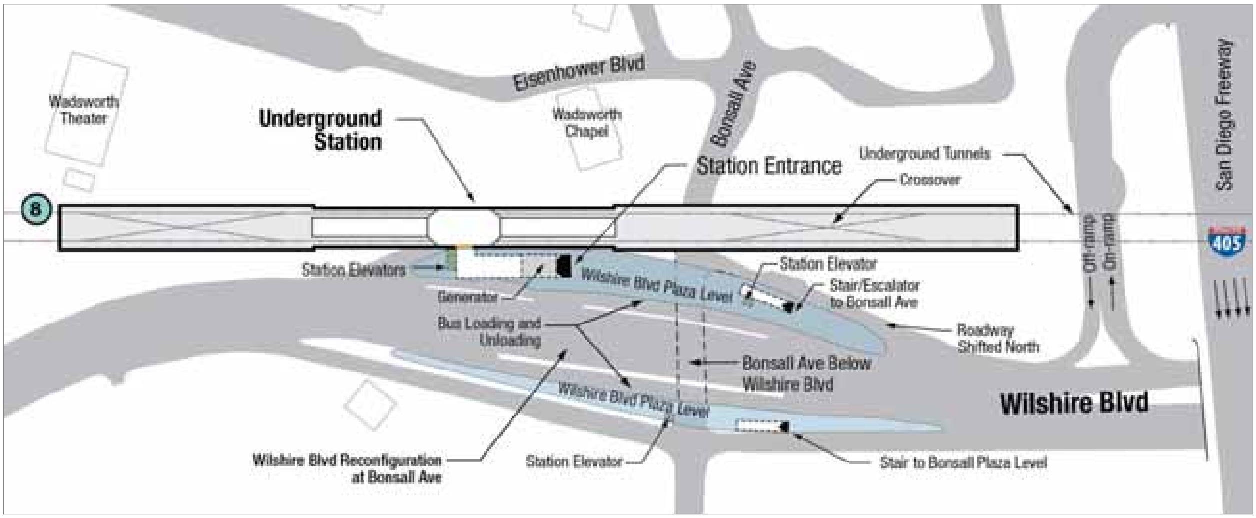


Figure 4-9: Measurement Site N8 near Westwood/VA Hospital Station North Option



4.1.1 Wilshire/La Brea Station

Noise levels were measured for 24 hours at 5353 Wilshire Boulevard (Site N1) on the northwest corner of Wilshire Boulevard and Detroit Street (Figure 4-2). This apartment building is the closest existing FTA Category B land use to the proposed station location; other apartment buildings are located on the northeast corner of Orange Street and Wilshire Boulevard and on the southeast corner of La Brea Avenue and Wilshire Boulevard. The remaining land uses along the frontage of the proposed station location are retail stores and parking lots. Single-family residential land uses are located behind the retail stores on both sides of Wilshire Boulevard. An L_{dn} of 67 dBA and a peak noise hour $L_{eq(h)}$ of 67 dBA were measured for this station location.

4.1.2 Wilshire/Fairfax Station

Noise levels were measured for 24 hours on the south side of Wilshire Boulevard at 6122 Wilshire Boulevard (Site N2) in the parking lot along the side of this apartment building in close proximity to Wilshire Boulevard and the proposed station (Figure 4-3). This is the closest Category B land use to the proposed station. Residential land uses on Orange Street to the north and Warner Drive to the south are other Category B land uses around the proposed station location. The first-row land uses along the proposed station site are retail stores and parking lots. Single-family residences are located behind the retail stores on both sides of Wilshire Boulevard. An L_{dn} of 68 dBA and a peak noise hour $L_{eq(h)}$ of 65 dBA were measured at this location.

4.1.3 Wilshire/La Cienega Station

Noise levels were measured for 24 hours at 8601 Wilshire Boulevard (Site N3) on the 11th floor sundeck of the apartment building. This is approximately 800 feet west of the station entrance and the closest FTA Category B to the proposed station location (Figure 4-4). The first-row land use along the proposed station location is retail, two restaurants, one movie theater, one gas station, and office buildings. Single-family residential land uses are located behind the first-row land uses on both sides of Wilshire Boulevard. An L_{dn} of 71 dBA and a peak noise hour $L_{eq(h)}$ of 78 dBA were measured at this location.

4.1.4 Wilshire/Rodeo Station

Noise levels were measured for 24 hours at 120 Canon Drive (Site N4) south of Wilshire Boulevard (Figure 4-5). This property is located behind the retail and office buildings that front the proposed station site. The first-row land uses along the proposed station location are retail and office buildings. Multi-family residential land uses are located behind the first-row land uses to the south of Wilshire Boulevard; one hotel and an apartment building are located north of Wilshire Boulevard behind the retail and office land uses. An L_{dn} of 64 dBA and a peak noise hour $L_{eq(h)}$ of 66 dBA were measured at this location.

4.1.5 Century City (Constellation) Station Option

Noise levels were measured for 24 hours at the northeast corner of Avenue of the Stars and Constellation Boulevard (Site N5) (Figure 4-6). A future condominium and offices are located on the northeast corner, and the Century Plaza Hyatt Hotel is located on the southwest corner. All other land uses in the area are office buildings. An L_{dn} of 74 dBA and a peak noise hour $L_{eq(h)}$ of 78 dBA were measured at this location.

4.1.6 Century City (Santa Monica) Station Option

There are no sensitive receivers at this station location that would be affected by the station ventilation fan noise.

4.1.7 Westwood/UCLA Station Options

Noise levels were measured for 24 hours at the northeast corner of the intersection of Wilshire Boulevard and Veteran Avenue (Site N6) (Figure 4-7). This measurement location is the same for the UCLA Off-Street and On-Street Station Options and applies to both stations since this measurement represents the same local ambient noise environment. Los Angeles National Cemetery is located on the northwest corner of Wilshire Boulevard and Veteran Avenue. All other land uses in the area are offices and retail stores. An L_{dn} of 74 dBA and a peak noise hour $L_{eq(h)}$ of 79 dBA were measured at this location.

4.1.8 Westwood/VA Hospital Station Options

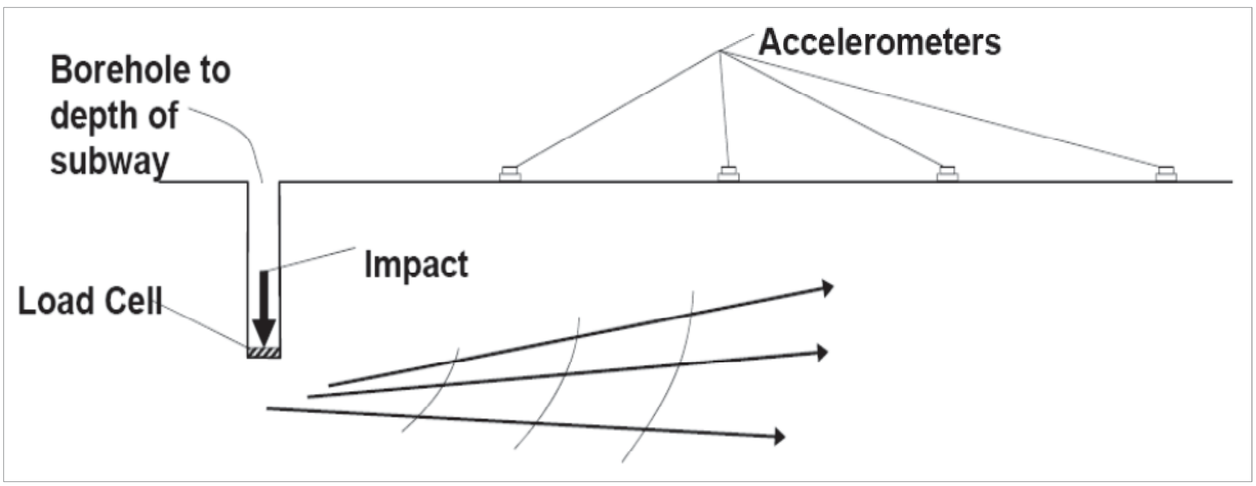
Noise levels were measured for 24 hours at the VA Hospital south of Wilshire Boulevard (Site N7) (Figure 4-8). The area contains green space, a surface parking lot, and a chapel (currently not in use). Measurements at this site apply to the South Station Option. An L_{dn} of 60 dBA and a peak noise hour $L_{eq(h)}$ of 64 dBA were measured at this location. Noise levels were measured for 24 hours at the Wadsworth Theatre north of Wilshire Boulevard (Site N8) (Figure 4-9). Measurements at this site apply to the South Station Option. An L_{dn} of 72 dBA and a peak noise hour $L_{eq(h)}$ of 70 dBA were measured at this location.

4.2 Existing Conditions—Vibration Environment

Ambient vibration levels were not measured as part of this study since the FTA vibration impact assessment is not based on the ambient levels but instead is based on FTA Vibration Impact Criteria. These criteria were used to identify vibration-sensitive receivers at the surface above the subway tunnel alignments where potential impacts may occur, based on existing land use activities. These receivers include residents, hotel/motels, medical facilities, schools, movie theaters, live theaters, and museums. The potential for vibration generated by the underground operation of the trains has been analyzed at these receiver locations. Existing ambient vibration levels were not measured at these locations. The FTA Vibration Criteria was used to assess potential effects.

The geology and soil through which the tunnel will be constructed will affect the transmission of vibration from the train operations to the surface. To accurately quantify the vibration attenuation of these soil conditions at different distances, propagation testing was conducted as part of the geotechnical investigations. These tests determine the rate at which the vibration attenuates or diminishes as it propagates away from the subway tunnel. The relationship between a vibration source, in this case train operations, and the resulting vibration of the ground is known as the transfer mobility. The transfer mobility was determined by conducting vibration measurements in which the vibration pulses from a dropped weight were measured at various distances from the source. A load cell (force transducer) is used to measure the force input to the ground from the dropped weight, and calibrated vibration transducers are used to measure the vibration pulses at various distances from the source, as shown in Figure 4-10. The frequency-dependent propagation characteristics are derived from the transfer function relationships of the ground surface vibration and the force. The tests were conducted by dropping the weight down a borehole to the depth of the subway tunnel invert.

Figure 4-10: Test Configuration for Measuring Transfer Mobility

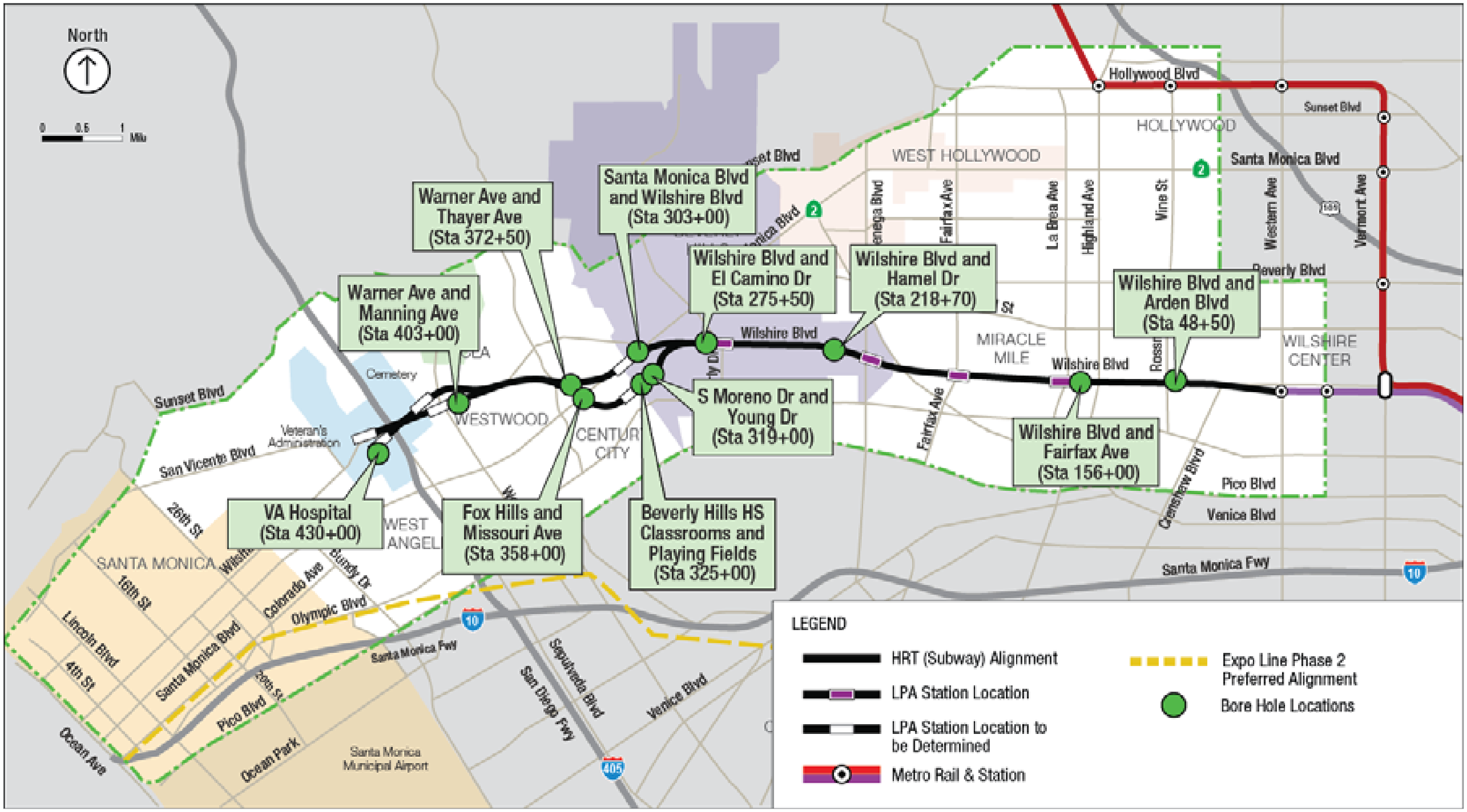


Vibration propagation tests were conducted as part of the geotechnical studies at the following locations along the LPA alignment (Figure 4-11). These locations can be found in Appendix A of the Final EIS/EIR, LPA Plan and Profile, using the stationing (Sta.) numbers in parenthesis.

- Wilshire Boulevard and Arden Boulevard (Sta. 48+50)
- Wilshire Boulevard and Fairfax Avenue (Sta. 156+00)
- Wilshire Boulevard and Hamel Drive (Sta. 218+70)
- Wilshire Boulevard and El Camino Drive (Sta. 275+50)
- South Moreno Drive and Young Drive (Sta. 319+00)
- Beverly Hills High School Classrooms and Playing Fields (Sta. 325+00)
- Fox Hills Drive and Missouri Avenue (Sta. 358+00)

- Wilshire Boulevard and Manning Avenue (Sta. 403+00)
- Santa Monica Boulevard and Wilshire Boulevard (Sta. 303+00)
- Warner Avenue and Thayer Avenue (Sta. 372+50)
- VA Hospital (Sta. 430+00)

Figure 4-11: Locations of Transfer Mobility Tests



5.0 ENVIRONMENTAL CONSEQUENCES

5.1 Analysis Methodology

5.1.1 Transit Noise Assessment Methodology

Noise generated by the Project's noise sources is not substantially different from noise generated by at-grade and elevated Heavy Rapid Transit projects with one important difference: the Westside Subway Extension Project is a deep subway. The subway train tracks are between 50 and 130 feet below the ground surface. The noise generated below ground from rail transit operations would be from the interaction of train wheels on track, motive power, signaling and warning systems, and the operation of traction power substations (TPSS). This noise would transmit to the surface through sidewalk gratings of the ventilation shafts.

Additional noise that would be generated above ground level by transit operations would include at-grade portions of stations, including patron portals to the underground stations, fan and vent shaft discharge locations, and emergency electrical power generators. Noise emissions from these above-ground components of the Project were evaluated, along with noise emissions from the proposed expanded Rail Operations Center, emergency egress locations, and maintenance facilities, such as yard and shop uses and the tracks servicing these facilities.

Future traffic increases at the station locations would be minimal and would not add to the existing measured noise levels presented in Table 4-1.

The noise assessment methodology for the analysis and the results remain similar to that in the Westside Subway Extension Project Noise and Vibration Technical Report (August 2010). Please refer to that report for more details.

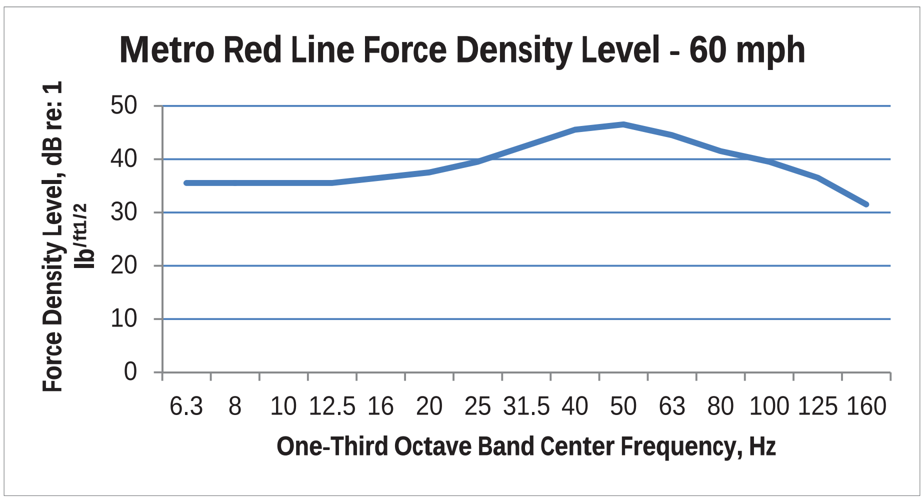
5.1.2 Transit Vibration Assessment Methodology

Vibration impacts from transit operations are generated by motions/actions at the wheel/rail interface. The smoothness of these motions/actions is influenced by wheel and rail roughness, transit vehicle suspension, train speed, track construction (including types of fixation), the location of switches and crossovers, and the geologic strata (layers of rock and soil) underlying the track. Vibration from a passing train has a relatively small potential to move through the geologic strata and result in building vibration from energy transferred through the building's foundation. Vibration levels that would be high enough to cause any building damage, even minor cosmetic damage, are extremely unlikely.

Ground-borne noise is a low-frequency rumble related to operational vibration that may occur when excessive levels of vibration of a building's floors and walls result from transit system operations. Ground-borne noise is not generally a concern for at-grade or above ground transit operations because the level of airborne noise from a passing at-grade or elevated train that is transmitted through the windows or walls of a building would exceed the ground-borne noise level occurring inside the building. However, a deep subway produces no appreciable airborne noise above the ground surface; therefore, the analysis considers the ground-borne noise related to the operational vibration, since the ground-borne noise may be slightly audible within a building that otherwise has low internal background noise. Because ground-borne noise is directly related to ground-borne vibration, the level of ground-borne noise is a function of the distance from the tracks to the building.

The process used to evaluate potential impacts from ground-borne vibration and ground-borne noise follows those outlined in *Transit Noise and Vibration Impact Assessment* (FTA 2006). The projections are based on characterizing the magnitude of the vibration forces generated by a transit train in terms of a force density and characterizing the propagation through the soil with a transfer mobility function. The force density is assumed to represent the combined effects of the vehicle suspension, the wheel and rail condition, and the track support system and is assumed to be independent of the local geologic conditions. Force density level measurements of the Breda vehicle, which would likely be the heavy rail vehicle used for this Project, were conducted by Wilson Ihrig & Associates as part of the report, *Ground Vibration Measurements of Train Operations on Segment 2A of the Los Angeles Metro Red Line* (Metro 1996). The force density levels (FDL) were measured at 40 miles per hour (mph) and, based on the different trackwork geomteries, were adjusted to the projected train operating speeds in the range of 40 to 70 mph following the FTA Detailed Vibration Analysis methodogy. The maximum train speed for the Metro Red Line vehicle is 70 mph. The FDL at 60 mph is shown in Figure 5-1:

Figure 5-1: Measured Metro Red Line Force Density Level



The measured transfer mobility function data used for this analysis are presented in Appendix A as a line source response for slant distances in the range of 50 to 100 feet from the top of rail to the surface. The combination of the force density (Figure 5-1:) and measured transfer mobility functions (Appendix A) provides an estimate at the ground surface as a function of distance from the tracks, the horizontal distance, and the depth of the subway tunnels. All estimates of ground-borne vibration are calculated in one-third octave bands. The overall vibration level in VdB is calculated from the individual one-third octave bands and compared to the FTA criteria presented in Section 3 of this report. The predicted vibration levels are at the foundation of each building and do not include any estimates of building attenuation. These projections are representative of first-floor vibration levels for buildings constructed as a concrete slab on grade. In addition, a 5-decibel safety factor has been incorporated into all of the ground-borne vibration and ground-borne noise projections. The purpose of the safety factor is to account for normal fluctuations in ground-borne vibration due to normal wheel and track wear, and unexpected differences in the local soil and geology that were not represented by the transfer mobility tests. Ground-borne noise was calculated by converting the 1/3 octave band vibration levels to sound pressure levels and applying an A-weighted adjustment using the FTA Detailed Vibration Analysis procedures.

The ground-borne vibration and ground-borne noise were calculated for tangent track and crossover track at 80 vibration-sensitive receivers along the LPA alignment and alignment options between the Wilshire/Rodeo and Westood/UCLA Stations. Crossover track are known to generate higher levels of ground-borne vibration and ground-borne noise.

Table 5-1 presents the predicted ground-borne vibration and ground-borne noise for tangent track at each of the 80 vibration sensitive receivers along with the corressponding FTA impact criteria for that location. Also included are the tunnel depth, horizontal distance of the receivers, and train speed. Table 5-2 presents the same information for crossover track. Figure 5-2 and Figure 5-3 show the locations of the receivers. Those locations where the FTA ground-borne noise criteria is exceeded is considered a significant impact and is highlighted in Table 5-1 and Table 5-2.

5.2 Transit Noise Impacts

5.2.1 LPA and Alignment Options

The project components with the potential to generate noise that would be audible at the surface are the station ventilation system fans and the emergency ventilation system fans, which are subject to periodic testing. Noise from rail operations, including the interaction of wheels on tracks, motive power, signaling and warning systems, and the TPSS, would occur well below ground.

The station ventilation system fans will be designed using sound attenuators on the fan outlets and sound-absorptive treatment in the ventilation shafts to comply with the MTA Design Criteria for noise from transit system ancillary facilities. The MTA design levels specify that the fan noise does not exceed the FTA Noise Impact Criteria at the noise-sensitive receivers identified in Section 4 of this report. At the residential and hospital noise-sensitive receivers (Sites N1 through N6 and N8) identified near the stations, the station ventilation fan noise would be designed so as not to exceed a maximum noise level of 45 dBA at a distance of 50 feet from the ventilation shaft outlet at the sidewalk grating or at the setback line of the nearest building, whichever is closer (Table 5-3). This same design criterion will be used for Site N7, Wadsworth Theatre, which is assessed by FTA using the one-hour Leq metric. The estimated fan noise levels over a 24-hour period (Ldn) and one-hour period (Leq) are presented in Table 5-3 along with the measured existing noise levels and the FTA noise impact criteria.

Emergency ventilation fans would be periodically tested during the afternoon when the existing ambient traffic noise levels are at their highest.

Emergency electrical power generating equipment will be required to meet the following provision in Section 2.8.7 D of Metro's *Design Criteria for Emergency Power Generation Equipment:*

"Emergency power generator equipment noise shall be tested during the time of day when existing ambient noise is at its maximum level. Equipment testing shall be limited to a maximum period of ten (10) minutes once a week or less. During times of periodic testing, the emergency power generator equipment shall be limited to no more than 10 dBA sound level above the ambient noise levels or 10 dBA more than the levels listed for continuous noise in [Metro Design Criteria] Table 5-4 at a distance of 50 feet from the generator or at the nearest building or occupied area, whichever is closer. Reduction of noise from these sources shall be achieved by barriers, enclosures, sound-absorptive materials and mufflers as applicable to the individual facility or unit design."

Table 5-1: Predicted Ground-borne Vibration and Ground-borne Noise along Tangent Track at Vibration-Sensitive Receivers

ID #	Receiver	Tunnel Depth (feet)	Horizontal Distance (feet)	Predicted Ground-borne Vibration Level (VdB)	FTA Ground-borne Vibration Criteria (VdB)	Predicted Ground-borne Noise Level (dBA)	FTA Ground-borne Noise Criteria (dBA)	Train Speed (mph)
V1	Ramada Inn	54	35	65	72	33	35	70
V2	St James Church	54	30	65	75	33	40	70
V3	Apartments	58	40	65	72	32	35	70
V4	Los Altos Hotel	62	30	65	72	32	35	70
V5	Dunes Inn	55	35	65	72	33	35	70
V6	Wilshire United Methodist Church	60	40	64	75	31	40	70
V7	Scottish Rite Masonic Temple	60	40	64	75	31	40	70
V8	Wilshire Ebell Theatre	64	40	64	72	31	30	70
V9	Apartments	66	40	64	72	31	35	70
V10	Apartments	72	35	64	72	31	35	70
V11	Apartments	68	30	64	72	31	35	70
V12	Apartments	65	60	64	72	30	35	70
V13	Apartments	84	40	64	72	30	35	70
V14	Apartments	71	50	64	72	30	35	70
V15	Wilshire Private School	70	60	64	75	30	40	70
V16	Apartments	69	30	64	72	31	35	40
V17	Apartments	66	40	59	72	26	35	40
V18	Korea Center	70	40	65	75	32	40	70
V19	Apartments	75	35	65	72	32	35	70
V20	Mid Wilshire Surgery Center	75	60	65	75	30	40	70
V21	Craft and Farm Art Museum	75	35	65	75	32	40	70

ID #	Receiver	Tunnel Depth (feet)	Horizontal Distance (feet)	Predicted Ground-borne Vibration Level (VdB)	FTA Ground-borne Vibration Criteria (VdB)	Predicted Ground-borne Noise Level (dBA)	FTA Ground-borne Noise Criteria (dBA)	Train Speed (mph)
V22	LA County Museum of Art	67	50	65	75	32	40	70
V23	Apartments	58	40	60	72	27	35	40
V24	Los Angeles Museum of the Holocaust	71	40	62	75	28	40	55
V25	Saban Theatre	58	30	65	72	33	30	40
V26	Fine Arts Movie Theater	60	30	67	72	35	35	55
V27	Apartments	60	30	67	72	35	35	55
V28	Specialty Surgical Center	65	35	67	75	34	40	55
V29	Montage Hotel and Condos	63	60	60	72	21	35	40
V30	Beverly Wilshire Hotel	66	35	62	72	24	35	45
V31	Apartments	92	0	62	72	32	35	65
V32	Hotel	93	0	62	72	32	35	65
V33	Medical Office	91	0	62	75	32	40	65
V34	Apartments	86	15	63	72	34	35	45
V35	Beverly Hills High School Offices and Classrooms	77	0	64	75	33	40	45
V36	Beverly Hills High School Classrooms	85	0	63	75	30	40	45
V37	Future Office Buildings	78	40	59	75	29	40	40
V38	SFR	96	0	63	72	33	35	70
V39	Apartments	88	0	64	72	35	35	70
V40	Pacific Crossroads Church	87	0	64	75	35	40	70
V41	SFR	92	0	63	72	33	35	70
V42	Apartments	120	0	61	72	30	35	70
V43	SFRs	121	0	61	72	30	35	70

Table 5-1: Predicted Ground-borne Vibration and Ground-borne Noise along Tangent Track at Vibration-Sensitive Receivers (continued)

ID #	Receiver	Tunnel Depth (feet)	Horizontal Distance (feet)	Predicted Ground-borne Vibration Level (VdB)	FTA Ground-borne Vibration Criteria (VdB)	Predicted Ground-borne Noise Level (dBA)	FTA Ground-borne Noise Criteria (dBA)	Train Speed (mph)
V44	SFR	100	0	62	72	32	35	70
V45	SFRs	89	0	64	72	35	35	70
V46	Apartments	81	0	64	72	35	35	70
V47	Apartments	86	0	63	72	34	35	65
V48	Apartments	96	70	59	72	29	35	55
V49	Apartments	103	70	59	72	28	35	55
V50	Apartments	108	60	59	72	28	35	55
V51	Apartments	110	80	59	72	27	35	55
V52	Apartments	108	50	59	72	29	35	55
V53	Apartments	102	50	59	72	27	35	55
V54	Apartments	102	60	59	72	27	35	55
V55	University Bible Church	100	60	59	75	27	40	55
V56	Concord School of Law	86	45	61	75	32	40	55
V57	Armand Hammer Museum	64	50	63	75	34	40	40
V58	Federal Building	64	110	58	75	25	40	55
V59	VA Hospital	73	400	53	72	20	35	55
V60	The Peninsula Hotel	79	120	59	72	29	35	40
V61	The Beverly Hilton	76	85	58	72	27	35	40
V62	SFRs	103	0	57	72	27	35	40
V63	SFRs	108	0	57	72	27	35	40
V64	SFRs	90	0	58	72	28	35	40
V65	Condominiums	85	0	59	72	30	35	40
V66	SFR	80 to 104	0	57-61	72	27-31	35	40
V67	SFR	96	0	58	72	28	35	40

ID #	Receiver	Tunnel Depth (feet)	Horizontal Distance (feet)	Predicted Ground-borne Vibration Level (VdB)	FTA Ground-borne Vibration Criteria (VdB)	Predicted Ground-borne Noise Level (dBA)	FTA Ground-borne Noise Criteria (dBA)	Train Speed (mph)
V68	Park Wilshire Hotel	105	30	57	72	27	35	40
V69	Palomar Hotel	105	15	57	72	27	35	40
V70	University Bible Church	115	0	57	75	26	40	40
V71	MFR	115	0	57	72	26	35	40
V72	MFR	118	0	57	72	26	35	40
V73	UCLA Extension	114	18	56	75	25	40	40
V74	Wadsworth Theatre	88	65	57	72	27	30	40
V75	Park Wilshire Hotel	105	30	57	72	27	35	55
V76	Palomar Hotel	105	15	57	72	27	35	55
V77	University Bible Church	115	0	57	75	26	40	40
V78	MFR	115	0	57	72	26	35	40
V79	MFR	118	0	57	72	26	35	40
V80	UCLA Extension	114	18	56	75	25	40	40

Notes:
1. XX—Predicted ground-borne noise levels that exceed the FTA criteria
2. SFR = Single-family residence; MFR = Multi-family residence
3. The ID numbers are shown on Figure 5-2 and Figure 5-3

Table 5-2. Predicted Ground-borne Vibration and Ground-borne Noise along Crossover Track at Vibration-Sensitive Receivers

ID #	Receiver	Tunnel Depth (feet)	Horizontal Distance (feet)	Predicted Ground-borne Vibration Level (VdB)	FTA Ground-borne Vibration Criteria (VdB)	Predicted Ground-borne Noise Level (dBA)	FTA Ground-borne Noise Criteria (dBA)	Train Speed (mph)
V16	Apartments	69	30	69	72	38	35	27
V37	Future Office Buildings	78	40	67	72	37	35	27
V58	Federal Building	64	110	66	75	34	40	37

Notes:
1. XX—Predicted ground-borne noise levels that exceed the FTA criteria
2. The ID numbers are shown on Figure 5-2 and Figure 5-3

Figure 5-2: Vibration-Sensitive Locations (Existing Wilshire/Western Station to Wilshire/Fairfax Station)

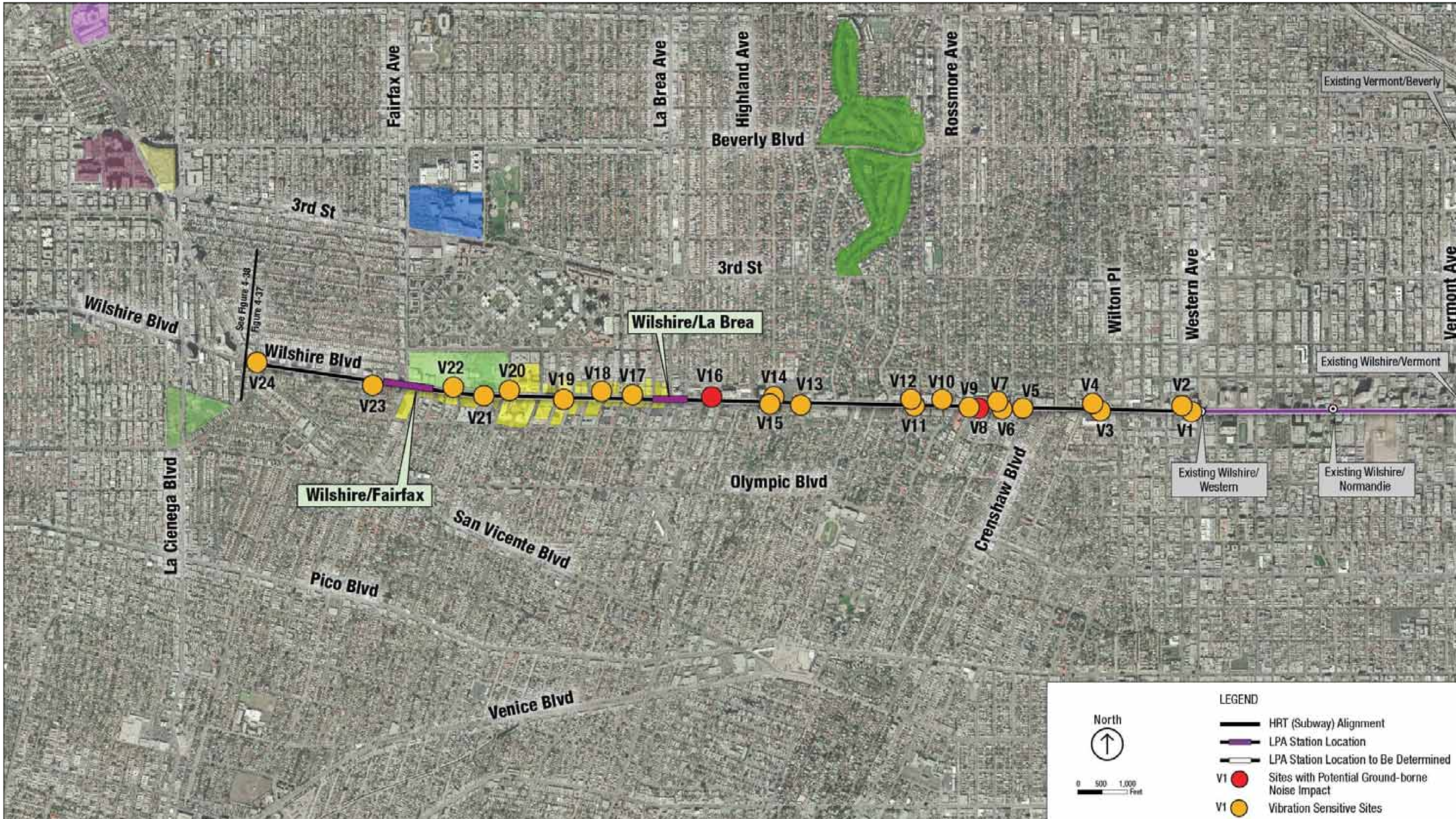


Figure 5-3 Vibration-Sensitive Locations (Wilshire/La Cienega Station to Westwood/VA Hospital Station)

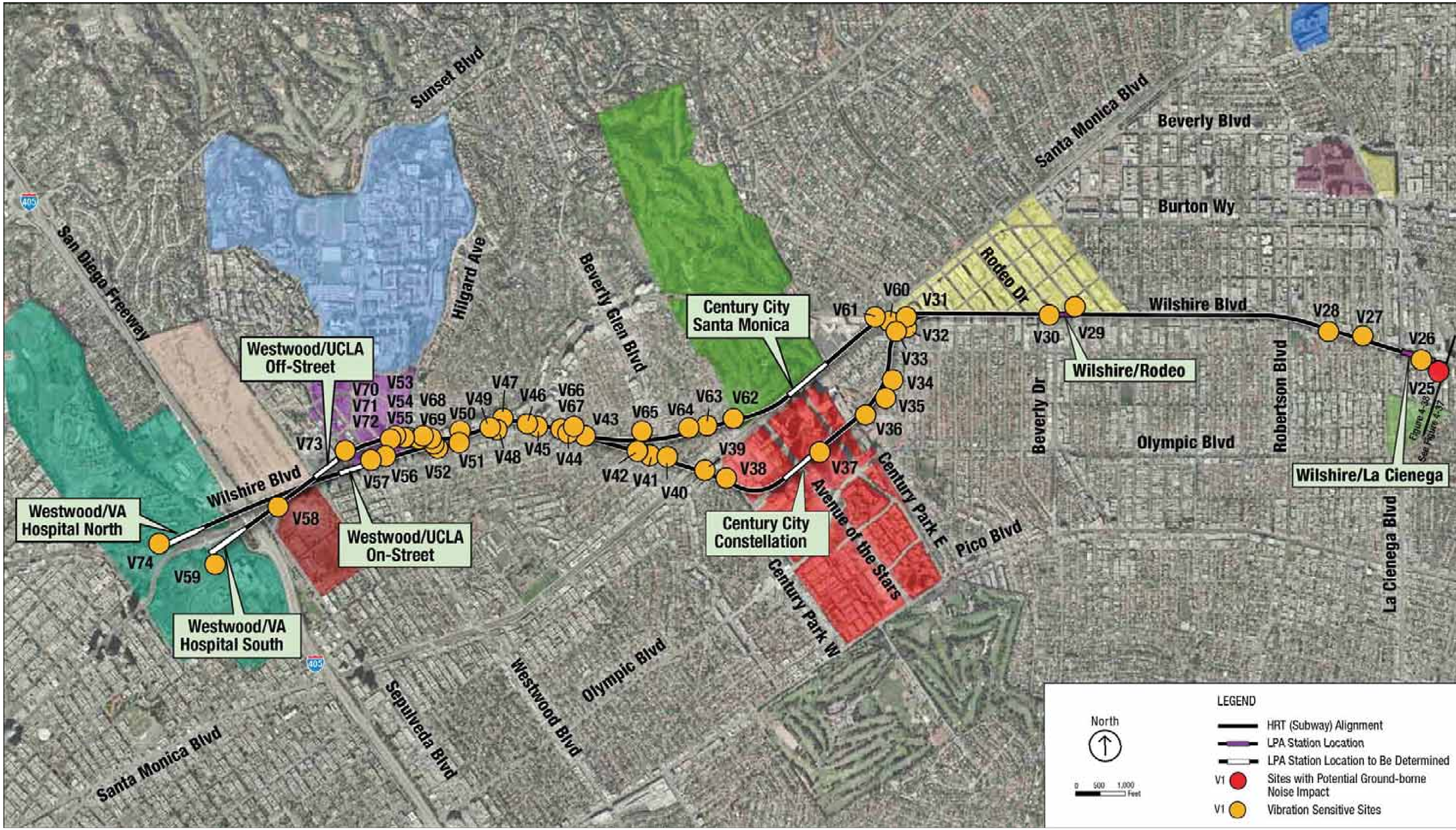


Table 5-3: Predicted Station Ventilation Fan Noise

Measurement Site	Station	Measured Existing Noise Level (dBA)	Estimated Maximum Fan Noise (dBA)	FTA Noise Impact Criteria (dBA)
N1	Wilshire/La Brea	Ldn=67	Ldn=61	Ldn=63
N2	Wilshire/Fairfax	Ldn=68	Ldn=61	Ldn=63
N3	Wilshire/La Cienega	Ldn=71	Ldn=61	Ldn=66
N4	Wilshire/Rodeo	Ldn=64	Ldn=61	Ldn=61
N5	Century City (Constellation)	Ldn=74	Ldn=61	Ldn=66
--	Century City (Santa Monica) Station	No noise sensitive receivers near this station location		
N6	Westwood/UCLA (Off-Street and On-Street)	Ldn=74	Ldn=61	Ldn=66
N7	Westwood/VA Hospital South of Wilshire	Leq=64	Leq=45	Leq=66
N8	Westwood/VA Hospital North of Wilshire	Ldn=72	Ldn=61	Ldn=66

Table 5-4: Metro Design Criteria for Noise from Transit System Ancillary Facilities

Community Area	Maximum Noise Level (dBA)	
	Transient	Continuous
Low-density residential	50	40
Average residential	55	45
High-density residential	60	50
Commercial	65	55
Industrial/highway	75	65

Source: Metro Design Criteria, Table 2-9 (Metro 2009)

The TPSSs for the entire system are planned to be co-located within the underground stations and would generate no noise outside of the stations. No noise impacts are anticipated from TPSSs.

Non-train-noise associated with subway transit operations typically occurs at station locations where increased street-grade activity, such as parking lot use, may locally generate noise. The Project does not propose to incorporate any station-related parking facilities; therefore, this source of transit-related noise would not be present and would not cause a noise impact.

The existing road and sidewalk network would be used by passengers to access the underground stations. The impact analysis found that, while noise could be generated in the above ground portion of stations from pedestrians, bicyclists, and passenger drop-off activities, these activities are not significant noise generators. Any brief noise would be minimal and would not result in noise impacts.

5.3 Transit Vibration Impacts

5.3.1 LPA and Alignment Options

The FTA has developed impact criteria for acceptable levels of ground-borne noise and vibration. As shown in Table 5-1 and Table 5-2 no vibration-sensitive receivers are predicted to exceed the FTA ground-borne vibration criteria. Exceedance of the FTA ground-borne noise criteria would occur at three locations: one residential building and two live theatres. These exceedances are in the range of 1 to 3 db above the FTA ground-borne noise criteria.

The locations along the LPA where exceedance of the FTA ground-borne noise criteria would occur due to train operations along tangent track or through crossovers, if mitigation measures were not implemented, are presented in Table 5-5.

Table 5-5: Receivers Exceeding the FTA Ground-Borne Noise Criteria

ID#	Receiver	Street Location	Cross Street	Source of Impact
V8	Wilshire Ebell Theatre	Wilshire Boulevard	S. Lucerne Boulevard	Tangent Track
V16	Apartments	Wilshire Boulevard	S. Orange Drive	Crossover Track
V25	Saban Theatre	Wilshire Boulevard	S. Hamilton Drive	Tangent and Crossover Tracks

6.0 MITIGATION MEASURES

The following sections modify and or replace Sections 6.1 and 6.2 of the Draft EIS/EIR:

6.1 Mitigation Measures for Project Operations Noise

Noise from project operations (station ventilation system fans, emergency ventilation fans, TPSSs, and emergency generators) will be designed to meet the noise-level limits specified in *Metro's Design Criteria,* as discussed in Section 3, and would not result in any noise impacts; thus, no mitigation measures are required.

6.2 Mitigation Measures for Project Operations and Ground-borne Noise

To mitigate the potential for ground-borne noise impacts to residential, theater, and hotel uses above the subway tunnel due to train operation along tangent track the trackwork will need to incorporate vibration isolation between the rail and the tunnel. The vibration isolation will be provided by a high compliance direct fixation resilient rail fastener incorporated into the design of the trackwork at the locations listed below, which would reduce ground-borne noise by 5 to 7 dBA:

- Sta. 42+50 to 45+50 for the Wilshire Ebell Theatre at Site V8
- Sta. 195+00 to 199+00 for the Saban Theatre at Site V25

To mitigate the potential for ground-borne noise due to trains operating through the gap between tracks at crossovers, a low impact crossover such as a moveable point frog or a spring-loaded frog will be used in the design of the following crossovers:

- Wilshire/La Brea No. 10 Double Crossover (Sta. 99+33 to 99+95) for the apartments at Site V16

6.3 Relationship between Local Short-term Use of Resources and Maintenance and Enhancement of Long-term Productivity

Incorporating necessary noise and vibration control and mitigation measures into any of the alternatives would require a minimal use of short-term resources, such as an upgraded exhaust silencer, a generator enclosure, or acoustical louvers on a vent discharge. The benefit is that noise- or vibration-sensitive activities would be unaffected and there would be no adverse effects on productivity.

6.4 Irreversible and Irretrievable Commitment of Resources

A substantial irreversible and irretrievable commitment of resources is not required to achieve no noise or vibration impacts from the Project.

6.5 Cumulative Impacts

Operational noise and vibration emissions of this Project would occur only at very specific locations (e.g., station ventilation fan discharge, emergency electrical power generators, subway tunnel vent discharge/emergency egress locations) and would not result in area-wide impacts. These emissions are independent and separated from each other in time and location and would not contribute to a cumulative impact.

6.6 California Environmental Quality Act (CEQA) Determination

The CEQA determination compares the effects of the LPA with the existing conditions described in the affected environment/existing conditions section. Applying CEQA guidelines, any vibration or noise impacts identified as a significant impact must be mitigated unless mitigation is infeasible or no mitigation provided if no abatement measures are available, due to economic, social, environmental, legal, or technological conditions. The City of Los Angeles and County of Los Angeles and the City of Beverly Hills Noise Ordnance are not applicable to any vehicles which are operated upon any public highway, street or right-of-way. Since CEQA does not provide specific thresholds for significant noise or vibration impact. The applicable standard for the Westside Subway Extension, the noise and vibration impact criterion, as defined by FTA, was applied as the CEQA threshold for significance.

CEQA guidelines indicate significant impacts would occur if a project would result in the following:

- Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance or applicable standards of other agencies
- Exposure of persons to or generation of excessive ground-borne vibration or ground-borne noise levels
- A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project
- A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project
- For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, exposure of people residing or working in the project area to excessive noise levels
- For a project within the vicinity of a private airstrip, exposure of people residing or working in the project area to excessive noise levels

In conformance with CEQA, the Westside Subway Extension Project's operational noise and operational vibration were evaluated to determine if the Project would cause significant noise or vibration impacts to the environment. The Project's impact analyses concluded that the Project as described, including the inclusion of noise and vibration control features as identified and discussed above for tunnel vent discharge locations, emergency power generators, resilient rail fasteners, and low impact crossovers, would result in the following:

- Would not expose persons to or generate noise levels in excess of standards established in the local general plan or noise ordinance or applicable standards of other agencies
- Would not expose persons to or generate excessive ground-borne vibration but would exceed thresholds of significance for ground-borne noise levels
- Would not result in a substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the Project
- Would not result in a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the Project

- The Project would not expose people residing or working in the project area to excessive noise levels
- The Project is not located within 2.0 miles of an airport boundary or in the vicinity of a private airstrip.

No operational noise and vibration impacts for any of the alternatives are anticipated, and no mitigation beyond what is described above for ground-born noise would be required in accordance with CEQA.

If future project design changes could result in an airborne noise impact, a vibration impact, or a ground-borne noise impact, a re-analysis should be conducted using the FTA General Analysis Methodology or Detailed Methodology (FTA 2006), as appropriate, to determine if the redesigned project would result in impacts and if mitigation would be required.

6.7 Impacts Remaining after Mitigation

Ground-borne noise impacts would be mitigated to a level below the threshold of significance. No operational noise impacts for any of the alternatives are anticipated, thus no impacts remain

7.0 REFERENCES

ANSI 1992	American National Standards Institute S12.9-1992/Part 2. *Quantities and Procedures for Description and Measurement of Environmental Sound. Part 2: Measurement of Long-term, Wide-Area Sound.* Standards Secretariat, Acoustical Society of America, New York, NY.
ANSI 1993	American National Standards Institute S12.9-1993/Part 3. *Quantities and Procedures for Description and Measurement of Environmental Sound. Part 3: Short-Term Measurements with an Observer Present.* Standards Secretariat, Acoustical Society of America, New York, NY.
BH 1990	City of Beverly Hills Noise Ordinance 90-0-2088, 2/8/1990.
CEQA 2009	California Environmental Quality Act (CEQA) Guidelines (2009) Appendix G
EPA 1974	EPA/ONAC 550/9-74-004. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. March 1974. Washington, DC.
FTA 2006	U.S. Department of Transportation, Federal Transit Administration (FTA). May 2006. FTA-VA-90-1003-06. Transit Noise and Vibration Impact Assessment. Office of Planning and Environment. Washington, DC.
LA 1982	City of Los Angeles Construction Noise Ordinance No. 144.331, Chapter XI, Section 41.40, Amended 3/82.
LAC 2009	County of Los Angeles, Title 2, Chapter 12.08 “Noise control ordinance of the county of Los Angeles.” (Ord. 11778 § 2 (Art. 1 § 101), 1978: Ord. 11773 § 2 (Art. 1 § 101), 1978.) Los Angeles Metro. April 2, 2009.
Metro 1995/ 2009 Draft	Metro Design Criteria. Section 2, Environmental Considerations. Part 2.8, Noise and Vibration. (Systemwide Baseline Change Notice (SBCN) 18 Rev. 001 05.03.95)
Metro 2005	*Los Angeles Eastside Corridor Final Supplemental Environmental Impact Statement/Final Subsequent Environmental Impact Report*, February 2005
Metro 2010a	Westside Subway Extension Project Noise and Vibration Technical Report, August 2010.
Metro 2010b	Westside Subway Extension Construction and Mitigation Technical Report, August 2010
SM 2004	City of Santa Monica Municipal Code, Ordinance No. 2115CCS, Article 4, Chapter 4.12 Noise, Amended 2/24/04.
WH 2007	City of West Hollywood Ordinance, No. 07-769U, Title 9, Article 2, Chapter 9.08 Noise. 2007

APPENDIX A

Results of Borehole Vibration Propagation Tests for Westside Subway Extension

MEMORANDUM

To: Steven Wolf
Parsons Brinckerhoff

From: Matthew Sneddon
Hugh Saurenman
ATS Consulting

Date: June 21, 2011

Subject: Results of Borehole Vibration Propagation Tests for Westside Subway Extension

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1. INTRODUCTION

1.1 Overview

This report presents the results of vibration propagation tests that were performed to assist in predicting the levels of groundborne vibration and noise that would be generated by the proposed Westside Subway Extension. The testing was performed as part of the Final Environmental Impact Statement and Environmental Impact Report (FEIS/EIR).

Borehole vibration tests were performed in order to determine directly the vibration propagation characteristics for subsurface vibration sources at a given site. The test method consists of generating ground vibration at the bottom of the hole using the drill rig penetration drop hammer. The impulsive forces transmitted into the soil at the bottom of the borehole are measured using a special load cell and the resulting surface acceleration measured at varying distances from the hole.

The resulting measurements are digitally processed to obtain the *transfer mobility*, which characterizes the relationship between the exciting force and the resulting ground motion. Additional details on the test procedure, equipment, and data processing is provided in Section 2.

Testing was performed at 12 sites, selected from the roughly 100 rotary-wash boreholes that were part of the overall geotechnical investigation undertaken by Mactec Engineering[1]. The locations of the test boreholes, the test dates, and the depths of the tests are given in Table 1 and Figure 1 shows the general locations of the test sites.

Table 1: Borehole Locations and Test Dates

Borehole	Location / Cross Street	Test Date(s)	Test Depths (ft)
G-106	Wilshire / Arden	24-Mar-2011	50, 60, 70
G-124	Wilshire / Fairfax	17-Mar-2011	40, 55, 60
G-134	Wilshire / Hamel	30-Mar-2011	50,60, 70
G-145	Wilshire / El Camino	14 - 15 Mar 2011	50, 60, 70
G-152	Santa Monica / Wilshire	31 Jan - 1 Feb 2011	55, 65, 75
G-164	Moreno / Young	26 - 27 Jan 2011	45, 55, 65
G-165	Beverly Hills HS (classrooms)	5-Mar-2011	55, 65, 75
G-166	Beverly Hills HS (Lacrosse field)	19-Mar-2011	55, 65, 75
G-173	Missouri / Fox Hills	21 - 22 Feb 2011	60, 70, 80
G-176	Warner / Thayer	27-Dec-2010	80, 90, 97
G-178	Wilshire / Manning	17-Jan-2011	65, 75, 85
G-203	VA Medical Center	3-May-2011	55, 65, 75

[1] MACTEC Engineering and Consulting Inc., Project 4953-10-1561

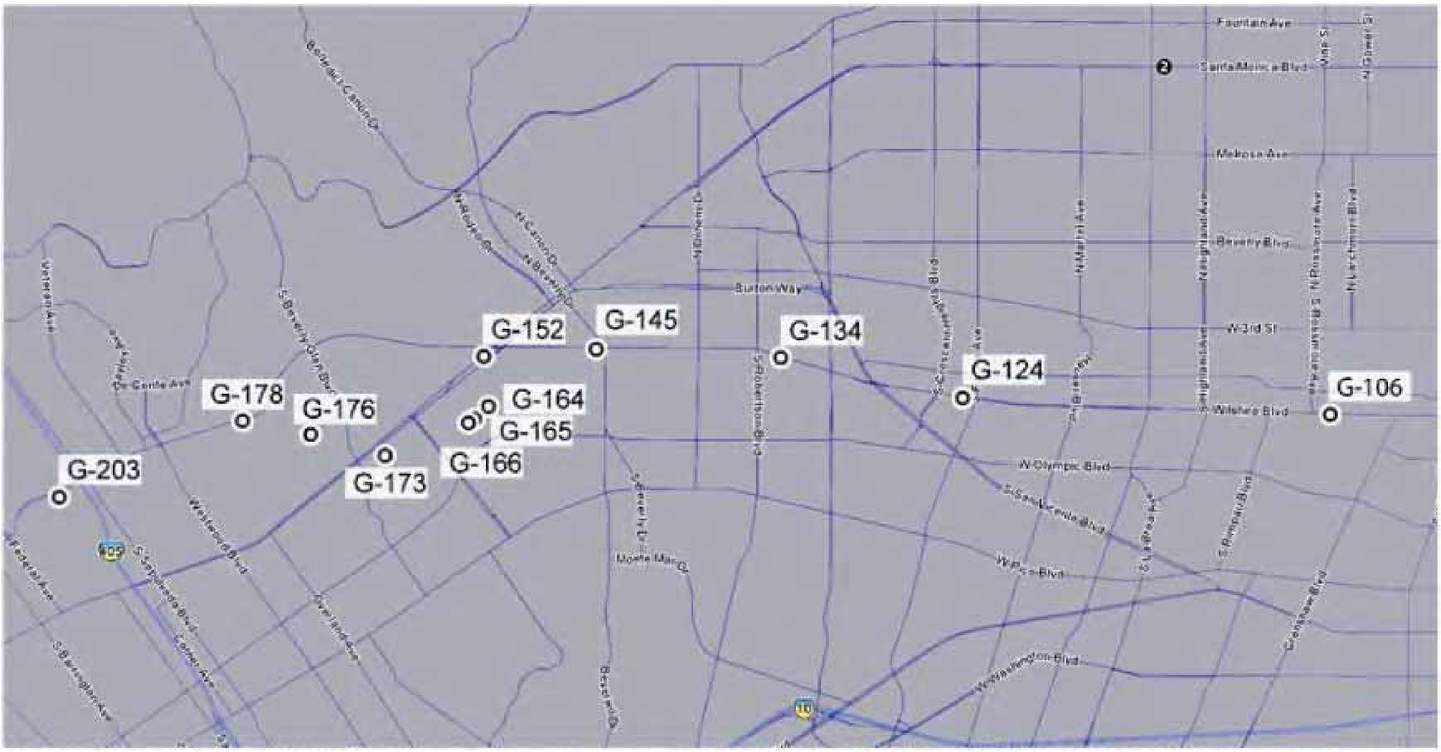

Figure 1: Overview of Vibration Test Borehole Locations

1.2 Executive Summary

The 12 borehole sites listed in Table 1 were selected for the vibration survey based on two criteria. The first consideration was to select test sites based on their proximity to vibration-sensitive sites previously identified in the draft EIS/EIR as exceeding the Federal Transit Administration (FTA) criteria. The second was to select locations that would provide a reasonably uniform sampling along the proposed subway alignment. Three of the sites selected for this study (G-164, G-165, and G-166) were located at or near Beverly Hills High School, which had been identified as a site of particular concern.

At many of the test sites, the borehole vibration measurements and the subsequent mobility calculations were affected by unexpectedly low force level being developed at the bottom of the boreholes, high ambient vibration levels, or a combination of the two. The resulting low signal-to-noise ratio levels resulted in a relatively high scatter in calculated point source transfer mobility (PSTM) values. The line source transfer mobility (LSTM) functions derived from the PSTM data have been reviewed for reasonableness and provide a good estimate of vibration propagation characteristics over frequency ranges that the coherence exceeds 0.3. However, care should be exercised applying the derived LSTM functions at low and high frequencies and at diagonal distances that are outside the 50 to 200 foot range of the measurement data.

Figure 2 provides an overview of the final LSTM curves for the twelve sites assuming a vibration line source that is the length of a 6-car train and a 100 foot receiver distance. The shapes of the 1/3 octave band spectra are all similar. There is a broad peak in the LSTM spectra between 16 and 40 Hz with the LSTM falling off at a rate of about 10 decibels per octave at higher frequencies. The LSTM curves all fall within an 18-dB wide envelope at essentially all frequencies. Sites that are toward the high side of this envelope are G-106, G-134, and G-176. Sites G-145 and G-178 fall noticeably below the mean for most of the frequency range.

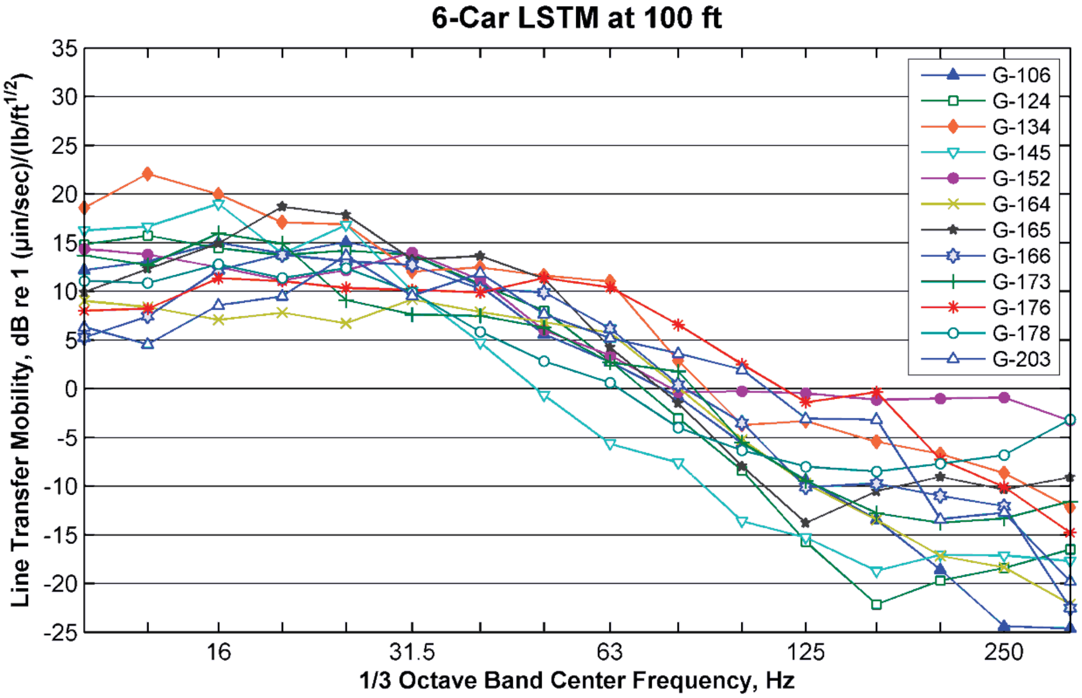

Figure 2: Cross-site Comparison of LSTM Values (6-Car trains at 100 Foot Diagonal Distance)

Additional observations from inspection of the 12 LSTM functions are:

- **Comparisons between G-164, G-165, and G-166:** These sites were closely spaced, with 475 feet separating G-164 and G-165, and only 220 feet between G-165 and G-166. The resulting LSTM spectra for these three sites are in most respects similar (particularly the LSTM spectra for G-165 and G-166), but with two notable differences. The 50-foot LSTM for G-166 is significantly elevated at 63 Hz (approximately 10 dB) with respect to the other sites. In addition, the LSTM levels in the 16-25 Hz bands vary as much as 15 dB between sites. It should be noted however that the PSTM coherence values at these frequencies were uniformly poor at these sites.

- **Comparison between G-173 and SB-2:** Site G-173 (Fox Hills Drive & Missouri Ave.) The site G-173 borehole was located only 75 feet from a prior borehole test (SB-2) conducted in June 2010. The SB-2 test results were documented in a previous report, but a top-level comparison of the results is of interest here. The SB-2 test consisted of PSTM measurements at six distances for a single test depth of 103 feet. The G-173 tests were done at depths of 60, 70, and 80 feet with the line array orthogonal to the SB-2 test. The peak force levels (35k lbs) developed during the SB-2 test were distinctly greater than for G-173, where typical levels were 20k lbs (60 ft), 15k lbs (70 ft) and 10k lbs (at 80 ft). The general shape of the PSTM spectra and the derived LSTM values are quite similar between the two tests, but the absolute levels in all cases are approximately 10 dB greater in the G-173 measurements. This is a significant difference, particularly in view of the otherwise consistent behavior and the (relatively) good quality of the data. After carefully inspecting the data, we are confident that the results reflect variations in the vibration transmission characteristics of the soil at a depth of 100 feet at SB-2 compared to the vibration transmission characteristics of the soil at shallower depths at G-173.

- **Indoor/Outdoor results from G-165:** Indoor vibration measurements were made in three classrooms at Beverly Hills High School during the G-165 borehole test. For two of the classrooms (123 and 201), little amplification was observed, but room 107 showed significantly increased levels at low frequency. Detailed results from the indoor measurements can be found in Sections 3.7.2 and 3.7.3

The remainder of this report presents the detailed result from each downhole vibration propagation test. The field testing and data procedures are described in Section 2 and the results for each borehole are presented in Section 3. Included in Section 3 for each site are:

- A description of the site.
- Graphs of the measured PSTM spectra and the corresponding coherence values at each measurement depth.
- The LSTM spectra derived from the PSTM spectra presented in tabular as well as graphic form.

All LSTM values presented in Section 3 are for a line source corresponding to a-6-car train. Table 2 presents the approximate difference between LSTM curves for different length line sources and different distances from the tracks. The absolute values of the adjustments increase with distance from the tracks and reach the maximum at distances of 300 to 600 ft from the tracks. All other things being equal, fewer cars per train will result in lower LSTM values.

Table 2: Adjustment Factors to Approximate LSTM for Different Length Trains

Distance (feet)	LSTM Adjustment in dB*	
	2-Car	4-Car
50	-0.4	-0.5
75	-1.3	-0.7
100	-2.1	-0.9
150	-3.0	-1.2
200	-3.4	-1.3
250	-3.9	-1.4
300	-4.2	-1.5
400	-4.6	-1.7
500	-4.8	-1.8
600	-4.8	-1.8
800	-4.8	-1.8
1000	-4.8	-1.8

Note:
* Value to be added to 6-car LSTM levels for 2- or 4--car train lengths

2. TEST PROCEDURE

2.1 Field Procedures and Equipment

The borehole vibration tests for this program involved generating subsurface vibration via hammer impacts while measuring the surface response at a number of locations, as illustrated in Figure 3. Surface vibration at each site was measured using six PCB model 393A03 seismic accelerometers, deployed on a single radial away from the hole, at (nominal) surface distances of 25, 37, 50, 75, 100, and 150 feet. These surface acceleration measurements were all made with the accelerometers oriented in the vertical direction. At two test sites (G-134 and G-145) supplemental triaxial acceleration measurements were made at one measurement location.

The driving force for the measurements was supplied by the drill rig's standard 140 lb drop hammer. A downhole load cell was used to measure the resulting impact force applied to the soil. All test signals (force and acceleration) were digitally recorded using 4-channel Rion DA-20 data recorders. The acceleration and force signals were stored in WAV files for subsequent analysis.

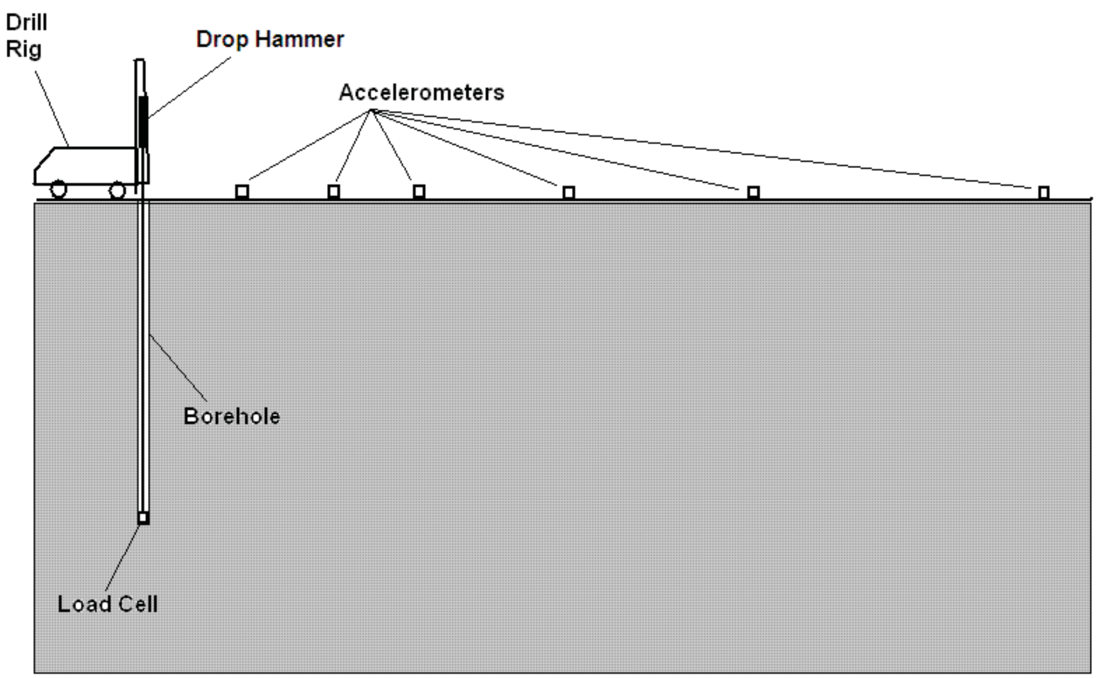

Figure 3: Borehole Test Configuration

The target test depths were set near the top, mid-plane, and bottom of the proposed tunnel structure at each site. The actual depth was usually adjusted slightly to accommodate other testing requirements such as soil sampling or pressure tests. Once on-site, the field crew would identify the measurement locations to be used, attach the accelerometers to the ground using base plates or ground stakes as appropriate, connect all transducers to the data recorders and check each data channel, making sure that the transducers were working, the channel assignments were correct, and that there are no electrical noise problems present.

Once the drilling crew reached each target test depth, the drill string would be withdrawn from the borehole, the load cell attached, and then re-inserted into the borehole. At each depth the test procedure consisted of the following steps:

1. The load cell and data recorders were powered on, and the load cell supply voltage checked.
2. One or more sets of trial impacts (of typically 5 hits each) were made to settle the load cell at the bottom of the borehole and provide a check of recording levels for the load cell and each of the accelerometer channels.
3. Once satisfied that the signal levels were correct, the data recorders were started and the drill rig operator asked to run off the desired number of hammer impacts. Typically 100 hits were requested, although in some instances an additional series of impacts were recorded where the ambient vibration levels were particularly high or the field team decided to use using alternate recording settings.
4. Once the desired number of impacts had been collected, the data recorders were stopped and the drill crew directed to bring up the load cell.

2.2 Data Processing Procedures

The data analysis was conducted in two principal phases as described in the following subsections. In the first phase all quality control and signal processing steps are performed, culminating in a set of *point source transfer mobility* (PSTM) estimates for each test site. This work was done using the MATLAB Signal Processing toolkit. The second phase of the analysis takes these individual PSTM estimates and derives *line source transfer mobility* (LSTM) values for each site. These calculations were done primarily using Excel spreadsheets.

2.2.1 Signal Processing Procedures

There were four main data steps involved in processing the recorded field data into the required PSTM estimates:

1. ***Quality Control:*** Parse the raw time history files into individual impacts and examine these individual samples for noise or other problems. Because of the large number of impacts (typically 100) and the high ambient vibration levels in many locations, we employed an automatic accept/reject function to reject samples with excessive interference from ambient vibration. The primary source of ambient vibration was vehicular traffic on Wilshire and Santa Monica Boulevards.
2. ***PSTM Estimation:*** Process the selected impact data to obtain the narrowband transfer functions between the exciting force and the response at each accelerometer position. These transfer functions are often termed *accelerance* functions. Mobility (velocity/force) is derived here from accelerance by applying a $1/\omega$ correction factor. The resulting transfer function relationship between the force and the vibration velocity response is referred to in this report as the *point source transfer mobility* (PSTM) and is the inverse of the system impedance.
3. ***One-Third Octave Levels:*** Consolidate the narrowband transfer mobility spectral values into 1/3 octave bands.
4. ***Curve Fitting:*** Pool the PSTM results at different depths and distances, and calculate a best-fit curve of transfer mobility as a function of diagonal distance from the impact location. These best-fit curves are developed for each 1/3 octave band.

2.2.2 Developing Line Source Transfer Mobility Curves

While the point source transfer mobility represents the response at the surface from a vibration source at a single subsurface point, the line source transfer mobility (LSTM) represents the response from forces distributed along a line such as a train. This more accurately represents the energy from trains that may be many feet long. For surface vibration propagation tests, it is common to measure point transfer mobility at 11 force locations in a line along the proposed alignment, and explicitly combine the point transfer mobilities to estimate the LSTM. This straightforward approach is impractical for a subway tests because it would require 11 boreholes. Therefore the contributions along the line must be calculated from one set of measurements.

To do this, the equivalent LSTM as a function of distance was derived from the measured point source transfer mobilities at the six accelerometer positions. A linear regression was first calculated for each frequency band as previously described, and used to predict the point source transfer mobility as a function of distance. Line integration of these regression functions was then used to calculate the equivalent LSTMs. The resulting LSTM functions can then be combined with separately developed *force density* functions to predict future groundborne vibration levels along the Westside alignments.

3. TEST RESULTS

The following sections provide descriptions of each site as well as the test results. For each test site graphs are provided showing the measured PSTM spectra and corresponding coherence values at each measurement depth. The LSTM spectra are provided in tabular as well as graphic form. All LSTM values in this section are for a line source corresponding to a 6-car train. Table 2 (page 4) provides adjustment factors that can be applied to these LSTM levels to estimate LSTM spectra for 2- or 4-car trains.

3.1 Site G-106

3.1.1 Site Description

Testing at this site was performed on 24 Mar 2011, at test depths of 50, 60, and 70 feet. The borehole was located in the median of Wilshire Boulevard, between Arden and Lucerne. The nearest vibration-sensitive receiver to this borehole is NV-9, identified as “Apartments”. The building is the Chateau Fremont at 4444 Wilshire Boulevard, directly across from the borehole position. The accelerometers were located at distances of 25, 37, 50, 75, 100, and 150 feet from the borehole, in a line extending eastward from the borehole with no lateral offset. Vehicular traffic on Wilshire Boulevard was particularly heavy throughout the testing period, with a few breaks. Additional observations from the measurements include:

- At the 50 ft depth, the load cell advanced 18 inches due to the impact hits, with little movement after hit 50. Typical peak forces ranged from 6-10k lbs. 120 impacts recorded.
- At the 60 ft test depth there was no perceptible drill string advancement after hit 20. Typical peak forces ranged from 10-20k lbs. 110 impacts recorded.
- At the 70 ft depth, the drill string advancement was not noted. Typical force levels were 17-25k lbs. 100 impacts recorded.

3.1.2 Results for G-106

- Coherence was poor at the 50 foot depth except for a few mid-frequency points at the closest accelerometer positions. This is probably due to the low force levels developed at the 50 test depth, in combination with the high ambient vibration levels.
- The coherence is somewhat improved at the 60 and 70-foot test depths although still poor at the lowest and highest frequencies.
- The levels and shapes of the PSTM at all depths were similar.
- The best fit LSTM shows the smallest decrease with distance in the 31.5 Hz band (almost none) where coherences never exceeded 0.5 and the greatest in the 125 Hz band where coherences were often the highest.

3.1.3 Plots and Tables

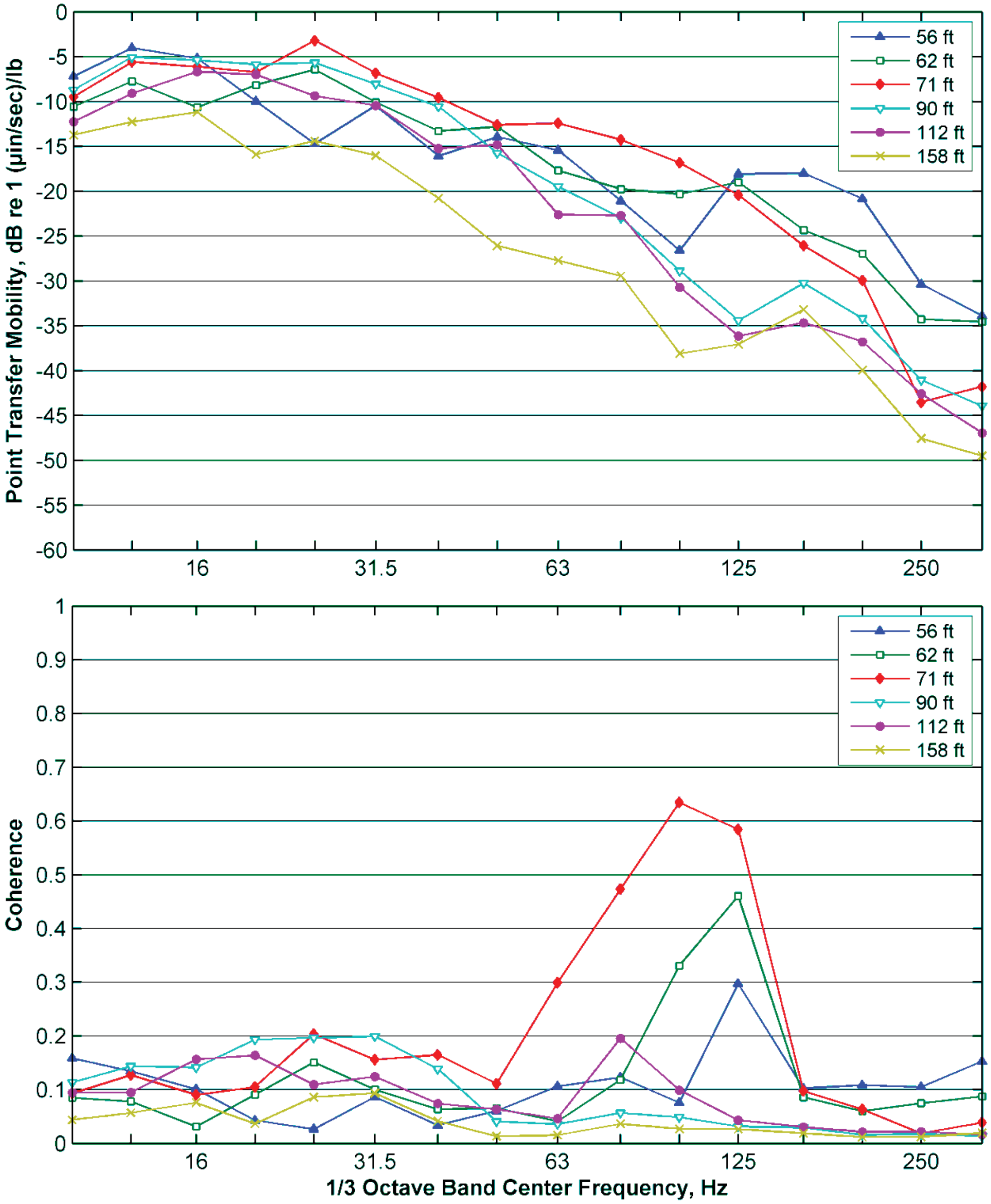

Figure 4: G-106. Measured PSTM at Depth of 50 ft

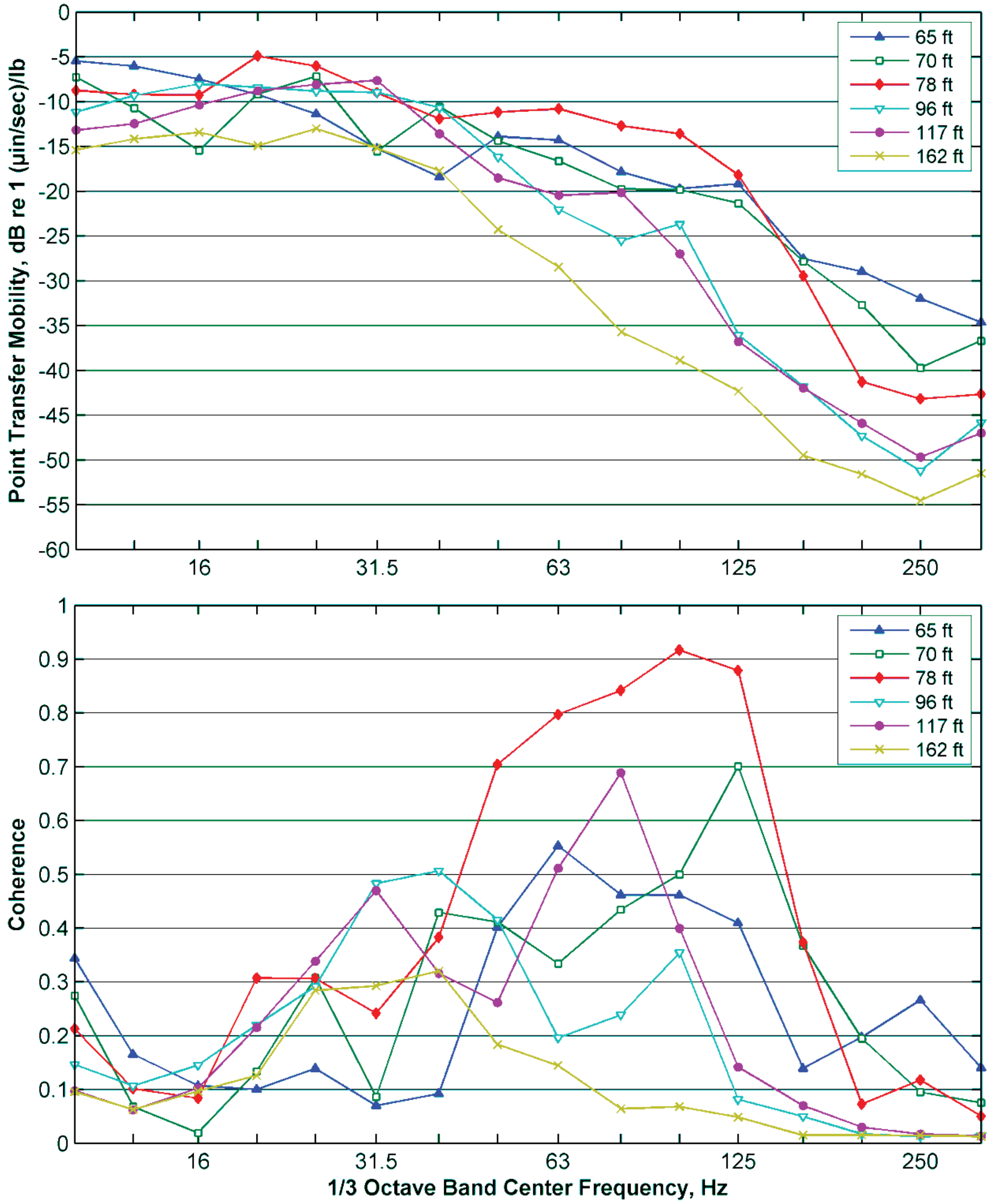

Figure 5: G-106. Measured PSTM at Depth of 60 ft

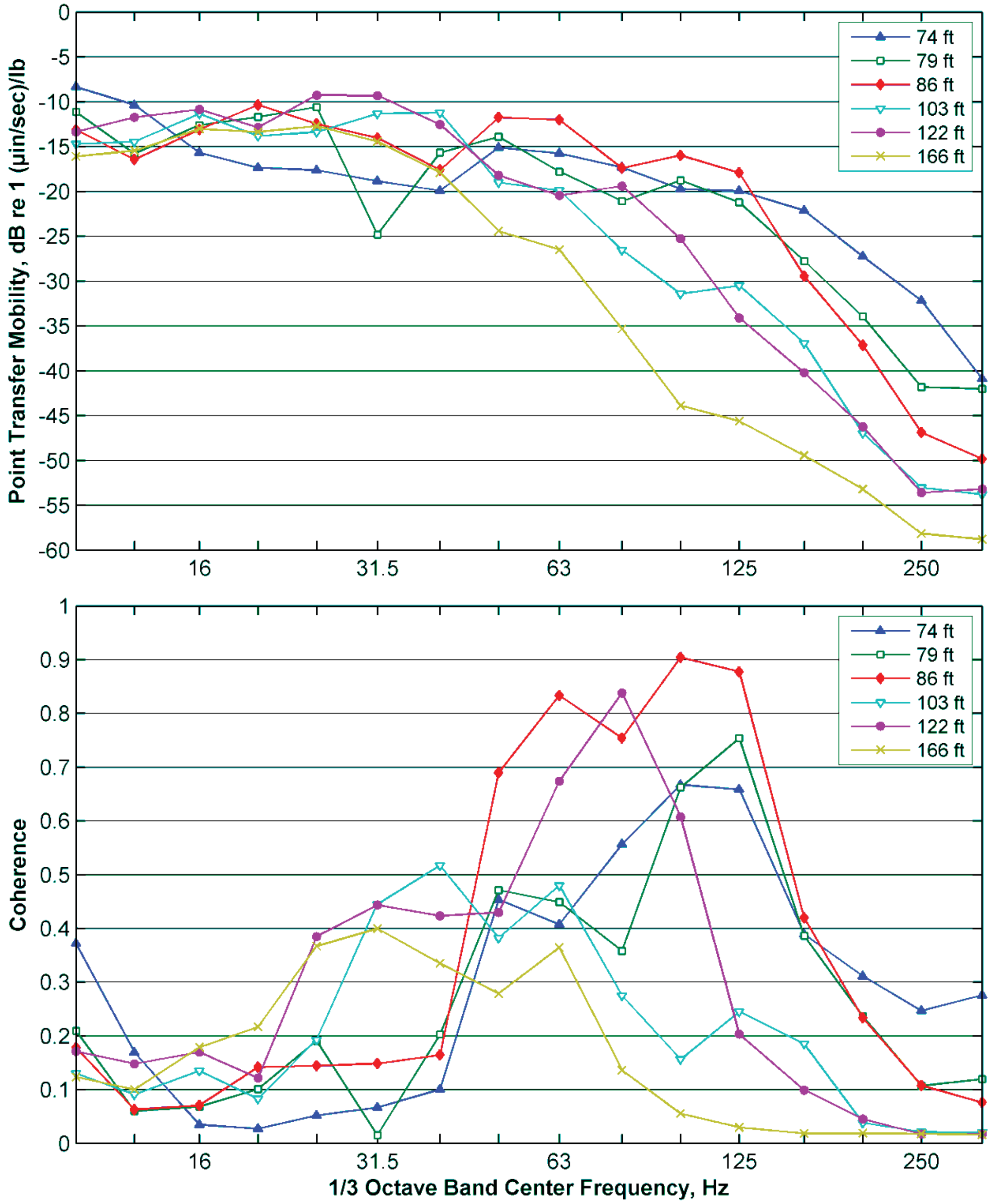

Figure 6: G-106. Measured PSTM at Depth of 70 ft

Table 3: G-106. Coefficients for Best Fit LSTM							
Freq. (Hz)	**A**	**B**	**C**	**Freq. (Hz)**	**A**	**B**	**C**
10	20.03	4.00	-3.97	**63**	30.49	-5.56	-4.16
12.5	18.25	4.92	-3.76	**80**	32.59	-8.61	-4.06
16	13.96	4.43	-1.96	**100**	57.10	-24.77	-3.30
20	15.04	5.66	-3.12	**125**	80.79	-39.98	-2.56
25	14.04	4.49	-2.00	**160**	63.11	-32.46	-2.91
31.5	13.29	0.99	-0.38	**200**	59.86	-33.49	-2.86
40	9.66	4.78	-2.18	**250**	41.10	-26.31	-3.22
50	26.96	-2.25	-4.23	**315**	30.31	-20.44	-3.52

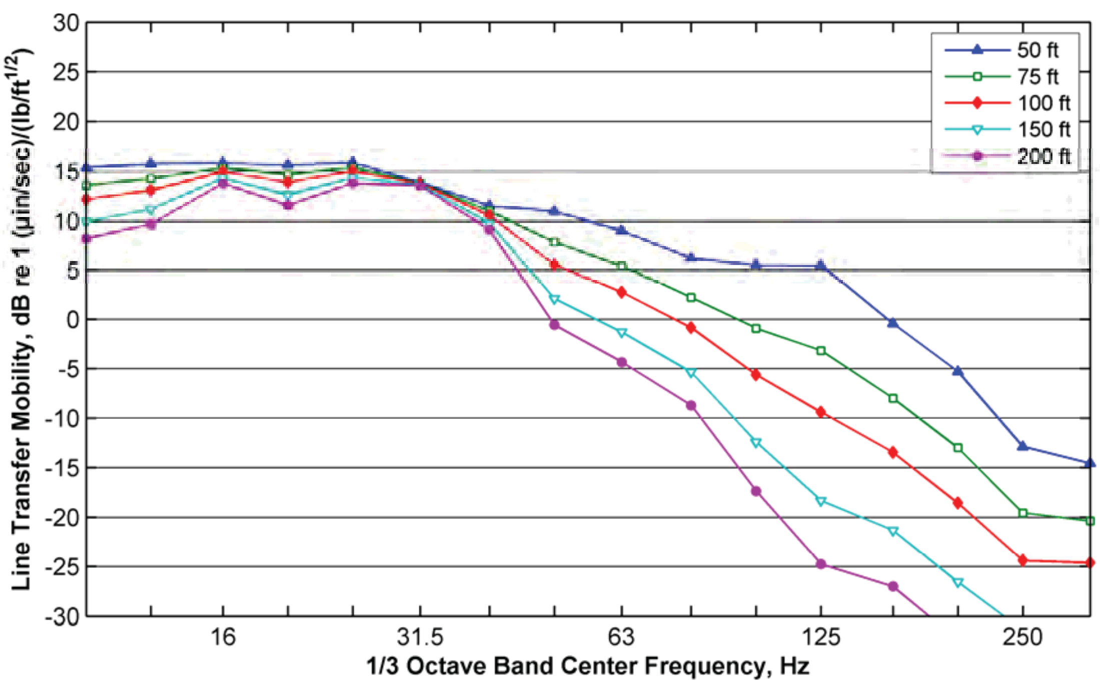

Figure 7: G-106. Best Fit LSTM

3.2 Site G-124

3.2.1 Site Description

Testing at this site was performed on 17 Mar 2011 at test depths of 40, 55, and 60 feet. The borehole was located in the median of Wilshire Boulevard, between Fairfax and McCarty Vista, in front of 6134 Wilshire Boulevard. The nearest vibration-sensitive receiver to this borehole is NV-24, identified as “Apartments”. The apartments at issue appear to be to the rear and above the businesses on the south side of Wilshire Boulevard, directly across from the borehole position. The accelerometers were located along Wilshire Boulevard at distances of 25, 37, 50, 75, 100, and 140 feet from the borehole location. The accelerometer line was offset from the borehole by 3 feet. The measurements were interfered by continuous vehicular traffic on Wilshire Boulevard. Additional observations from the measurements include:

- At 40 ft depth, the load cell advanced 6 inches due to the impact hits. Typical peak forces ranged from 8k to 12k lbs. 100 impacts recorded.
- At 55 ft, the drilling supervisor reported encountering tar. There was no perceptible drill string advancement during the test. Typical peak forces ranged from 17k to 20k lbs. 100 impacts recorded.
- At 60 ft, the drill string advanced only two inches from the impact hits. Typical force levels were 12k to 15k lbs. 100 impacts recorded

3.2.2 Results for G-124

- The center-depth measurement was taken at 55 feet. Not surprisingly the PSTM values for the 55 and 60 ft depths were comparable at all measurement distances.
- The coherences for the measurements at all but the farthest (150-foot) accelerometer were generally good between 20 and 80 Hz. This is attributed to relatively high force levels (and correspondingly improved signal-to-noise ratios) compared to other sites (e.g., site G-106).

3.2.3 Plots and Tables

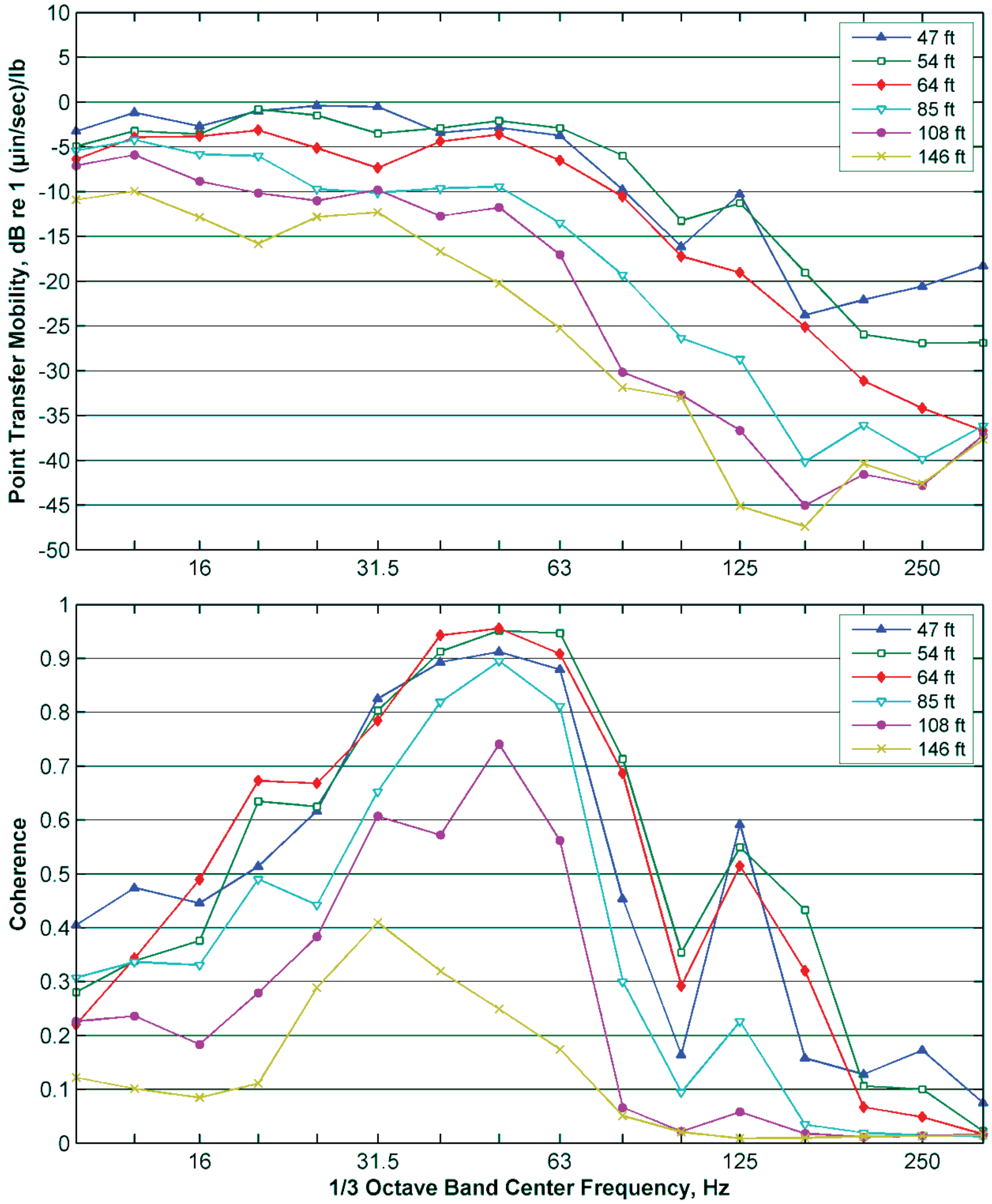

Figure 8: G-124. Measured PSTM at Depth of 40 ft

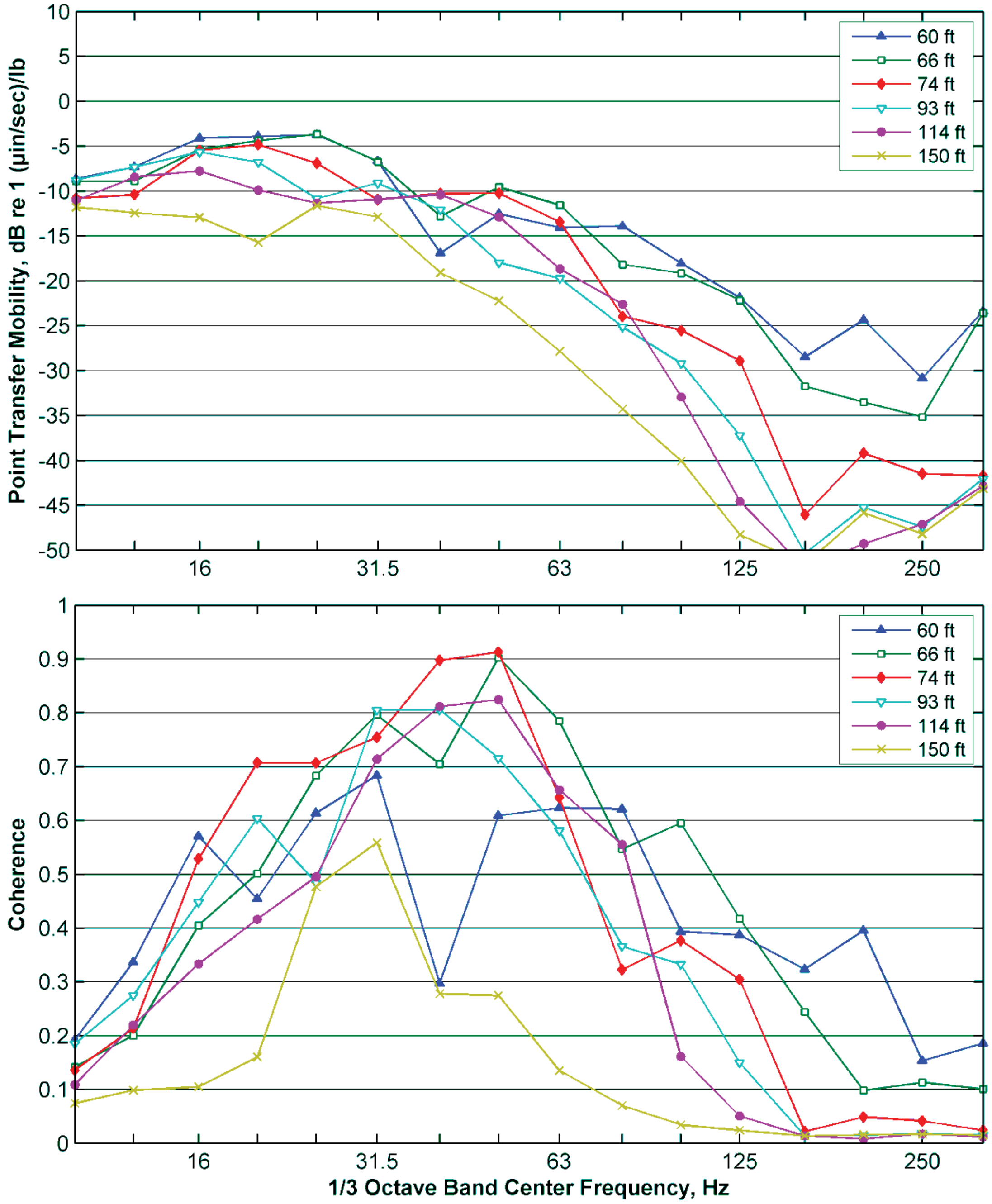

Figure 9: G-124. Measured PSTM at Depth of 55 ft

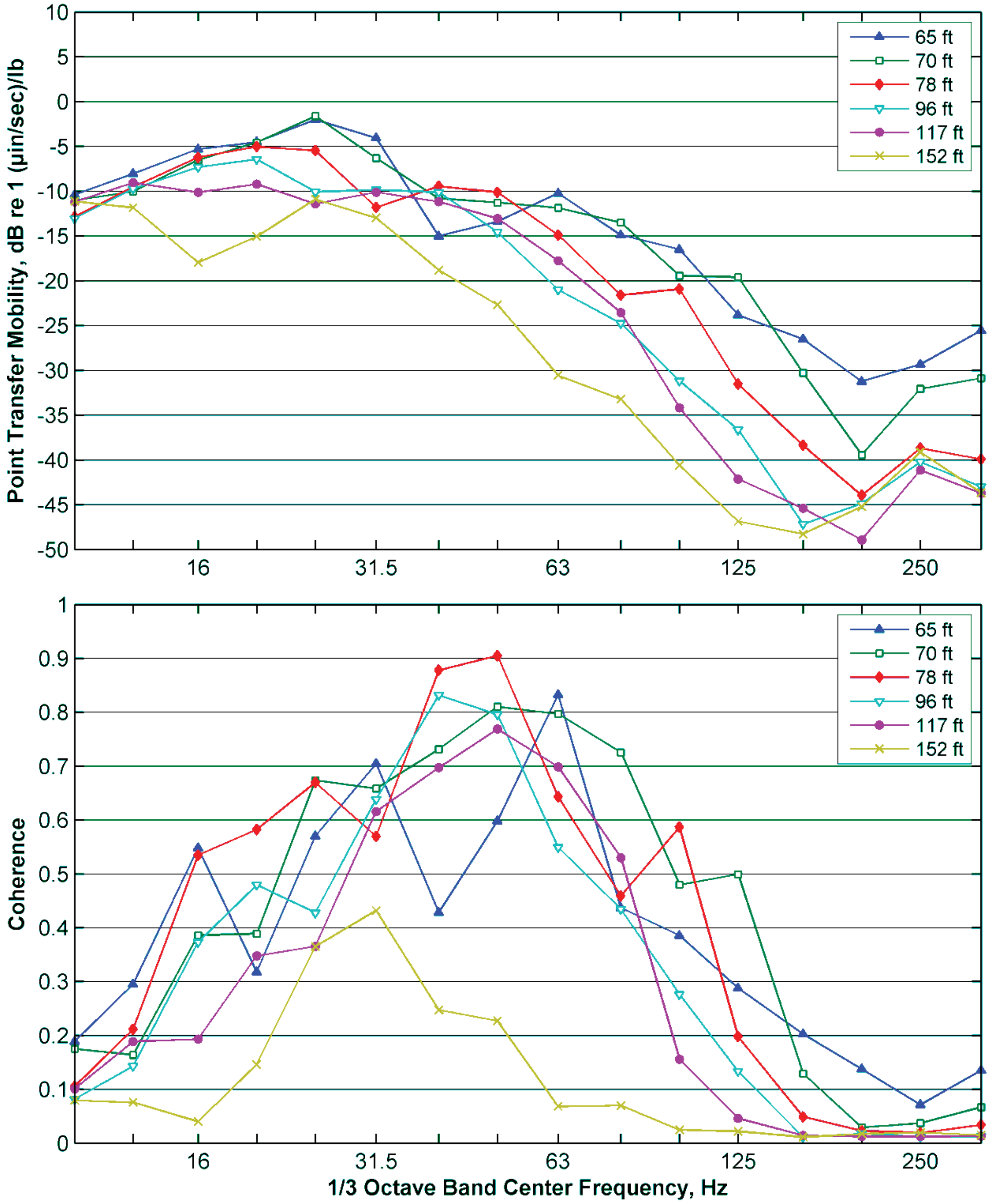

Figure 10: G-124. Measured PSTM at Depth of 60 ft

Table 4: G-124. Coefficients for Best Fit LSTM

Freq. (Hz)	A	B	C	Freq. (Hz)	A	B	C
10	15.50	5.63	-2.99	**63**	62.98	-23.34	-3.37
12.5	18.40	5.53	-3.44	**80**	65.62	-28.07	-3.13
16	29.36	0.93	-4.20	**100**	68.00	-32.38	-2.92
20	39.16	-4.35	-4.19	**125**	108.66	-58.59	-1.81
25	32.71	-0.81	-4.23	**160**	72.00	-42.15	-2.46
31.5	23.33	3.31	-4.06	**200**	38.69	-22.37	-3.42
40	21.69	2.74	-4.11	**250**	28.40	-15.94	-3.74
50	40.27	-7.98	-4.08	**315**	36.71	-19.49	-3.56

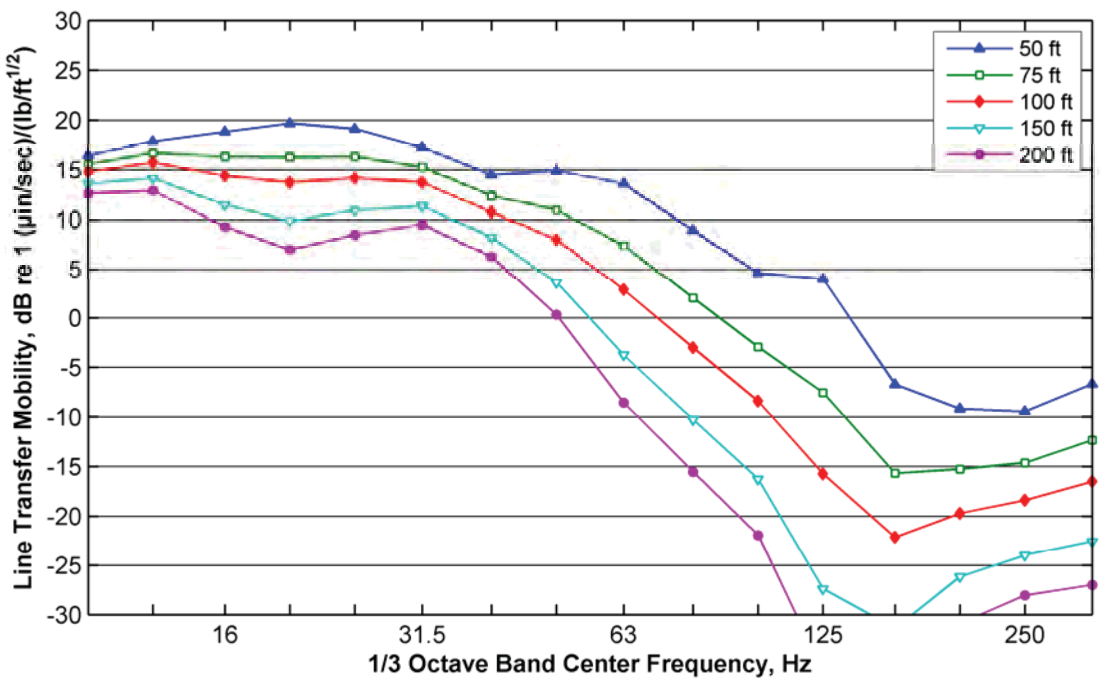

Figure 11: G-124. Best Fit LSTM

3.3 Site G-134

3.3.1 Site Description

Testing at this site was performed on 30 Mar 2011 at test depths of 50, 60, and 70 feet. The borehole was located in the median of Wilshire Boulevard between Arden and Willaman. The nearest vibration-sensitive receiver to this borehole is NV-132, a residence approximately ½ block north of Wilshire on N. Hamel Drive. The accelerometers were located at distances of 25, 37, 50, 75, 100, and 140 feet from the borehole, in a line extending eastward from the borehole with 4 feet of lateral offset. This was one of two test sites where triaxial recordings were made. Additional observations from the measurements include:

- At the 50 ft depth, the load cell advanced 18 inches due to the impact hits. Typical peak forces ranged from 7k to 9k lbs. 100 impacts recorded.
- At the 60 ft test depth there was 12 inches total advancement. Typical peak forces ranged from 8k to 9k lbs. 100 impacts recorded.
- At 70 ft, the drill string advanced by 2 feet, and was still moving at 100 hits. Typical force levels were from 7k to 11k lbs. 100 impacts recorded.

3.3.2 Results for G-134

- Coherences were relatively good for the 50 and 60 foot depth measurements, but poor at the final (70 foot) test depth. Again, the low coherence is believed to be the result of the low force levels and elevated background vibration levels along Wilshire Boulevard.
- At 50 and 60 feet the 25 to 50 Hz frequency bands showed the highest coherence, but interestingly the coherence did *not* diminish uniformly with increasing distance.

3.3.3 Plots and Tables

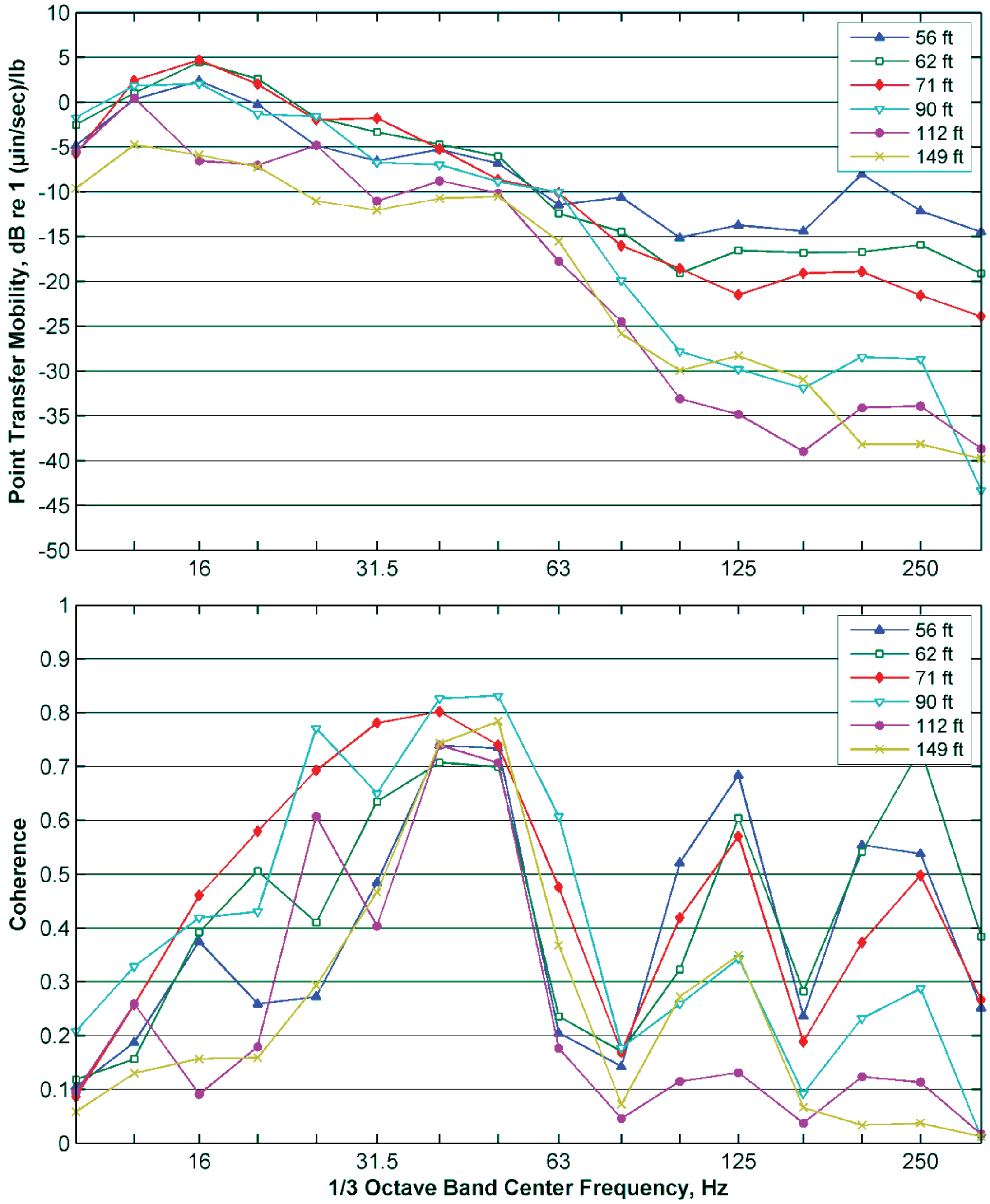

Figure 12: G-134. Measured PSTM at Depth of 50 ft

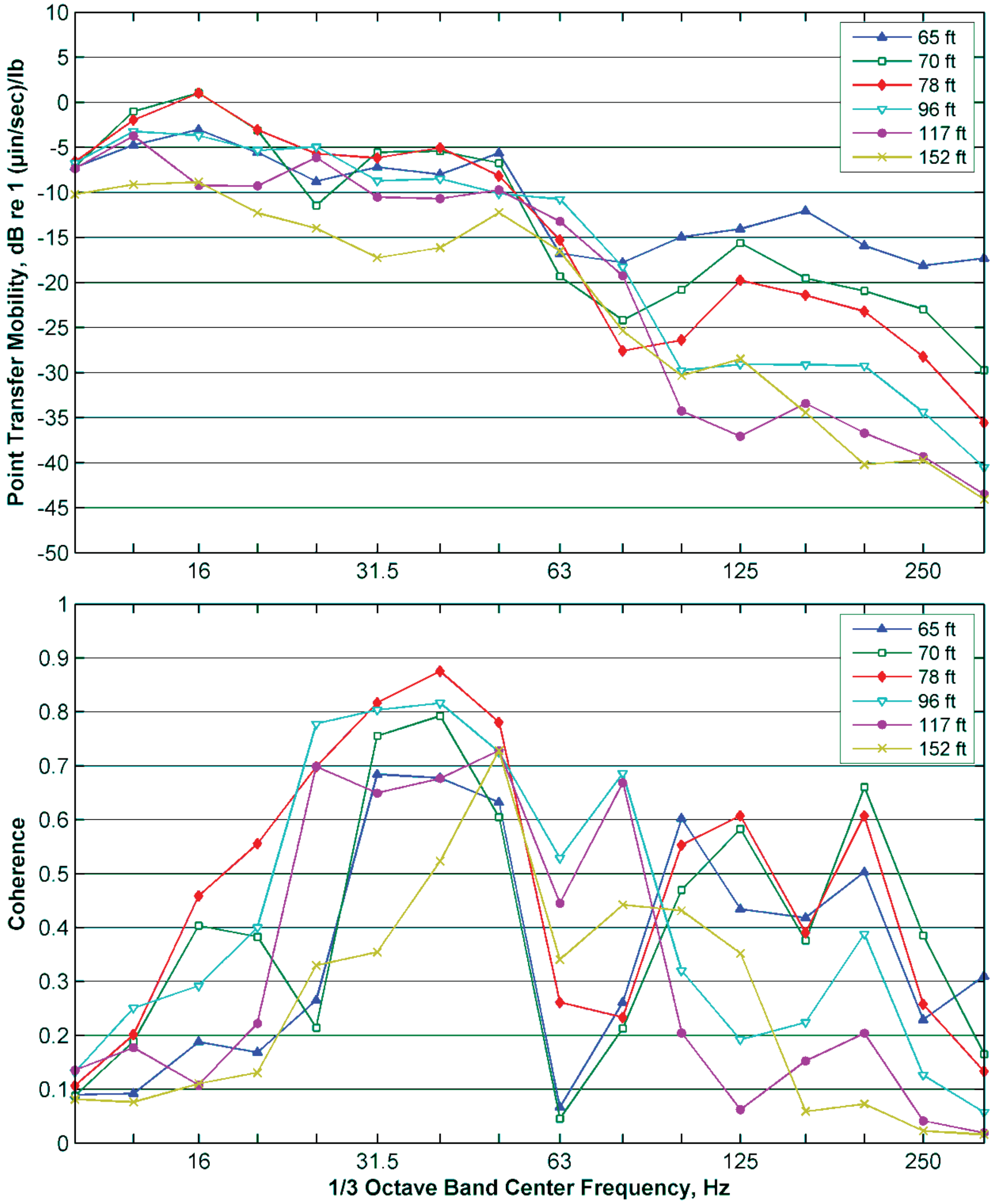

Figure 13: G-134. Measured PSTM at Depth of 60 ft

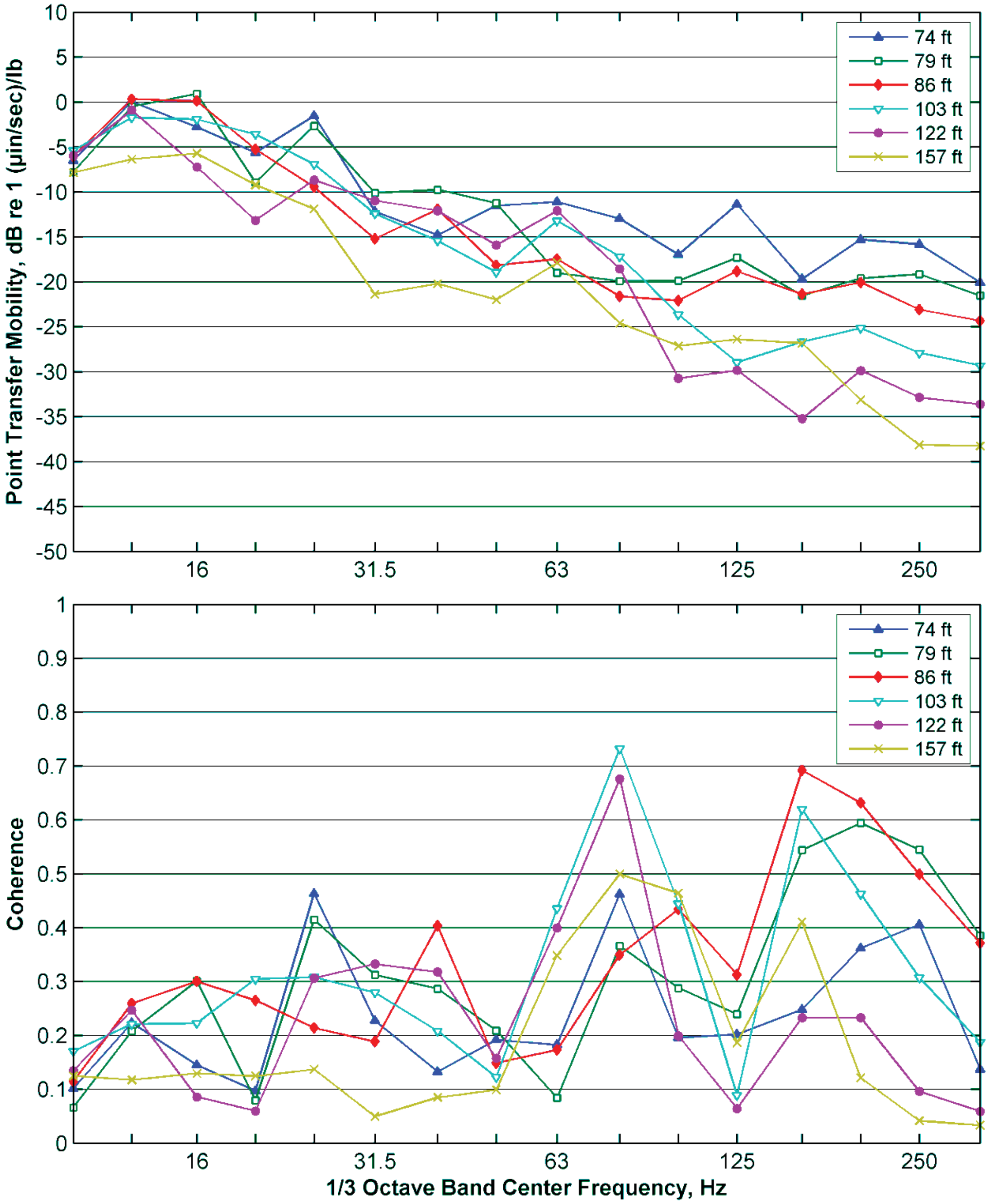

Figure 14: G-134. Measured PSTM at Depth of 70 ft

Table 5: G-134. Coefficients for Best Fit LSTM							
Freq. (Hz)	**A**	**B**	**C**	**Freq. (Hz)**	**A**	**B**	**C**
10	17.98	5.13	-2.42	**63**	9.89	4.00	-1.73
12.5	25.56	5.37	-3.56	**80**	14.49	2.44	-4.13
16	39.68	-1.41	-4.23	**100**	37.23	-12.71	-3.89
20	33.02	0.45	-4.21	**125**	50.67	-19.92	-3.54
25	22.93	4.64	-3.84	**160**	56.28	-24.22	-3.32
31.5	33.25	-2.17	-4.23	**200**	85.79	-41.25	-2.50
40	27.62	0.83	-4.21	**250**	82.46	-40.50	-2.54
50	23.06	2.52	-4.13	**315**	73.58	-37.55	-2.67

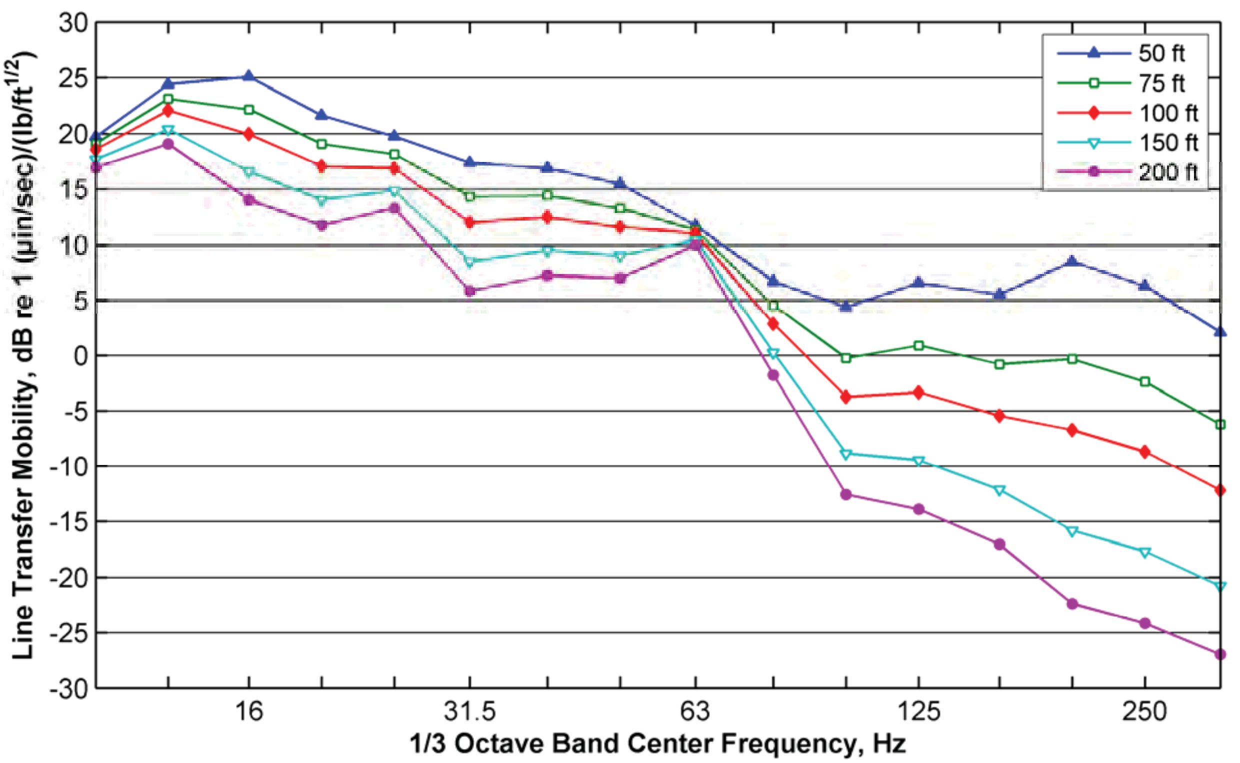

Figure 15: G-134. Best Fit LSTM

3.4 Site G-145

3.4.1 Site Description

Testing at this site was performed on 14 and 15 April 2011 at test depths of 50, 60, and 70 feet. The borehole was located in the median of Wilshire Boulevard between El Camino and Beverly. The nearest vibration-sensitive receiver to this site was the Beverly Wilshire Hotel (NV-38), approximately 175 feet southwest from the borehole position. Due to traffic control restrictions, the accelerometers were located at distances of 25, 32, 50, 62, 75, and 100 feet from the borehole, in a line extending eastward from the borehole with 5 feet of lateral offset. Vehicular traffic on Wilshire Boulevard was particularly heavy throughout the testing period, with a few breaks. This was one of two test sites where triaxial recordings were made. Additional observations from the measurements include:

- At the 50 ft depth, the load cell advanced nearly 3 feet and testing halted at approximately hit 80 to insert a drill rod extension. Typical peak forces ranged from 6k to 9k lbs. 120 impacts total were recorded.
- At the 60 ft test depth the drill string advancement was not noted. Typical peak forces ranged from 8k to 20k lbs. 100 impacts recorded.
- At 70 ft, the drill string advancement was not noted. Typical force levels were from 7k to 11k lbs. 100 impacts recorded.

3.4.2 Results for G-145

- This was a site where the coherence was poor for most of the measurements. Referring to the graphs of coherence in Figure 16, Figure 17, and Figure 18, it can be seen that the only time that coherence exceeded 0.5 was at 31.5 and 40 Hz for the 60 foot depth. At the 50 ft and 70 ft depths the coherences never exceeded 0.3.
- Force levels at 50 and 70 feet were low; levels at 60 feet were higher but unusually variable.
- In spite of the poor coherence, the PSTMs have similar shapes to those measured at the other boreholes and the fall off with distance is similar to the fall off at the other sites.

3.4.3 Plots and Tables

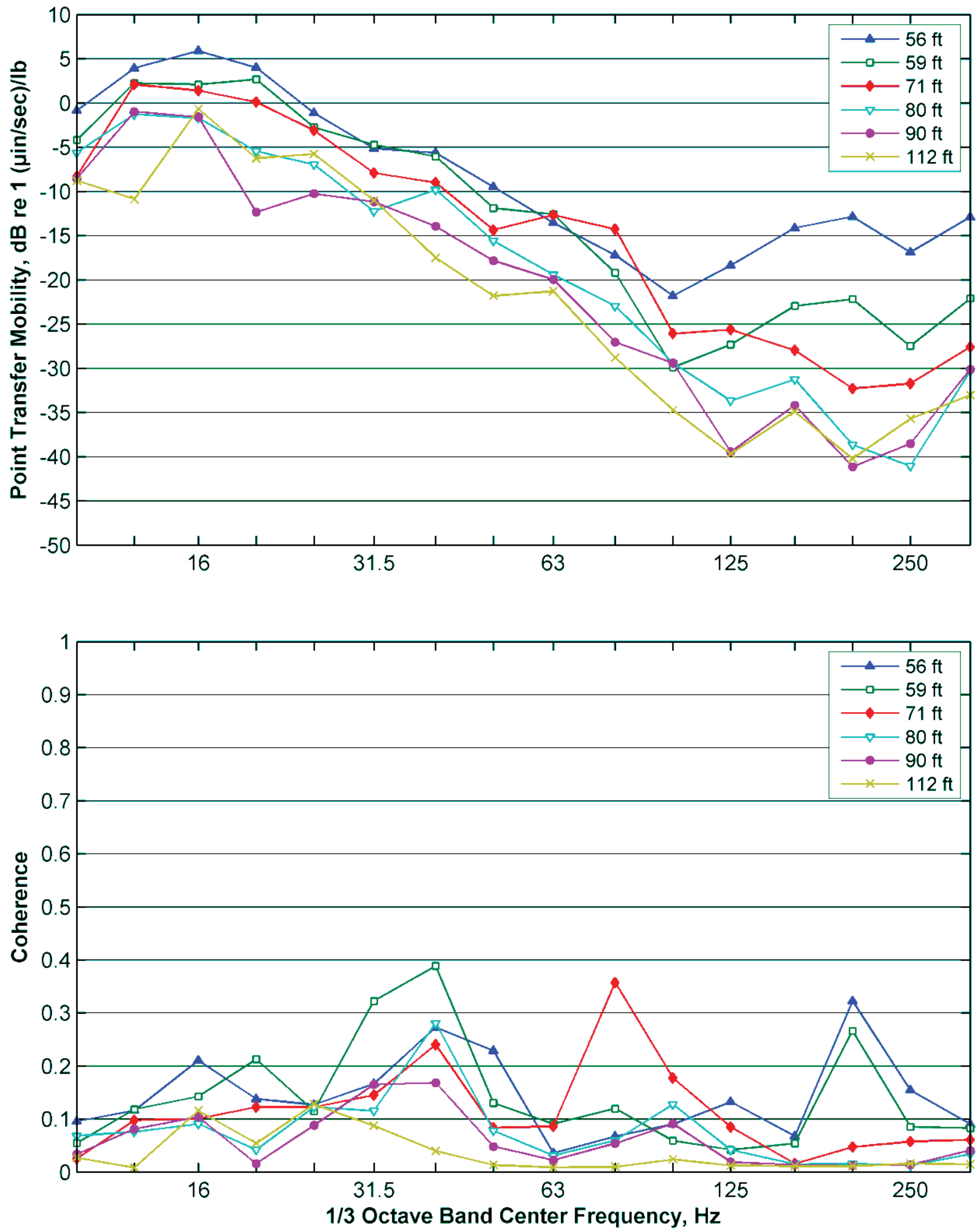

Figure 16: G-145. Measured PSTM at Depth of 50 ft

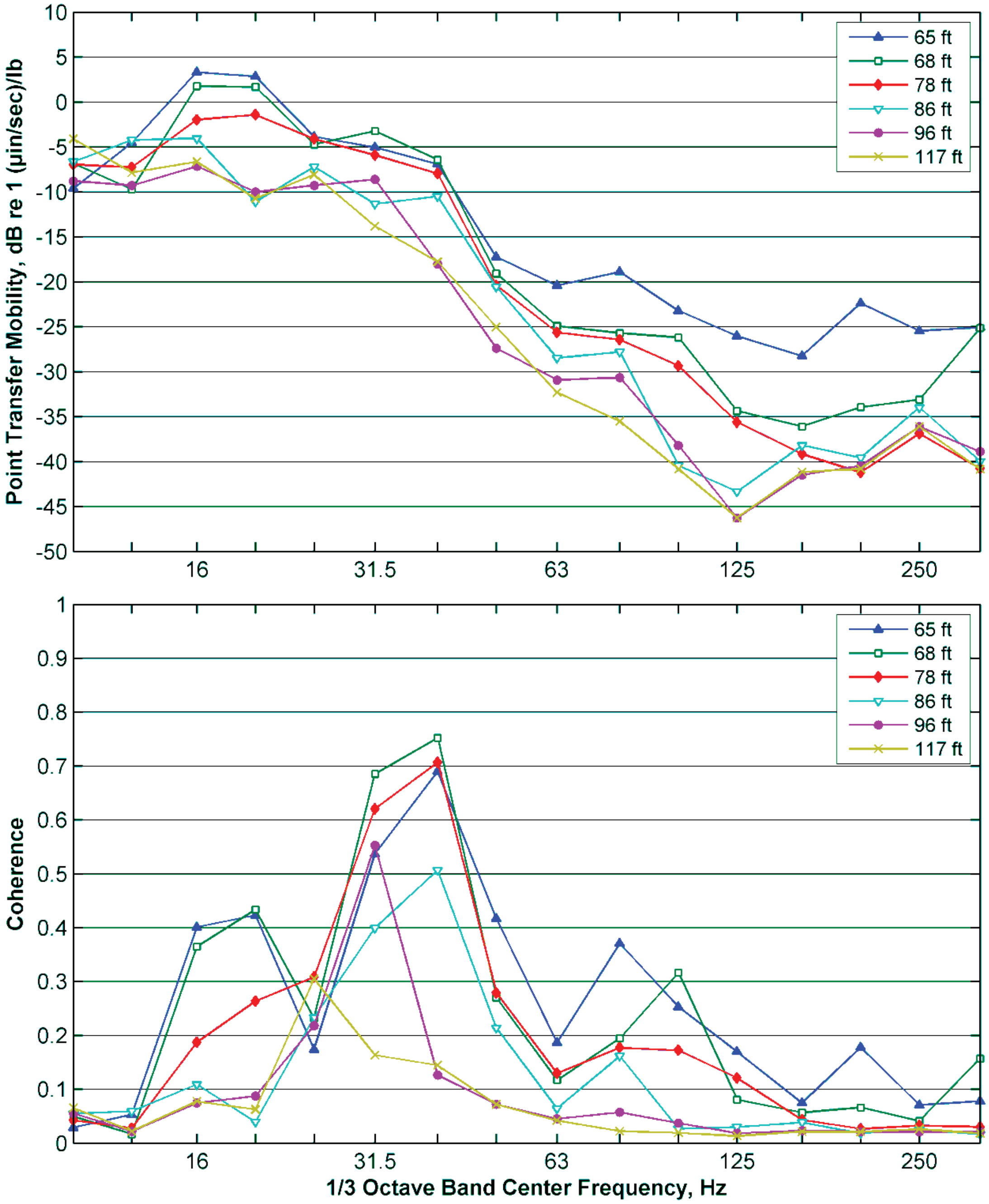

Figure 17: G-145. Measured PSTM at Depth of 60 ft

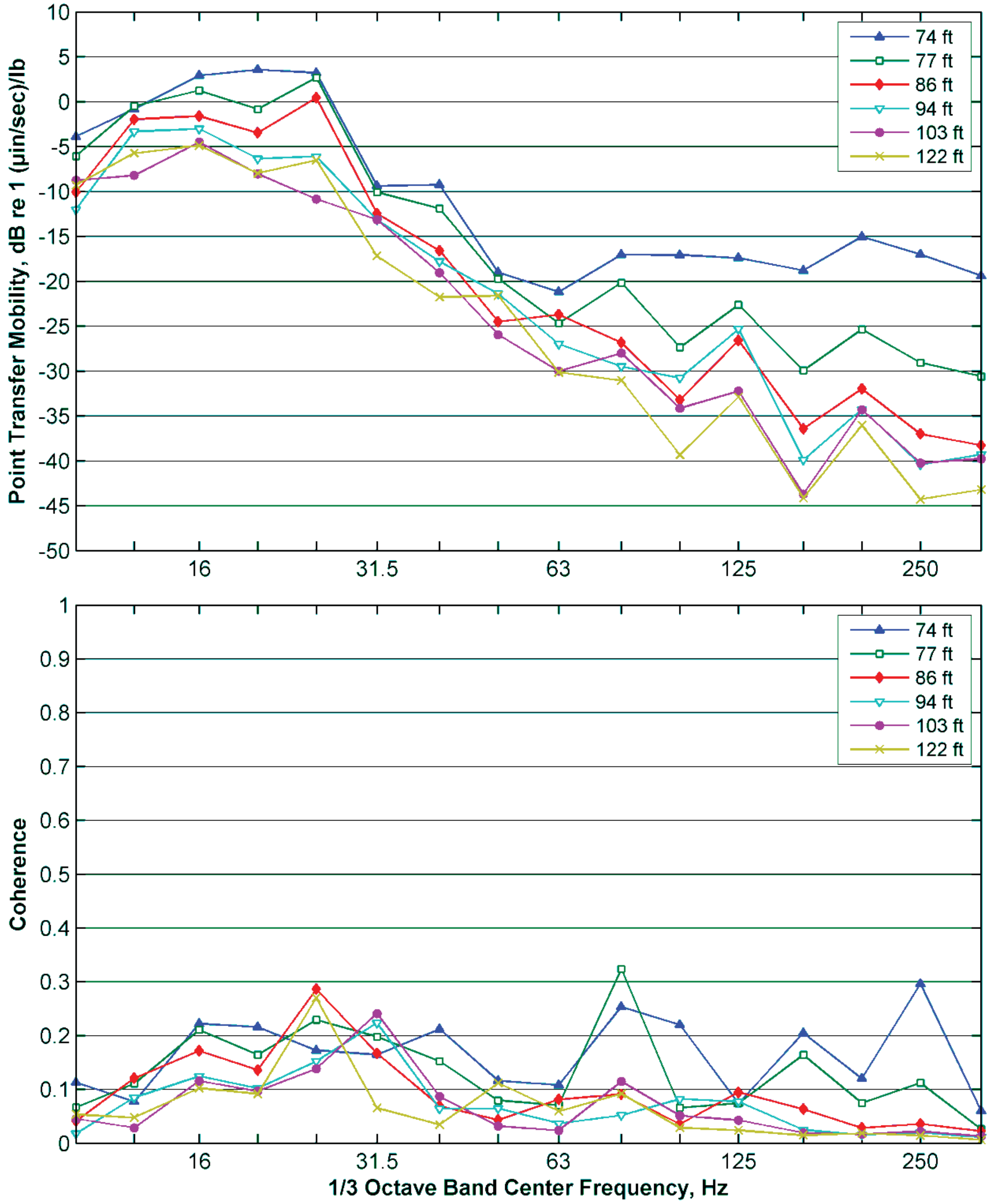

Figure 18: G-145. Measured PSTM at Depth of 70 ft

Table 6: G-145. Coefficients for Best Fit LSTM

Freq. (Hz)	A	B	C	Freq. (Hz)	A	B	C
10	18.77	5.56	-3.41	**63**	57.32	-24.92	-3.29
12.5	41.57	-4.07	-4.20	**80**	61.33	-28.23	-3.12
16	48.33	-6.41	-4.14	**100**	58.75	-30.13	-3.03
20	75.65	-24.26	-3.32	**125**	65.01	-34.53	-2.81
25	31.54	1.02	-4.20	**160**	92.89	-51.68	-2.06
31.5	42.60	-8.14	-4.08	**200**	84.69	-46.32	-2.28
40	73.31	-28.04	-3.13	**250**	67.72	-37.03	-2.70
50	42.97	-14.19	-3.82	**315**	100.61	-55.30	-1.93

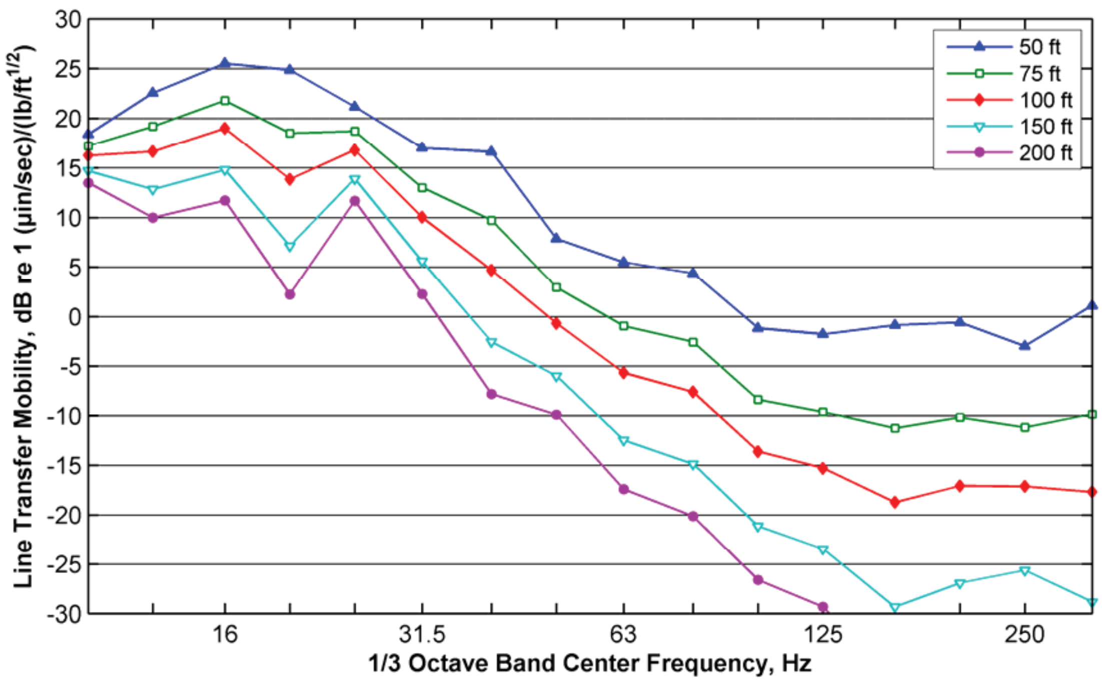

Figure 19: G-145. Best Fit LSTM

3.5 Site G-152

3.5.1 Site Description

This site was located adjacent to the Beverly Hilton Hotel, identified as site NV-41. Testing was performed on 31 Jan and 1 Feb 2011, at test depths of 55, 65, and 75 feet. The test consisted of 100 hits at each test depth. The measurements were performed on the south side of Santa Monica Boulevard, approximately 350 feet from the intersection of Santa Monica and Wilshire, and opposite to the hotel. The accelerometers were located westward along Santa Monica Boulevard at distances of 25, 37, 50, 75, 100, and 150 feet from the borehole location. The accelerometer line was offset from the borehole by 4 feet. The measurements were interfered with by continuous vehicular traffic on Santa Monica Boulevard. Additional observations from the measurements include:

- At 55 ft depth, the drill string advanced 2 feet during 15 test hits. Additional drill rod was inserted and 100 impacts recorded with an additional 3 feet of advancement. Force levels ranged from 3k to 9k lbs. 100 hits recorded.
- At 65 ft depth, the drill string advancement was simply noted as being "much less". Force levels were in the 8k to 12k lb range. 100 hits recorded.
- At 75 ft depth, the drill string advancement was not noted. Force levels were again very low (6k to 7k lbs) and 130 impact hits were recorded. The drill crew supervisor reported "stiff clay" at this depth.

3.5.2 Results for G-152

- The low coherence below 20 Hz at all test depths indicates potential low-frequency background noise problems.
- The PSTM showed peaks between 80 and 125 Hz for the three closest accelerometer positions suggesting efficient transmission at shorter distances.
- The measured coherence at the 75-foot test depth was close to zero at all measurement positions at 63 Hz and below, indicating that almost no signal made it through to the measurement positions in the 10 to 63 Hz range. At higher frequencies, only the three closest accelerometers had coherence that was clearly non-zero.

3.5.3 Plots and Tables

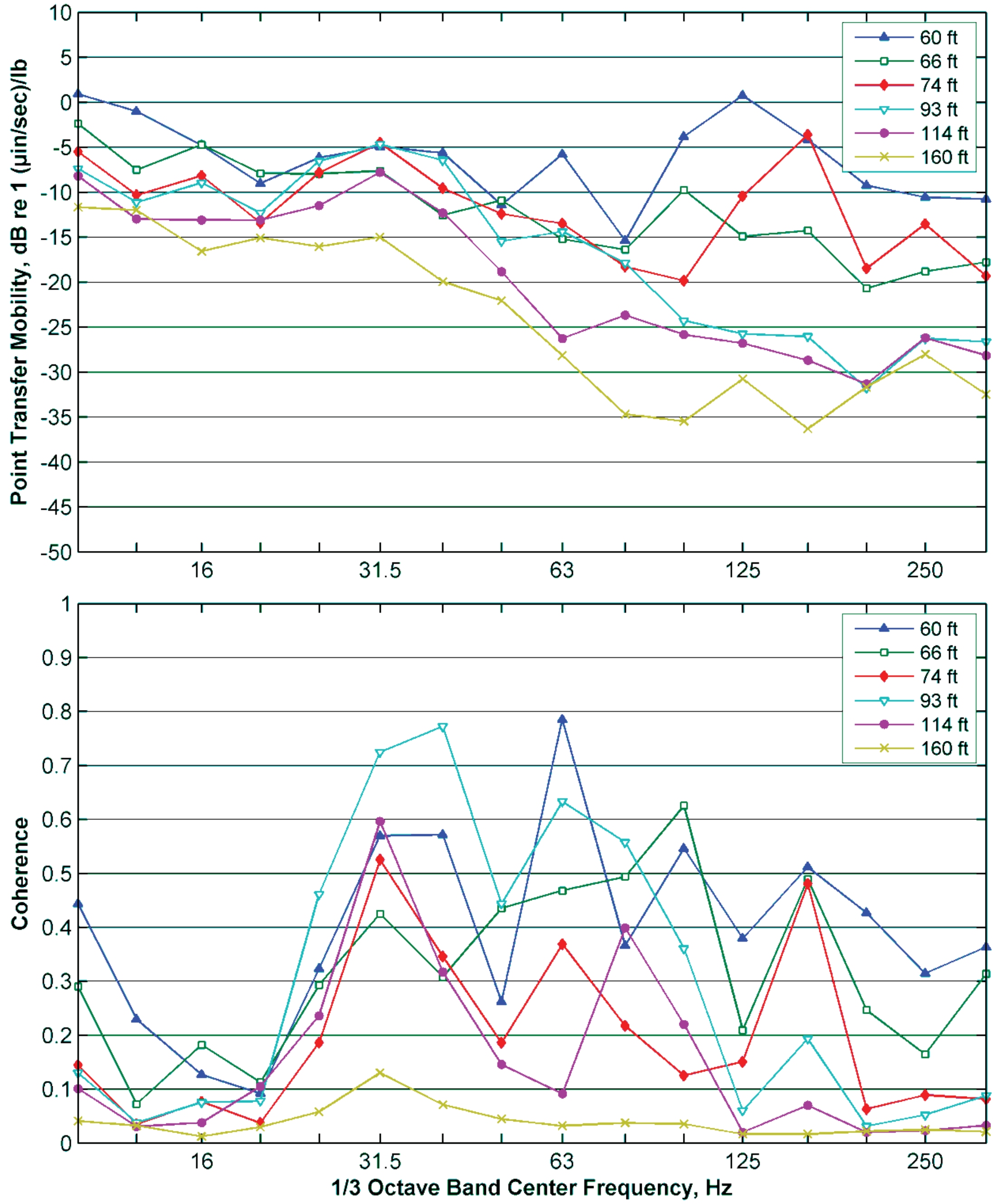

Figure 20: G-152. Measured PSTM at Depth of 55 ft

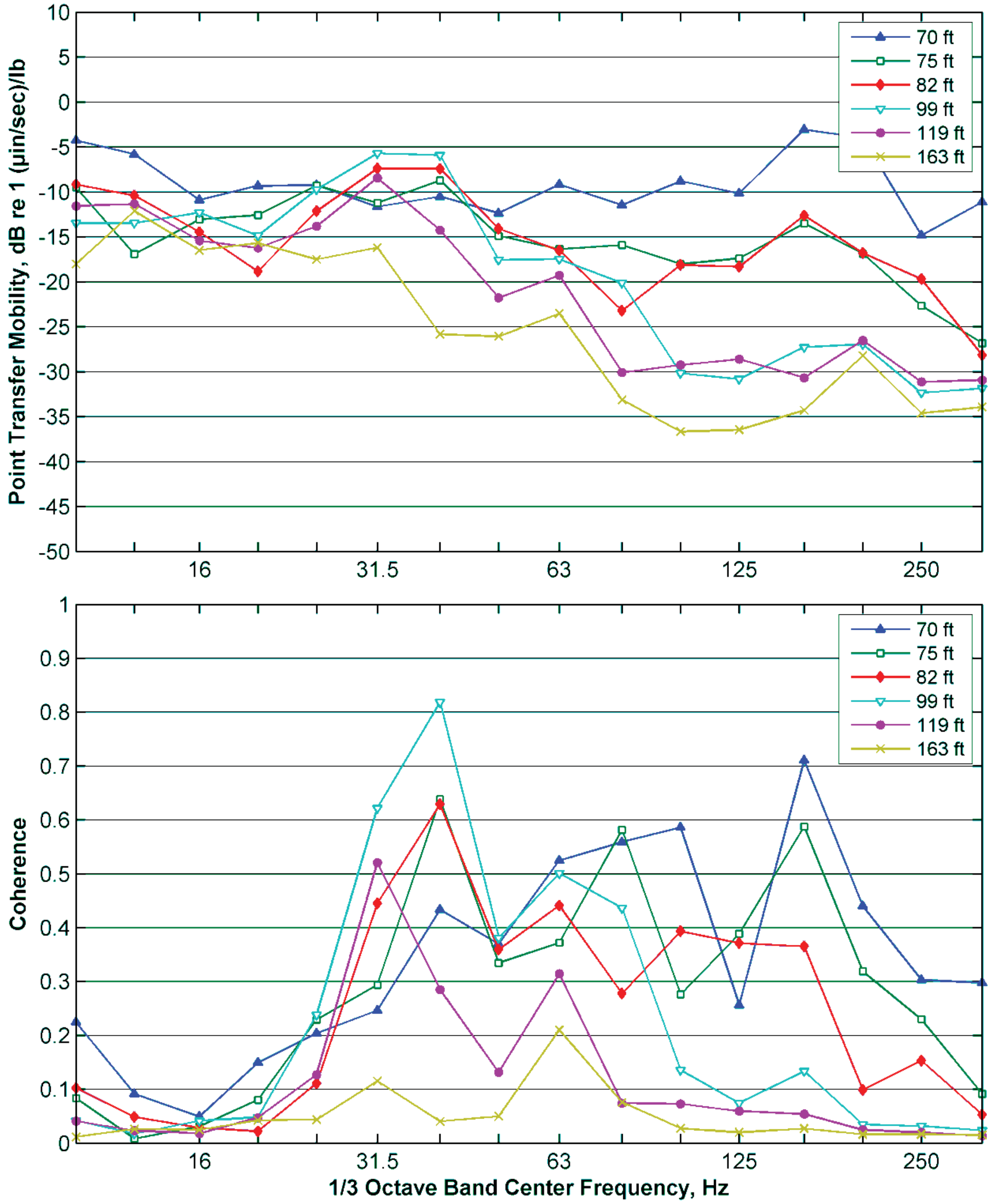

Figure 21: G-152. Measured PSTM at Depth of 65 ft

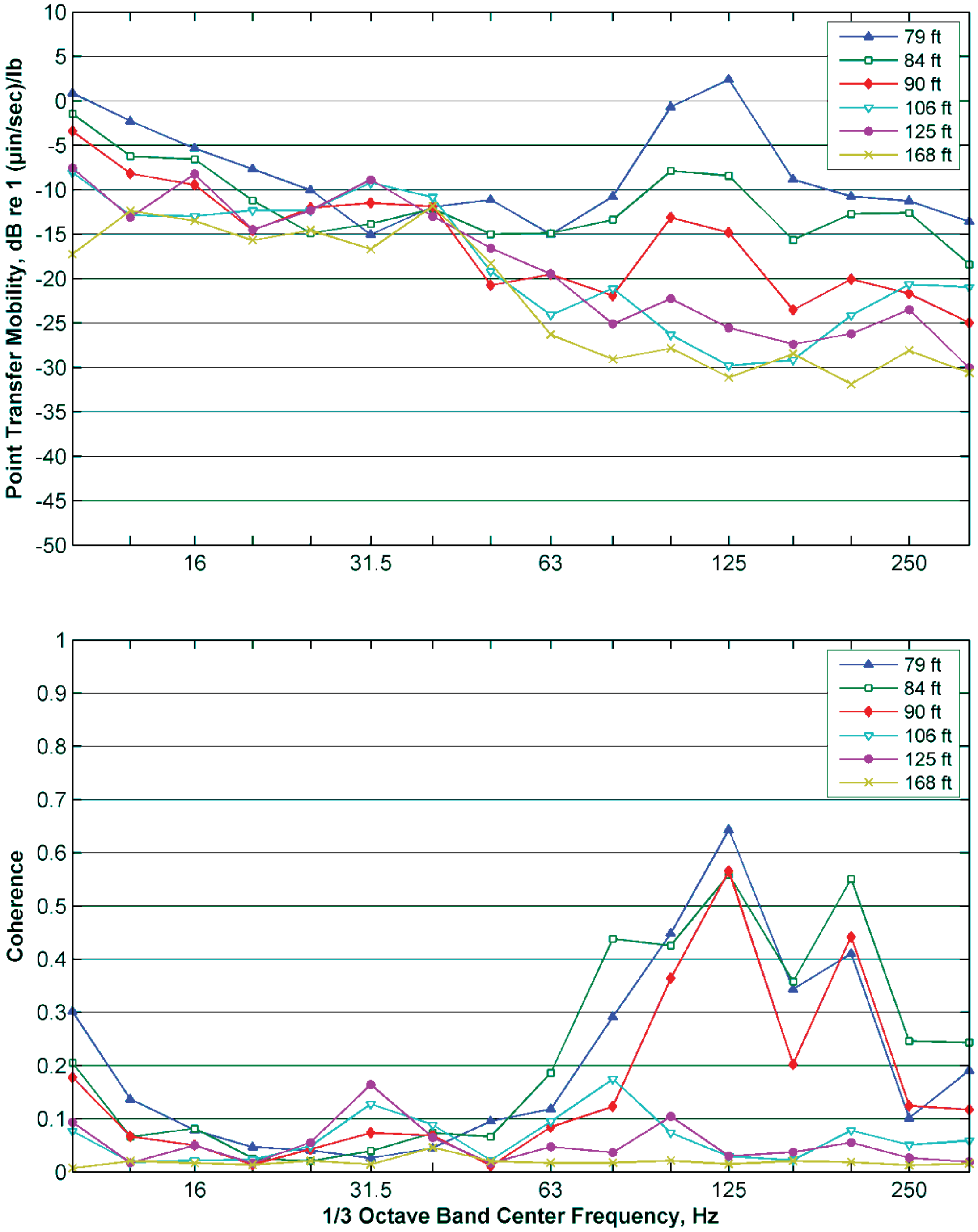

Figure 22: G-152. Measured PSTM at Depth of 75 ft

Table 7: G-152. Coefficients for Best Fit LSTM							
Freq. (Hz)	**A**	**B**	**C**	**Freq. (Hz)**	**A**	**B**	**C**
10	46.25	-7.77	-4.09	**63**	46.62	-13.95	-3.83
12.5	19.87	4.64	-3.84	**80**	59.36	-23.10	-3.38
16	23.21	2.83	-4.10	**100**	100.41	-45.74	-2.31
20	14.57	5.38	-3.56	**125**	109.84	-50.98	-2.09
25	21.12	3.57	-4.03	**160**	113.11	-53.12	-2.01
31.5	18.50	5.11	-3.69	**200**	67.28	-27.88	-3.14
40	27.41	0.31	-4.22	**250**	51.31	-18.94	-3.59
50	26.80	-1.96	-4.23	**315**	52.41	-20.86	-3.49

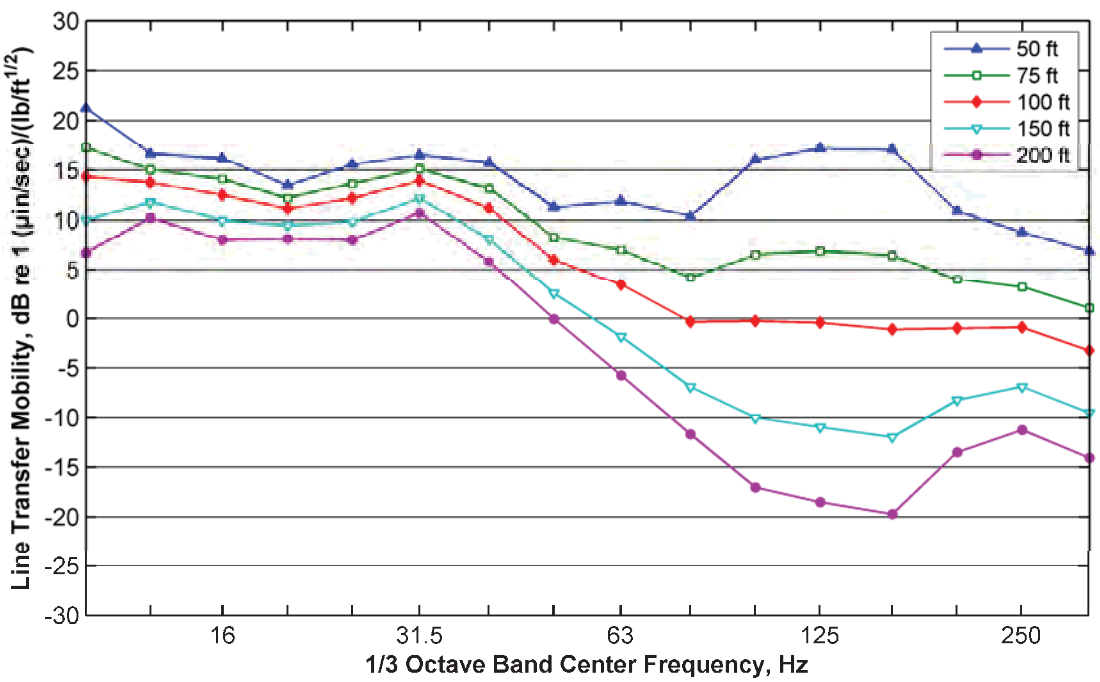

Figure 23: G-152. Best Fit LSTM

3.6 Site G-164

3.6.1 Site Description

This site was located on Moreno Avenue between Young and Lasky directly in front of the Beverly Hills Unified Instructional Center. Testing was performed on 26 and 27 Jan 2011, at test depths of 45, 55, and 65 feet. The accelerometers were located along South Moreno Drive at distances of 25, 37, 50, 75, 100, and 150 feet from the borehole location. The line of accelerometers extended southward from the borehole with an offset of 3 feet. Additional observations from the measurements were:

- At the 45 ft depth, only 70 impact hits could be recorded due to excessive (> 3 feet) load cell advancement. Test forces ranged from 4k to 8k lbs.
- At 55 ft depth, drill string advancement was 2 feet. Typical force levels were 3k to 7k lbs. 100 hits recorded.
- Testing at the 65 ft depth was conducted with two series of 100 impacts each, to accommodate instrumentation restrictions. Typical force levels were from 7k to 20k lbs for the first series of impacts and from 22k to 26k lbs for the second series of impacts.

3.6.2 Results for G-164

- Traffic vibration was less of an issue at this site than at many of the other test locations.
- The measured peak force levels were between 3k and 8k lbs at the 45 and 55 foot depths.
- The coherence was variable for all measurements. However, coherence was generally good (higher than 0.3) for most frequencies except at the farthest accelerometer position.
- The LSTM at higher frequencies have a faster drop-off with distance than lower frequencies. This is consistent with LSTM behavior at other sites.
- The LSTM at 20 Hz has a very small drop-off with distance, only 5 dB from 50 to 200 ft.

3.6.3 Plots and Tables

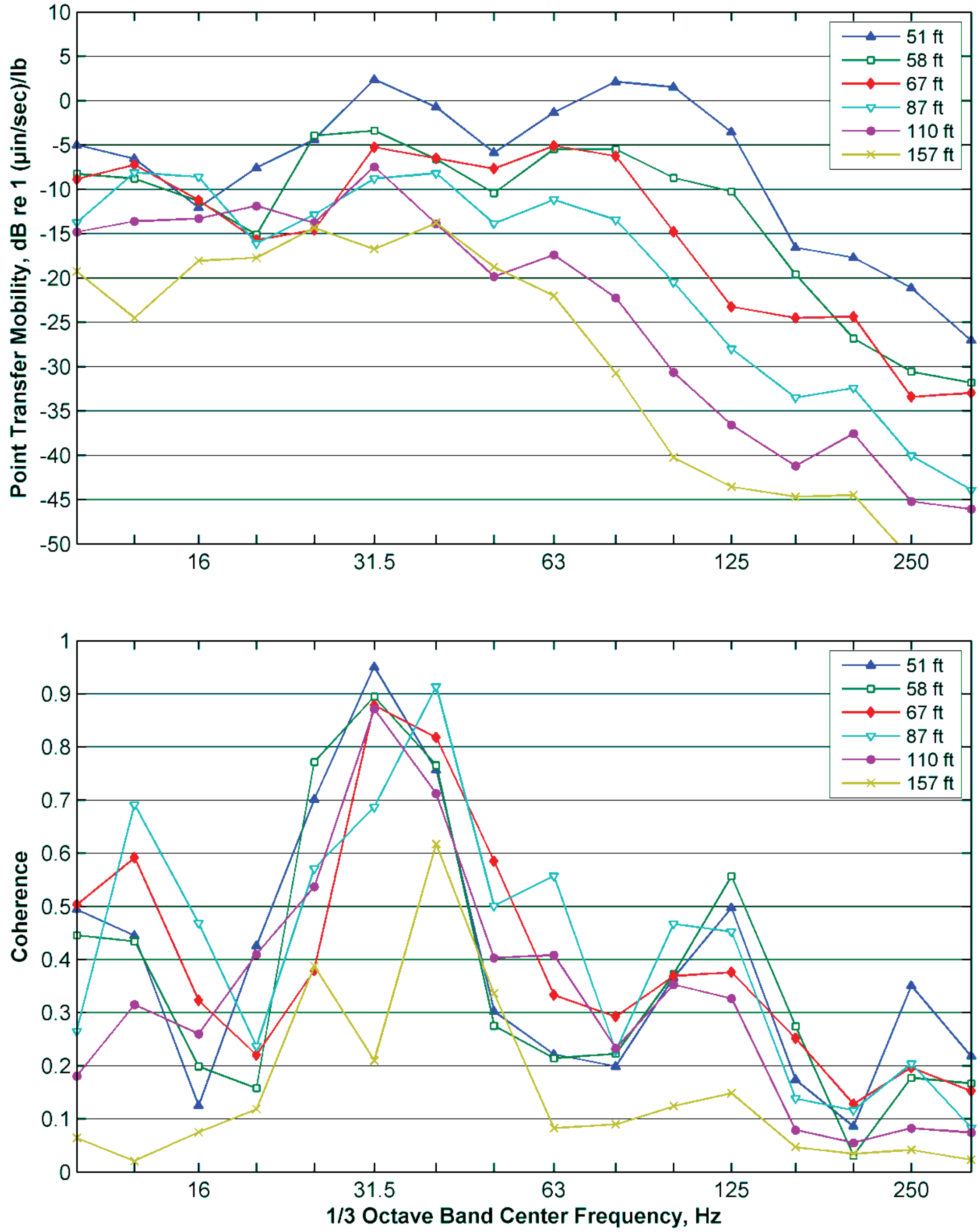

Figure 24: G-164. Measured PSTM at Depth of 45 ft

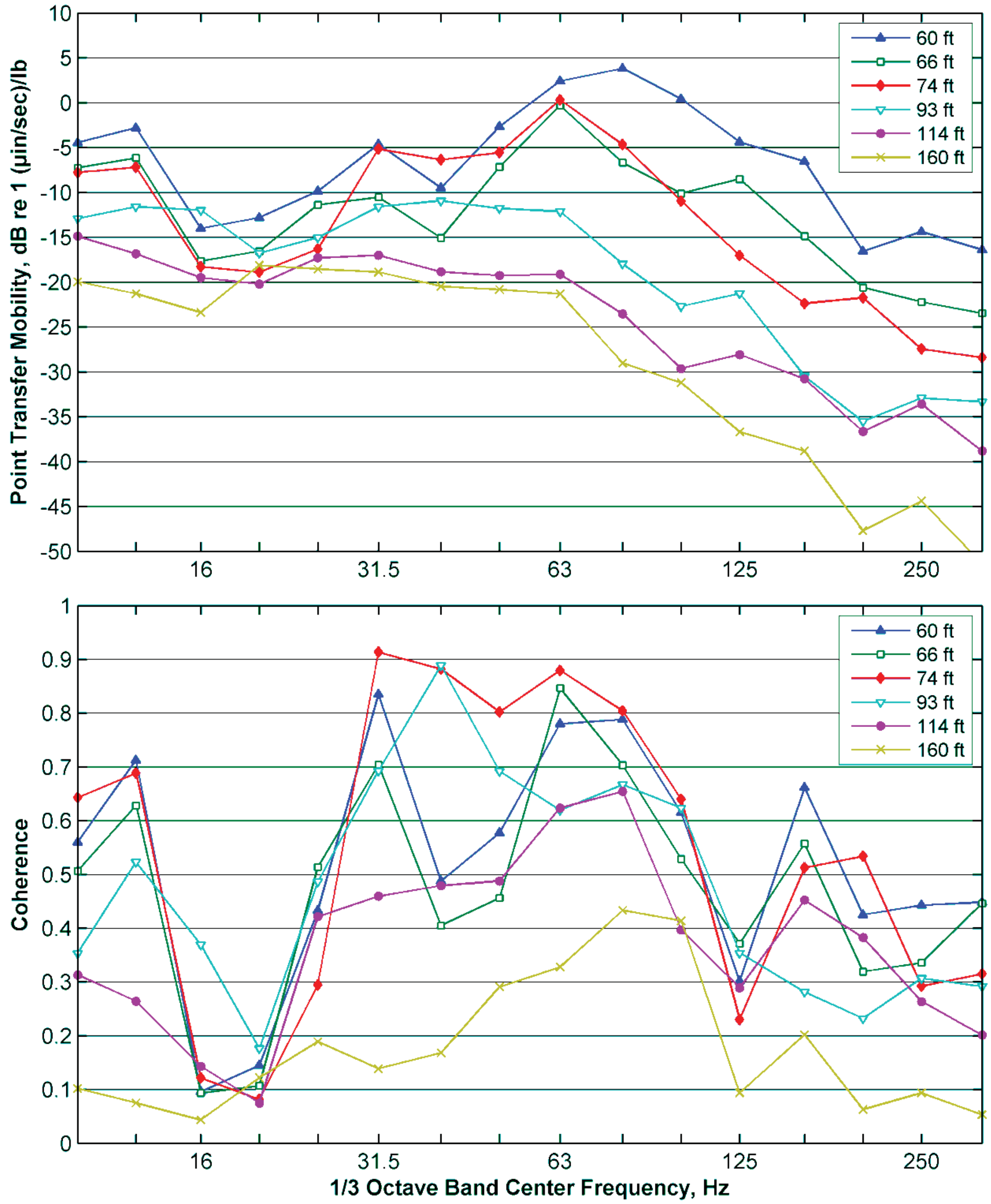

Figure 25: G-164. Measured PSTM at Depth of 55 ft

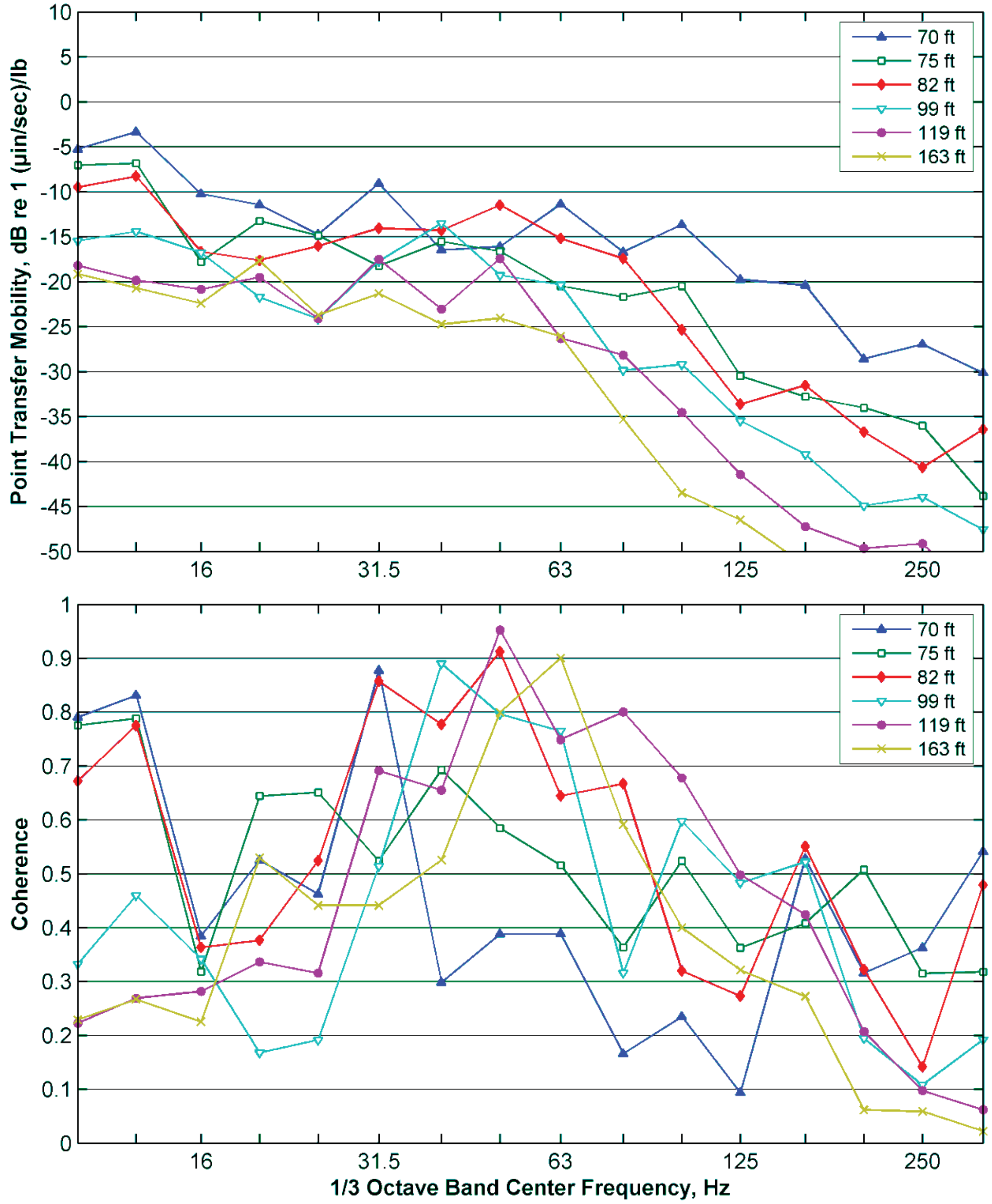

Figure 26: G-164. Measured PSTM at Depth of 65 ft

Table 8: G-164. Coefficients for Best Fit LSTM

Freq. (Hz)	A	B	C	Freq. (Hz)	A	B	C
10	41.36	-8.02	-4.08	**63**	76.63	-29.31	-3.07
12.5	54.60	-15.61	-3.75	**80**	109.21	-50.32	-2.12
16	15.65	3.72	-4.01	**100**	125.39	-61.94	-1.69
20	10.27	5.57	-3.40	**125**	116.22	-59.43	-1.78
25	26.61	-1.49	-4.23	**160**	97.22	-51.18	-2.08
31.5	45.01	-9.91	-4.01	**200**	92.29	-50.51	-2.11
40	35.39	-5.44	-4.16	**250**	74.95	-41.69	-2.48
50	41.27	-9.15	-4.04	**315**	87.68	-50.71	-2.10

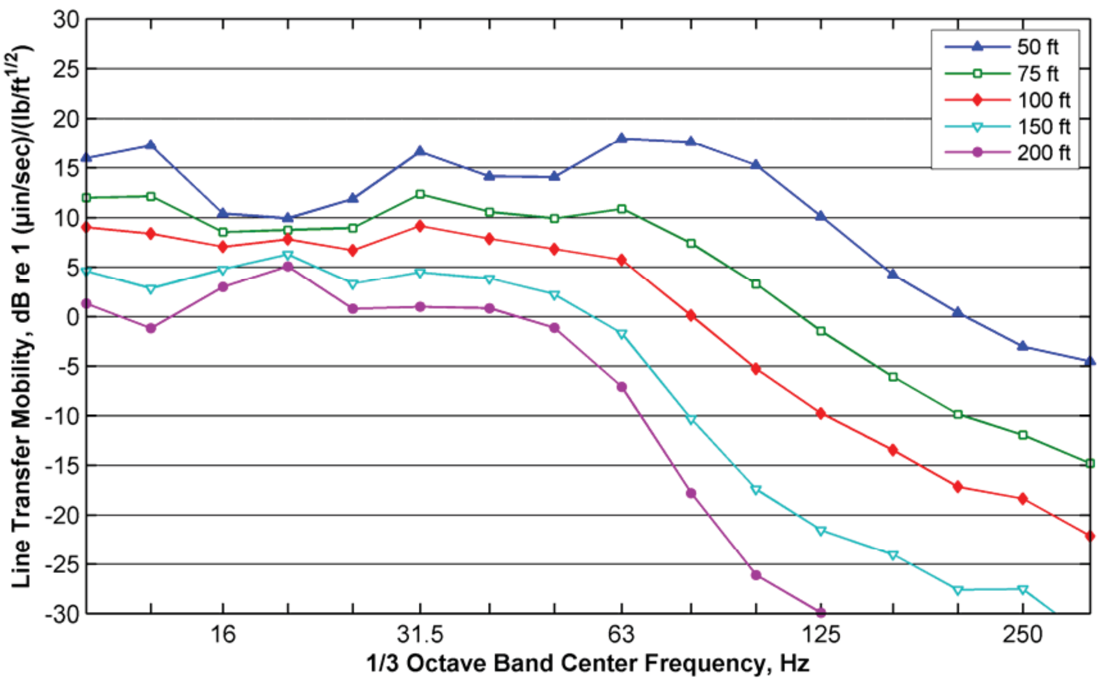

Figure 27: G-164. Best Fit LSTM