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BART – Hayward Maintenance Complex

Noise and Vibration Technical Report

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Executive Summary

This report by Wilson, Ihrig and Associates, Inc. (WIA) presents results of the noise and vibration environmental impact assessment for the Bay Area Rapid Transit (BART) Hayward Maintenance Complex (HMC Project). The assessment of noise and vibration impacts from operations and construction has been performed following the procedure described in the Federal Transit Administration (FTA) guidance manual "Transit Noise and Vibration Impact Assessment"[1].

The proposed Project would include adding up to six crossovers or turnouts in the area south of Whipple Road (on the mainline tracks, test track and yard lead), adding storage tracks to the northeast of the existing Hayward Yard to accommodate up to a maximum of 250 BART cars, implementing a new traction power station for new tracks on the east side of the Hayward Yard, and erecting a new Overhaul Shop (replacing an existing building). The Project includes upgrades to the three remaining buildings (component repair shop, central warehouse, and Maintenance and Engineering (M&E) shop storage area). Information used to prepare this draft report was obtained from preliminary drawings of the proposed Hayward Maintenance Complex provided by BART, received August 24, 2010.

The primary variables and assumptions that were used in the noise and vibration models include:

- Cumulative noise levels were estimated based on the future schedule proposed for the Silicon Valley Rapid Transit Project (SVRTP).
- Proposed BART future operations (SVRTP) on the main line would bring 271 trains through the Hayward Maintenance Complex during the daytime and 44 trains at night (in both directions of travel).
- Future yard operations for the analysis were estimated at 80 train movements during daytime and 40 during nighttime hours. This number includes the current dispatch activities (60 trains) which would originate on the west side of the HMC and the new activities on the east.
- Operations on the test track for the cumulative noise analysis would be 12 trains per hour from 7 am to 11 pm. This schedule is a worst-case condition for the noise modeling, and it includes the future expected trains from SVRT car commissioning. The train consist is assumed to be 4 cars long with operational speeds of 30 to 40 mph south of Whipple Road.
- Phase 1 construction includes all work related to the west side of the Hayward Yard, including the new Overhaul Shop and associated crossovers and trackwork, a non-rail vehicle storage area and an enhanced vehicle inspection area (east side).
- Phase 2 construction would implement work related to the east side of the Hayward Yard, including at least one flyover, new storage tracks, associated crossovers and trackwork and third rail power, communications, and train control systems.
- Construction work on the test track and storage areas would be performed during daytime hours. Construction work involving mainline tracks would be done during nighttime hours and weekends. Thus, new switch installation and flyover construction would typically be done during nights and weekends (Phase 1 and Phase 2). However, preparation for construction involving the mainline would be done during daytime.

[1] Federal Transit Administration. Transit Noise and Vibration Impact Assessment. FTA-VA-90-1003-06, May 2006

Noise and vibration measurements were conducted near the Project site to obtain the environmental ambient settings and to supplement the general information presented in the FTA guidance manual. Ambient noise was obtained at four sites along the eastern residential area near the Project. Ground surface vibration and wayside noise from BART train passbys were obtained at three locations along the existing BART mainline. In addition, noise and ground vibration measurements from BART trains passbys on crossovers, and current operations from the existing Main Shop building were obtained at the Hayward Yard.

The criteria used to assess potential impact from BART operations are those recommended by the FTA. The FTA noise criteria are based on the increase in total (Project + Existing) noise level over the existing ambient noise due to operations of the project or combination of projects, and the amount of noise increase determines whether a *Severe, Moderate or No Impact* occurs. *Noise Impact* has been determined for those receptors with *Severe Impact* and *Moderate Impact* (as defined by FTA). Noise control measures have been evaluated for both categories of impacts.

The operational FTA vibration criteria are level-based criteria depending on the land use at the receptor and the frequency of the events. The level of service expected for BART for 2030 would be classified as a system with *Frequent Events*. The vibration analysis was based on a field-derived set of vibration attenuation curves specific to the site. Adjustments have been made to the curve to account for speed, special trackwork, and the building vibration response (BVR).

The criteria for assessing noise and vibration from construction activities are also based on the FTA criteria. The FTA noise criteria are specified in terms of 8-hour equivalent noise level (L_{eq}) for residential, commercial and industrial land uses. The criterion applicable to residences in the vicinity of the project would be 80 dBA for daytime and 75 dBA for nighttime construction.

The criteria for assessing vibration effects from construction activities have been divided into two categories: interference with human activity (annoyance) and building damage (impact). The applicable criteria for evaluating potential annoyance are identical to those used to assess annoyance during train operations by land use category (e.g., Category 2 for residential homes). The FTA criteria relating to potential cosmetic cracking due to building vibration are applicable to four categories, considering different building structures. All residential buildings in the vicinity of the Project could be categorized as engineered concrete and masonry (Category II) with a threshold of 0.3 in/sec.

Operational Noise and Vibration Assessment Results

Noise

Results of the analysis show a potential for wayside *Noise Impact* on sensitive receptors near crossovers P100, P100B, P101 and P102 (see Figure 6 for location of these crossovers). The impact expected would be associated with the increase in wayside noise levels from trains crossing the turnout frogs.

The Phase 1 of the Project (which includes crossover P100 and P102) would generate *Noise Impact* at three single-family homes along 11th Street near the crossover P100. Trains crossing the gap at crossover P102 would also generate noise impacts at 14 single-family residences at the Innovation

Homes community[2]. The increase associated with the Project would be up to 2.7 dBA. Sound walls are the recommended noise mitigation control for reducing the level of impact to *No Impact*. The height of sound walls required to mitigate *Noise Impacts* from Phase 1 would be 10 to 13 feet tall measured from BART top-of-rail.

Phase 2 of the project would generate a *Severe Impact* at nine single-family residences on La Brea Terrace. The impact is due to the increase in noise levels associated with crossover P100B. Noise impact is also projected from crossover P101 at six single-family homes located on Carrara Terrace.

With the exception of receptors at La Brea Terrace, all noise impacts generated by the Project would be at a level of *Moderate Impact* as defined by FTA. A sound wall at the BART east property line is the recommended noise mitigation measure to reduce both *Severe* and *Moderate* impacts to *No Impact*. The height of the wall would range between 9-feet and 14-feet tall measured from top-of-rail depending on the final location selected for the sound wall. The schematic of the location and preliminary height of sound walls is presented in the report. However, the specific location and height of sound walls would be addressed later in detail during final design, when further details about track and receiver elevation, track location and other pertinent information would be available.

BART operations at the train storage area and the new HMC would result in *No Noise Impacts* from the additional activities. The increase due to operation on residences located east to the Yard would be 1.2 dBA and lower. Consequently, no mitigation measures would be necessary.

No Noise Impacts are expected from the new traction power substation. *No Noise Impacts* are expected for the Enhanced Vehicle Inspection Area.

Vibration

Results of the vibration evaluation show *Vibration Impact* from implementing the HMC Project at 10 single-family residences during Phase 1 of the Project and at 20 additional single-family residences during Phase 2 (Twenty-four residences would be impacted if Phase 2 is considered by itself). All residences identified with a *Vibration Impact* are located at the Innovation Homes. The impact would be associated with trains crossing the frog at crossover P100B, P101 and P102 and the proximity to the sensitive receptors (60 to 120 feet).

Vibration levels associated with BART trains on the crossovers would exceed the FTA criterion by up to 7 VdB during Phase 1 and up to 12 VdB during Phase 2. Recommended mitigation measures include relocating the crossover switches 130 feet or further away from homes, or installing track mitigation measures such as tire-derived aggregate or floating slab track at the location of P100B, P101 and P102. Recommended vibration mitigation measures would reduce the level of impact to *No Vibration Impact*. Schematics of the recommended extent of the vibration mitigation are presented in the report.

Finally, *No Vibration Impact* is expected from train movements at the east storage tracks. Consequently, no mitigation measures would be needed.

[2] Innovation Homes are the single-family community in Union City east of the BART tracks, south of Whipple Road and north of Dry Creek.

Construction Noise and Vibration Assessment

Construction activities for the HMC Project evaluated include the use of heavy equipment such as excavators and compactors, track installation equipment such as ballast tampers and ballast regulators, and pile drivers (specifically for the flyover). The construction of the Project would occur in two phases: Phase 1 includes the construction of the all Yard elements on the west side of the Hayward Yard (new Overhaul Shop and related trackwork plus the enhanced vehicle inspection area), and Phase 2 includes all Yard elements related to the east side storage tracks, including new storage tracks, flyovers and traction power.

Noise

Construction noise resulting from activities during Phase 1 and Phase 2 of the Project were compared against the FTA criteria (daytime and nighttime) to determine the degree of potential impact and the noise mitigation measure to implement. The analyses include activity caused by the use of heavy equipment and by the equipment expected during track installation (including ballast tamping and regulating).

Airborne noise impacts would occur as follows:

- In the absence of sound walls, general construction activities would result in *Noise Impacts* at noise sensitive receptors located within 75 feet of heavy equipment during daytime operations and 110 feet if construction was conducted at night.[3]
  - Including the effect of the existing sound wall, no impacts would occur at single-family residences at the Innovation Homes development (South of Whipple Road) during daytime or nighttime construction hours.
- Track installation would generate a *Noise Impact* for residences within 100 feet of daytime construction activities or within 190 feet of nighttime track-laying activities, assuming an unobstructed line of sight.
  - Impacted residences include homes on 11th Street during nighttime construction.
    - Phase 1 would generate a nighttime *Noise Impact* at 3 residences
    - Phase 2 would have *No Noise Impact* in this area.
  - Impacted residences would include single-family residences at the Innovation Homes development (South of Whipple Road) during nighttime construction hours.
    - Phase 1 would generate *Noise Impact* at 17 homes during nighttime construction
    - Phase 2 would generate *Noise Impact* at 32 homes during nighttime construction

[3] These distances are based on unobstructed line of sight to the noise source. Actual noise levels at sensitive receiver locations that were obstructed by other structures may be substantially lower; at the Innovation Homes complex, the effect of the existing sound wall was included.

    - Track-laying activities for the storage yard would be limited to daytime operations (no conflict with mainline operations), thus there would be noise impact at 14 homes on Ithaca Street and 55 homes on Carroll Avenue.

- Vibratory pile drivers for the flyover(s) would used during installation of foundation footings. Noise Impact from a vibratory compactor is expected to generate impact at residences that are located within 50 feet during daytime and 140 feet during nighttime hours.
    - The closest residences t*o the pile d*riving zone are expected to be about 400 feet and farther. Consequently *No Noise Impacts* are projected from pile driving activities.

Unshielded construction staging areas (CSA) would generate noise impacts if they are located closer than 70 feet from residential land uses in the case of daytime operations and closer than 110 feet away for nighttime operations. The closest homes to either staging area would be at least 150 feet from the nearest property line resulting in *No Noise Impact*. Noise control measures are recommended and presented herein to reduce temporary *Noise Impacts* during Project construction.

Vibration

This report evaluates the effect of annoyance and building damage on nearby sensitive receptors due to construction-induced vibration activities during Phase 1 and Phase 2. The result of the analysis shows that due to the distance between the construction site and the residential homes during both Phases 1 and 2, the vibration from all construction equipment would be well below the threshold of cosmetic building damage. *No Vibration Impacts* from construction activities would be expected during for the Project. However, there is a potential for vibration annoyance at receptors that are located within 100 feet of any vibratory construction sources.

- Phase 1 would generate vibration annoyance at 26 residences in the Innovation Homes Development during trackwork and switch installation activities from crossovers P100 and P102.
- Phase 2 would generate vibration annoyance at 29 residences in the Innovation Homes Development during trackwork and switch installation activities from crossovers P100B, P101, P103 and P104.

The use of a pile driver during construction could potentially generate annoyance to receptors located within 190 feet of the activity. However the closest distance to nearby residences from pile driving activities at the flyover is 400 feet resulting in vibration that would be below the threshold for vibration annoyance.

Construction-induced vibration form staging areas would be expected to be below the threshold of building damage and annoyance at all times. Consequently *No Vibration Impacts* are expected from staging areas.

Conclusions and Recommendations

The proposed project would generate noise and/or vibration impacts for which noise or vibration control measures should be implemented. The recommended noise or vibration control measures would eliminate the impacts.

Operations Phase 1 – West Side Improvements

- *Moderate Noise Impacts* at seventeen receptors near crossovers P100 and P102. Noise impacts would be reduced to a level of *No Impact* by implementing a sound wall.
- *Vibration Impact* at 10 single-family residences south of Whipple Road due to crossover P102 should be reduced to *No Impact* by either relocating the crossover 130 feet or further from any residential home or implementing track mitigation measures such as the use of tire-derived aggregate (TDA) or a floating slab track-bed (FST).

Operations Phase 2 – East Side Improvements

- *Moderate Noise Impacts* at six receptors near crossovers P101. Noise impacts would be reduced to a level of *No Impact* by implementing a sound wall.
- *Severe Noise Impacts* at nine receptors near crossovers P100B. Noise impacts would be reduced to a level of *No Impact* by implementing a sound wall.
- *Vibration Impact* at twenty-four single-family residences south of Whipple Road due to crossover P100B and P101. *Vibration Impact* should be reduced to *No Impact* by either relocating the crossover 130 feet or further from any residential home or implementing track mitigation measures such as the use of tire-derived aggregate (TDA) or a floating slab track-bed (FST).

East Storage

- *No Noise Impacts* and *No Vibration Impacts* are expected due to activities in the East Yard Expansion.

Construction

Phase 1 – West Side Improvements

- *Noise Impact* at twenty homes would be generated during track installation if construction is scheduled during nighttime hours. A temporary noise barrier should be implemented to reduce impacts at homes on 11th Street, and this barrier would eliminate the noise impact for these homes.
- *No Vibration Impacts* would damage buildings during Phase 1 construction. There is a potential for vibration annoyance at 26 residences during track installation.

Phase 2 – East Side Improvements

- *Noise Impact* at 32 receptors for nighttime construction during track installation. Noise control measures would be required to mitigate the nighttime noise impacts at the Innovation Homes complex. More details are discussed in this report.
- *No Noise Impact* during eastside storage track installation because the work would be conducted during the daytime hours.
- *No Noise Impacts* from vibratory pile driving and therefore no noise control would be required.
- *No Vibration Impact* would be expected during construction of the flyover aerial structure, but there is a potential for vibration annoyance at 32 single-family homes at the Innovation Homes during track construction.

Staging Areas

- *No Noise Impacts* are expected from staging areas. Therefore, no noise mitigation would be needed.
- *No Vibration Impacts* are expected from staging areas. Therefore, no vibration control measures would be required.

Introduction

This report prepared by WIA presents results of the noise and vibration impact assessment from the Hayward Maintenance Complex (HMC Project). The Project includes incorporating new special trackwork (i.e., turnouts and crossovers) in the Hayward Yard, but also some new special trackwork in the mainline and test track south of the Yard, building a storage area for up to a maximum of 250 cars and new traction power substation to the east of the Hayward Yard, two flyover structures (north and south), upgrades to the Maintenance and Engineering (M&E) yard, shops, a new Overhaul Shop and storage for non-revenue maintenance equipment located to the west of the Hayward Yard.

Measurements of the ambient background noise in the residential areas near the project, and the typical noise and vibration from train passbys were obtained by WIA in September 2009. Site-specific wayside noise and ground vibration measurements from BART train passbys were also obtained. This report presents the results of these measurements and also projected levels of noise and vibration from BART operations due to the Project.

Noise and Vibration Measurements

WIA obtained measurements of the environmental ambient noise, as well as passby noise and vibration from train operations at several locations near the project site. The purpose of the field measurements was to evaluate the existing environmental conditions in the area of the project and also to obtain the baseline for the noise and vibration analysis.

Long-term Ambient Noise Measurements

Ambient noise measurements were obtained at four locations between September 15 and September 20, 2009. Figure 1 and Figure 2 show an aerial view of the measurements locations. A description of the monitoring locations and photographs of the sites are presented in the following pages.

Long-term noise measurements were obtained by means of calibrated, precision, logging sound level meters over a 6-day period. All noise-measuring instruments used during the noise survey meet ANSI S1.4-1993 specifications for Type I Sound Level Meters. The sound level meters monitored the level of noise continuously providing statistics of the noise level over consecutive one-hour intervals. The measured hourly equivalent noise levels (L_{eq}) were used to calculate the daily Day-Night Noise Level (DNL or L_{dn}) over each 24-hour period measured.

Ambient noise at location N1 is dominated by BART train passbys, local traffic, and train noise from the nearby freight/Amtrak track (including train horn noise from the grade crossing at Whipple Road). The Day-Night noise level (L_{dn} or DNL) was 64 dBA. There is a partial sound wall at the BART property line that provides some shielding to BART train noise. The hourly equivalent noise levels are shown in Figure A- 1 (see Appendix A).

Similarly, ambient noise at location N2 is dominated by BART train noise, local traffic, and train noise from the nearby freight/Amtrak track. The ambient noise level ranged between 59 and 61 dBA L_{dn} with an average of 60 dBA. The lower noise level obtained at N2 compared with location N1 is a result of the more effective (i.e., higher) sound wall at location N2. The height of the sound wall for residences located north of Boyle Street is about 12 feet. The hourly equivalent noise levels are shown in Figure A- 2 (see Appendix A).

Location N3 was selected to characterize ambient noise for residences located in the Innovation Homes residential complex. The noise monitor was hung from a light pole on Calle La Mirada Common to provide representative ambient noise levels at these residences. Even though this location may experience higher noise levels due to motor vehicle traffic than most homes facing the alignment, this location provided the most suitable measurement site to obtain BART passby noise unshielded from the two-story homes. The ambient noise at N3 ranged between 59 and 64 dBA with an average of 62 dBA. Due to the proximity of the residential homes to the grade crossing at Whipple Road, freight train horn noise dominates noise levels measured during night hours. Figure A- 3 in Appendix A shows the hourly equivalent noise levels obtained at N3.

Finally, ambient noise at location N4 is dominated by train noise (Amtrak, UPRR and BART trains) and noise from activities from the existing Hayward Yard. The L_{dn} ranged from 63 to 68 dBA with an average of 67 dBA. Weekday noise levels remained very stable at about 67 to 68 dBA. Figure A-4 in Appendix A shows the hourly equivalent noise levels obtained at N4 between September 15 and September 21, 2009.

Table 1 summarizes the existing day-night ambient noise levels at the four locations.

Location N1

Noise logger was hung from a street light pole at the corner of 11th Street and D Street at approximately 130 feet from BART tracks.

Location N2

Noise logger was hung from street light pole in front of 33240 11th Street at approximately 120 feet from BART tracks.

Location N3

The noise logger was hung from a street light pole on Calle La Mirada Common in the Innovation Homes residential community. The monitor was approximately 200 feet from BART tracks.

Location N4

Noise logger was hung from a utility pole on Gressel Street, east to the Hayward Yard at a distance of approximately 70 feet from the active UPRR freight rail (shared with Amtrak) and 400 feet from the BART Hayward Yard.

Table 1 – Summary of the existing daily ambient noise levels (Day-night level) in the proximity of the project

Location	Tues, 15	Wed, 16	Thu, 17	Fri, 18	Sat, 19	Sun, 20	Avg.
11th Street and D Street	64	64	65	63	61	64	64
11th Street (Park)	60	60	61	60	59	60	60
Calle Innovation Homes	62	61	63	62	62	59	62
Gressel Street	68	67	67	68	66	63	67

Source: WIA, September 2009

Short-term Noise and Vibration Measurements

Noise Measurements of BART Train Passby

WIA performed measurements of airborne noise from train passbys at four locations to characterize the typical noise levels of BART trains operating on tangent track and special trackwork (i.e., turnouts and crossovers). The data were also used to calibrate the noise increase due to special trackwork in the noise model and to compare the modeled sound wall reduction with that measured for an existing sound wall.

Figure 1 and Figure 2 shows the locations chosen for the passby test. The equipment setup used during noise measurements is shown in Figure 3 (left photo). Several revenue train passbys were recorded on September 15 and September 17, 2009 at each measurement location. Subsequently, the data recorded in the field were analyzed in the WIA laboratory using a Larson Davis 2900 real time analyzer to obtain the frequency spectra and the overall noise level from each train passby. BART trains recorded at all locations were either 3-cars or 4-cars long, traveling at approximately 70 mph.

Measurements of wayside noise at location S1 were obtained at the corner of 11th Street and D Street at a distance of 125 feet from the northbound BART mainline track. The distance selected for S1 represents the setback distance from the BART main track to residences on 11th Street. There is a sound wall at the BART property line that runs from the Dry Creek Park to D Street. However, the sound wall steps down to the height of the BART tracks or lower by the time it reaches D Street. There is no sound wall south of D Street. This measurement location is representative of wayside noise levels with no sound wall on tangent track. The measured wayside noise levels of five train passbys ranged between 68 and 73 dBA with an average of 70 dBA.

Location S2 was located at the Dry Creek Park. The microphone was placed 135 feet from the northbound BART main track, which is the typical setback distance to the residential single-family homes on 11th Street. There is a 9-foot high sound wall at the measurement location that provides shielding to BART passby noise. The distance from the single-family homes to the sound wall is about 70 feet. The typical overall A-weighted noise level obtained at location S2 ranged between 62 and 65 dBA with an average of 63 dBA, which is about 7 dBA lower than that obtained at location S1.

Similarly, wayside noise was recorded at location S3 to characterize BART train passby noise for the Innovation Homes. The microphone location was about 70 feet from the northbound BART mainline track, which is the typical distance between the track and homes at this residential complex. The results show wayside noise levels from seven BART train passbys ranging from 62 to 68 dBA with an average of 65 dBA. There is an existing noise wall at the property line (top of the embankment) that provides shielding of the train noise to ground level receptors. The height of the wall is 7.5 feet from the receiver's ground elevation.

Locations S1 through S3 provided a characterization of BART trains operating on tangent track. At Location S4 adjacent to the Hayward Yard, WIA recorded noise from revenue trains operating through a crossover. Measurements at the Hayward Yard were performed at interlock 77, which is the turnout connecting the mainline tracks with the test track. The noise measurement equipment was positioned at 70 feet and 125 feet from the northbound mainline, which corresponds to the typical distance from BART tracks to homes located on 11th Street and at the Innovation Homes. A total of eight train passbys were recorded at a speed of 70 mph. The dataset included 3-car to 5-car long trains. The noise levels ranged from 79 to 81 dBA at the 70 foot location and 77 to 79 at 125 foot location. The increase associated with the crossover was 8 dBA for the 125-foot location

Table 2 shows the comparison of the data for airborne noise from train passby obtained at the three sites. It was observed that the existing sound wall provides a noise reduction of 7 dBA, when compared to the scenario of no sound walls measured at location S1.

Table 2 – Summary of wayside noise level from BART train passbys

Location ID	Description	Type of track	Distance from near track CL, feet	Wayside Noise Level, dBA (1)
S-1	11th Street and D Street	Tangent	125	70
S-2	11th Street (Park)	Tangent	125	63 (2)
S-3	Innovation Homes	Tangent	70	65 (2)
S-4	Hayward Yard	Crossover	70	79
			125	78

Note:
(1) Microphone located at 5 feet from existing ground elevation
(2) Passby noise level obtained behind the existing barrier wall

Source: WIA 2009

Ground Vibration Measurements of BART Train Passby

As for the measurement of noise from BART train passbys, recordings of ground vibration from BART train passbys was obtained at four measurement sites. Three measurement sites were selected to characterize ground vibration from BART trains operating on tangent track and one location for BART trains operating on special trackwork. The data were also used to obtain the site-specific ground vibration attenuation curve versus distance for application in the projection model.

Ground vibration was measured using Mark Products Type L282LBU 4.5 Hz geophones and a Teac LX10 solid-state multi-channel recording system. Figure 3 shows the typical equipment setup used during the data collection. Geophones were placed at distances between 40 feet and 270 feet from the nearest BART mainline track. The overall ground vibration velocity level obtained from each BART train passby was plotted against the distance and a regression analysis was applied to fit the measured data. The least square regression method was used for all measured vibration presented in this report. Figure 4 shows the results of the measurement at all five locations.

Vibration location V-1 was located at the corner of 11th Street and D Street. Geophones were located at distances of 75, 122, 172 and 222 feet from the northbound BART mainline track. Four northbound BART trains were recorded traveling at 70 mph at V-1. This measurement location was chosen to characterize ground vibration from BART trains on residences at 11th Street between Stone Street and E Street. The typical ground vibration level measured at the setback distance of homes from BART tracks was 59 VdB.

Measurement location V-2 was located inside the Dry Creek Park on 11th Street. Vibration geophones were set at 70, 120, 220, and 270 feet from the northbound BART track. Results of the analysis of four BART train passbys show ground vibration levels of about 62 VdB at the typical location of the closest homes to mainline track. This measurement location was used for residences located on 11th Street to Stone Street.

Similar to location V-2, location V-2A was located on the north side of the Dry Creek Park as an effort to estimate ground vibration for single-family residences on La Vita Terrace and La Brea Terrace (both located north to the creek), and to study the effect of ground vibration from BART trains due to the proximity of the creek. Geophones were located at 70, 120, 220, and 270 feet from the nearest northbound BART track. As shown in Figure 4, ground vibration at location V-2A was lower than V-2 up to 80 feet, but higher for all distances beyond. Loose local soil at the park could be the main reason driving the results, and the creek could be the explanation for the slower decay rate at distances further than 80 feet. Since residences north to the creek are 60 to 70 feet from the nearest BART track and 30 to 35 feet from the test track, for the purpose of the analysis we have used V-2 as the representative vibration location for residences on La Vita and La Brea Terrace at the Innovation Homes.

Vibration inside the Innovation Homes complex (Location V-3) was characterized at the park on Calle La Mirada Common. The vibration sensors were placed on the ground at a distance of 75, 95, 120, 170 and 195 feet from the northbound BART mainline track. Four train passbys were recorded and plotted against the distance. The result shows that at the typical distance to the homes (70 to 90 feet), ground vibration ranged from 65 to 67 VdB.

Measurements of ground vibration were also performed at the Hayward Yard (Location V-4) in September 17, 2009 near the interlock switch 77 connecting the mainline with the test track. Five geophones were set at 40, 70, 80, 120 and 180 feet from the crossover frog. The passbys of eight northbound trains at 70 mph were recorded and later analyzed to obtain the frequency spectra and overall vibration level; the overall vibration was then used in a regression analysis. Figure 4 shows the curve obtained from the analysis. Vibration levels from operations on the crossover are 12 VdB higher than those obtained on tangent track at 50 feet (location V-2). However, the decay rate with distance is much higher than for tangent track. This is explained by the fact that vibration from trains operating through the crossover acts like a discrete point source while a train passby is more like a line source. Figure 4 shows that at a distance of 180 feet, ground vibration from BART trains operating on the turnout of the crossover is identical to that obtained for tangent track.

Figure 1 – Long-term and short-term noise and vibration measurement locations (N of Whipple Rd)

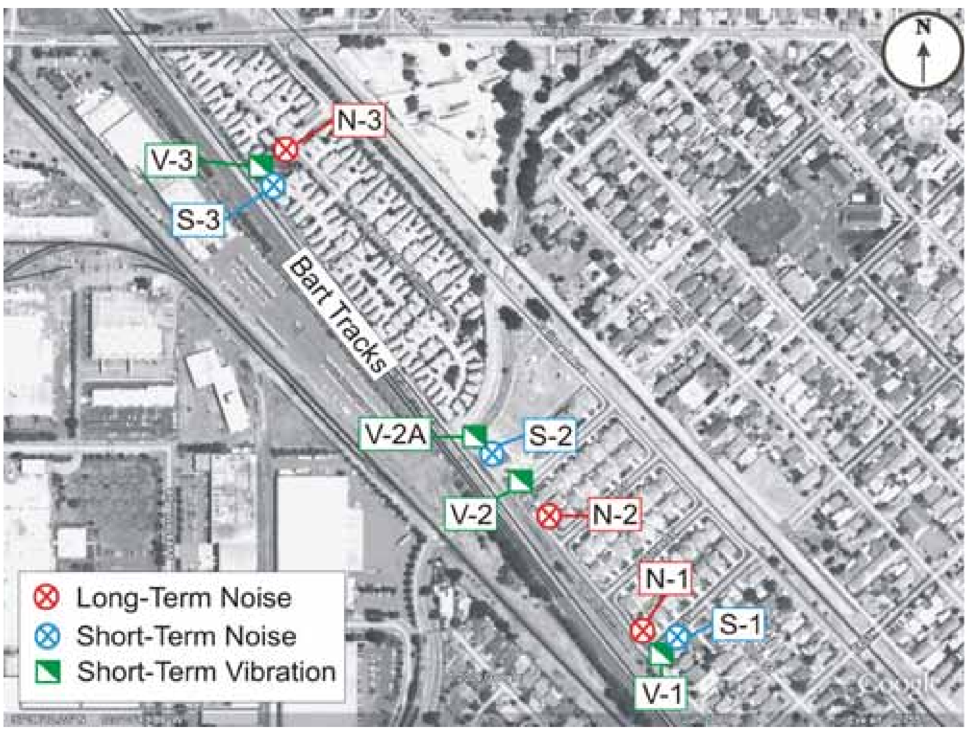

Figure 2 – Long-term and short-term noise and vibration measurement locations (S of Whipple Rd)

Figure 3 – Equipment setup used for noise and vibration passby measurements

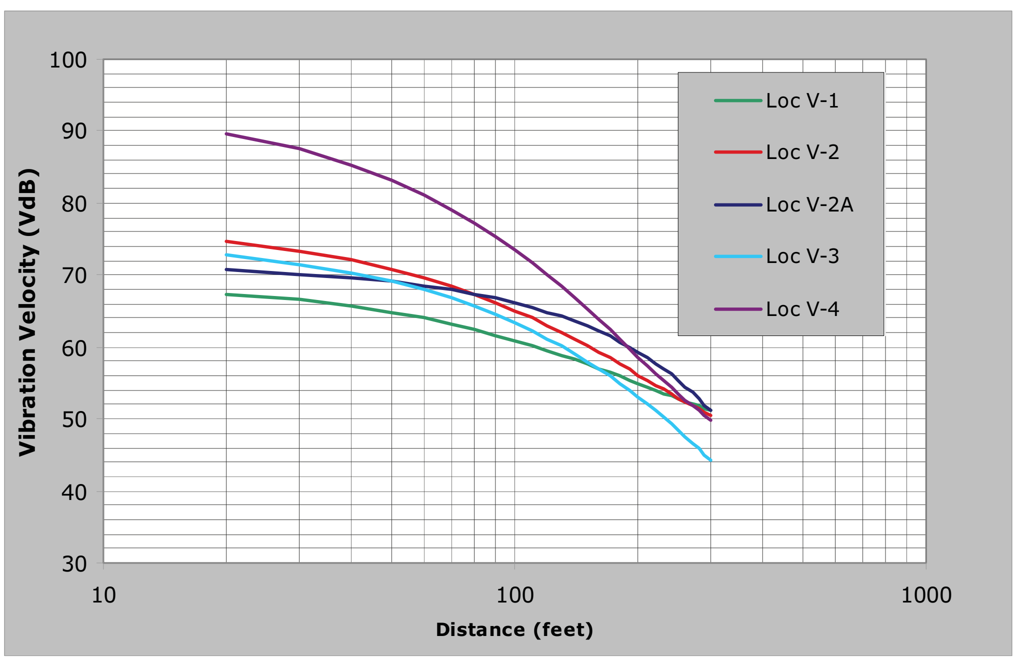

Figure 4 – Projected ground vibration levels versus distance from BART train passby on tangent and special trackwork based on site specific measurements

Applicable Noise and Vibration Policies

FTA Noise Criteria

The FTA Guidance Manual provides three levels of criteria for assessment of noise impact from rail transit projects: *No Impact*, *Moderate Impact* and *Severe Impact*. These sets of criteria depend on the existing outdoor ambient noise and the type of land use.

Noise sensitive land-use is grouped into three categories: Category 1, Category 2 and Category 3. The criteria are shown graphically in Figure 5 for the Category 1 and Category 2 land uses.

The FTA guidelines specify a particular noise metric to be used depending on the specific land-use (e.g., residential). The L_{dn} is typically used for residential uses and the worst-hour L_{eq} is typically used for office use. Thus, the ambient measurements described in the previous section were conducted to characterize the existing environments accordingly.

Table 3 describes the FTA land-use categories and specifies the appropriate noise metric and the criterion for each Category. The FTA noise impact thresholds, as indicated in Figure 5 are based on the increase of the existing ambient noise level associated with operations of the Project or in combination with other new planned projects (i.e., cumulative impact).

Table 3 - FTA Land Use Categories and Metrics for Transit Noise Impact Criteria

Land Use Category	Noise Metric (dBA)	Description of Land Use Category
1	Outdoor L_{eq}(h)	Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use.
2	Outdoor L_{dn}	Residences and building where people normally sleep. This category includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor L_{eq} (h)	Institutional land uses primarily daytime and evening use. This category includes schools, libraries, and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios and concert halls fall into this category. Places for meditation or study associated with cemeteries, monuments, museums. Certain historical sites, parks and recreational facilities are also included.

Source: FTA, May 2006.

The FTA noise impact thresholds, as shown graphically in Figure 5 below, are based on the noise exposure increase over the existing ambient noise level associated with the projected future noise level (created by the project or combination of new projects). Two levels of noise impact are defined by the FTA guidelines: *Moderate Impact* and *Severe Impact*. The range between both the upper (*Severe Impact*) and lower curves (*Moderate Impact*) represents an area where it has been observed that the increase in cumulative noise exposure is noticeable to most people, but generally not sufficient to cause an adverse reaction by the surrounding communities. The FTA Guidelines established the threshold on the upper area as the limit above which a substantial percentage of receptors in the vicinity of the Project may be highly annoyed.

For the BART HMC Project, *Noise Impact* would be indicated when noise exposure levels exceed the threshold for *Severe Impact* and *Moderate Impact* as defined by the FTA Guidelines. Mitigation measures would be evaluated on sensitive receptors identified with either category of impact. Noise in the *Severe Impact* range has the greatest adverse effect on the community, requiring mitigation unless extenuating circumstances prevent it, if mitigation is found not to be feasible or prudent. *Moderate Impacts* also require consideration and adoption of mitigation measures when it is considered reasonable to do so.

Source: FTA, May 2006.

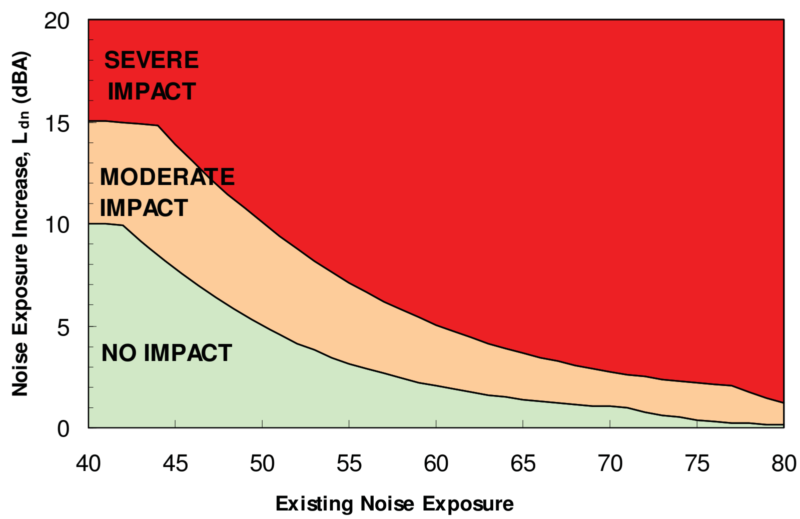

Figure 5 – Allowable Increase in Cumulative Noise Levels for FTA Category 1 and 2

FTA Vibration Criteria

The ground-borne vibration criteria for the FTA General Assessment analysis accounts for the frequency of events, where *Frequent Events* are defined as more than 70 events (trains) per day, *Occasional Events* are for between 30 and 70 events per day, and *Infrequent Events* for less than 30 events per day. Additionally, FTA provides separate criteria (not included in any Category presented above) for buildings that are especially sensitive to vibration (e.g., research laboratories). There are currently no special buildings in the area of the Project.

In year 2030, BART is expected to run a total of 315 trains daily once the Silicon Valley Rapid Project (SVRTP) is in place. However, even with the current train schedule, BART can be categorized as a system with *Frequent Events*. Similarly, future operation of the test track falls into the *Frequent Event* Category (more than 70 events per day). The current test track activities are considered by the FTA guidelines as *Occasional Events*.

The FTA guidelines group vibration sensitive land uses into three categories: High Sensitivity, Residential and Institutional. Table 4 shows the description of each land use category applied to the analysis. Vibration sensitive land uses in the proximity of the HMC Project are Category 2 exclusively. No Category 1 or 3 land uses were identified in the area of the Project.

Table 4 – Category of Land Use for the FTA Vibration Analysis

Vibration Category	Description of Land Use Category
Category 1 - High Sensitivity	"Included in Category 1 are buildings where vibration would interfere with operations within the building, including levels that may be well below those associated with human annoyance." "Typical land uses covered by Category 1 are: vibration-sensitive research and manufacturing, hospital with vibration-sensitive equipment, and university research operations."
Category 2 - Residential	"This category covers all residential land uses and any buildings where people sleep, such hotels and hospitals. No differentiation is made between different types of residential areas."
Category 3 - Institutional	"Vibration Category 3 includes schools, churches, other institutions, and quiet offices that do not have vibration-sensitive equipment, but still have the potential for activity interference. Although it is generally appropriate to include office buildings in this category, it is not appropriate to include all buildings that have any office space."

Source: FTA, May 2006.

Table 5 - FTA Ground-borne Vibration Impact Criteria for General Assessment

Land Use Category	GBV Impact Levels (VdB re 1 micro-inch/sec)		
	Frequent Events	Occasional Events	Infrequent Events
Category 1	65 VdB	65 VdB	65 VdB
Category 2	72 VdB	75 VdB	80 VdB
Category 3	75 VdB	78 VdB	83 VdB

Source: FTA, May 2006.

Noise and Vibration Impact Assessment

The noise and vibration assessment in this report evaluates the construction and operational noise and vibration impacts of the Project, including BART train movements on the east storage tracks, the new Overhaul Shop, the Maintenance and Engineering (M&E) yard, shops, and storage for non-revenue maintenance equipment, and the new traction power substation.

The alignment evaluated in this report includes both the south and north dispatch flyovers shown in Figure 6. The Phase 1 Project proposes implementing two new crossovers between the southbound and northbound tracks in the area of 11th Street (crossovers P100 and P102)[4]. This special trackwork would be located approximately 150 feet from the nearest single-family homes on 11th Street. Also during Phase 1, the Project would provide access to the Hayward Maintenance Complex (HMC). Crossovers proposed for accessing the HMC include a single turnout off the southbound main track (crossover P102) which is located approximately 95 feet from the nearest homes. Figure 6 shows the location of these new crossovers.

During Phase 2, a new No. 15 crossover (crossover P101 in Figure 6) would be placed between the northbound track and the test track just south of the Whipple Road overpass. The distance between P101 and the closest sensitive receptors would be about 60 feet.

Two crossovers (P103 and P104) on the dispatch and reception lead track would be located just south of the Whipple Road overpass at a distance of approximately 130 feet from the closest sensitive receptors. Both crossovers P103 and P104 would be implemented during Phase 2 of the Project.

The Project also includes site improvements to 20 acres of undeveloped land to the northeast of the Yard that would provide storage tracks to accommodate up to a maximum of 250 cars, and a traction power substation to the south end of the east storage area. The location of these improvements is shown in Figure 6.

Finally, the proposed project would acquire three properties to the west of the existing Hayward Yard to accommodate the new maintenance complex that would include a new overhaul shop, component repair shop, central warehouse, and the maintenance and engineering shop and storage.

The primary variables and assumptions that were used in the noise and vibration models include:

- Alignment on ballast and tie tracks except on the aerial structure for which a direct fixation system was assumed.
- Cumulative noise levels were estimated based on the future schedule proposed for the Silicon Valley Rapid Transit Project (SVRTP).
- Proposed BART future operations (SVRTP) on the main line would bring 271 trains through the Hayward Maintenance Complex during the daytime and 44 trains at night (in both directions of travel).
- BART future trains operations would be 10-cars long (700 feet) during peak-hour operation and 5-cars long (350 feet) during off-peak operations. BART vehicles on the test track would be 4-cars long (280 feet).

[4] Labels given to crossovers in this report are intended for identification purpose only.

- Maximum BART train speed on the main line and test track would be 70 mph. BART maximum speed on the storage and yard lead tracks would be 30 mph.
- Ground vibration projections use a locally derived ground vibration curve obtained by field measurements.
- To establish interior vibration levels, an adjustment of +3 VdB was applied to account for the general response of wood-framed residential structures.
- Future yard operations for the analysis were estimated at 80 train movements during daytime and 40 during nighttime hours. This number includes the current dispatch activities (60 trains) which would originate on the west side of the HMC and the new activities on the east.
- A 34.5 KVA track power substation was assumed for the east storage area. The reference sound exposure level used in calculations was 99 dBA at 50 feet.
- Operations on the test track for the cumulative noise analysis would be 12 trains per hour from 7 am to 11 pm. This schedule is a worst-case condition for the noise modeling. This schedule assumes the future train activities expected from future car commissioning. The train activity is associated with the testing of the new vehicles on the test track before BART accepts them for service. The train consist is assumed to be 4 cars long with operational speeds of 30 to 40 mph south of Whipple Road.

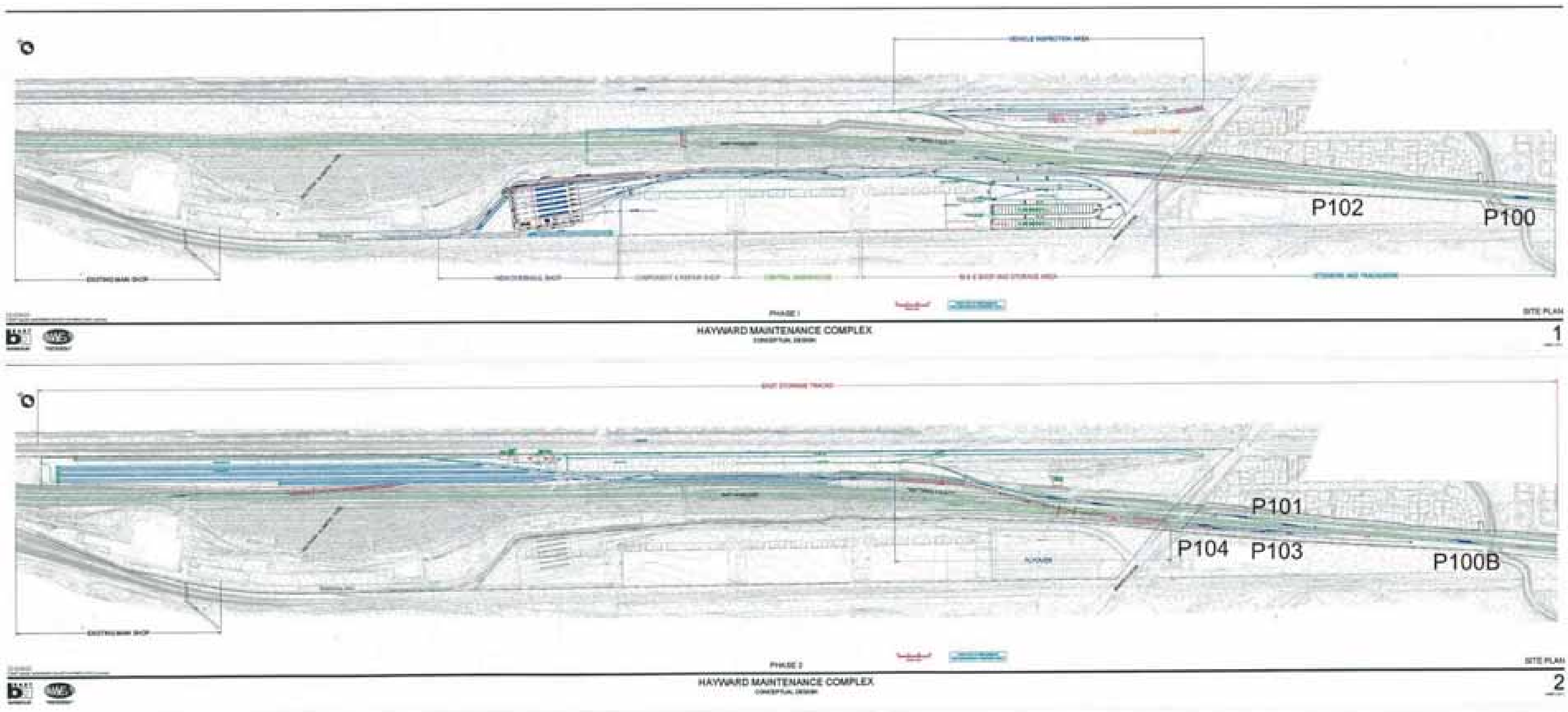

Figure 6 – Hayward Maintenance Complex. Phase 1 (top) and Phase 2 (bottom) conceptual design plan view

Noise Assessment

Methodology

BART Operational Noise Analysis

The assessment of wayside noise impacts from operations of BART trains in the vicinity of the Hayward Yard Project was done in accordance with the FTA Guidance Manual. The FTA guidelines provide two levels of analysis during an environmental analysis: Screening and General Assessment. The assessment of potential noise impacts due to BART operations as part of the Project were based on the level described by FTA as General Assessment. The FTA Criteria are based on the relative change in the cumulative noise exposure that would occur, using the "day-night" noise level descriptor (L_{dn}) for residential or other buildings with nighttime occupancy and peak hour L_{eq} for buildings with daytime occupancy only. WIA obtained the existing ambient noise levels along the corridor in September of 2009.

Cumulative noise levels due to the Project depend on train length, speed and distance from both tracks to the buildings. The projected wayside noise levels also account for the noise shielding effects of the existing sound walls.

For the purpose of this analysis, the current schedule of BART trains on the Fremont to Richmond and Fremont to Daly City lines indicates 204 daytime trains and 52 nighttime trains through the Hayward Yard (in both directions of travel). Traffic on the mainline is projected to receive additional trains from two proposed BART extension projects: Warm Springs Project (WSX) and the Silicon Valley Rapid Transit Project (SVRTP). The WSX project is expected to operate with a similar number of trains as the current schedule. However for the SVRTP, BART proposes to operate 271 trains through the Hayward Yard during the daytime and 44 trains at night (in both directions of travel), which is approximately 59 trains per day greater than the current schedule. BART trains operating on the SVRT Project will be 10-cars long (700 feet) during peak-hour operation and 5-cars long (350 feet) during off-peak operation[5].

Cumulative noise levels were estimated based on the future schedule proposed for the SVRT Project, which represents a conservative approach for the Hayward Yard Expansion considering the proposed opening date for the SVRT Project is unknown. Figure 7 shows the projected unshielded day-night noise level versus distance expected from future BART operations on tangent track (year 2030).

Additional adjustments to the unshielded noise exposure in Figure 7 include those that account for increases due to the crossovers, speed changes at the storage and yard lead tracks, and the reduction of noise level provided by existing sound walls.

[5] Silicon Valley Rapid Transit Project. Line Segment Wayside Noise Report, December 2006. Prepared by Wilson, Ihrig and Associates, Inc.

Figure 7 – Projected unshielded day-night noise level of BART trains on at-grade ballast and tie tracks at 70 mph with 12-minute headways (future condition).

Hayward Yard Operations

Noise from BART operations as part of the HMC Project include BART train movements on proposed tracks and crossovers, and noise from the traction power substation constructed at the south end of the storage track area to provide power to the storage tracks.

The methodology to assess wayside noise was taken from the FTA guidance manual. The reference sound exposure level (SEL) specified in the guidance manual is 118 dBA for 20 train movements during peak hour activities. The HMC East storage expansion proposes adding 40 train movements during daytime hours and 20 train movements during nighttime hours to the existing train movements (originated on the west side of the Yard). This represents a doubling of yard traffic, with half (60 trains) operating from the west side of the Hayward Yard and half (60 trains) operating from the east side of the yard. This assumption represents a worst case condition for noise modeling.

The unshielded noise levels from the 34.5 KVA substation were projected to nearby residences and the level compared to the FTA criteria shown in Figure 5. The reference sound exposure used in the calculation was 99 dBA at 50 feet. We understand that BART requires its substations meet the National Electrical Manufacturers Association (NEMA) rating. The maximum NEMA ratings, which are specified in terms of the average sound level, are 60 dBA for a self-cooled ventilated system, 59 for a self-cooled sealed and 67 dBA for a ventilated forced air cooled. These sound levels are much quieter than that specified in the FTA guidance. Therefore, following the FTA procedure will be a conservative approach for this project.

Noise from future operations on the new overhaul shop, component repair shop, maintenance and engineering shop and storage, and central warehouse was based on field measurements performed on the existing main shop at the Hayward Yard. Noise measurements and field observations performed by WIA during July 2010 helped to determine an outdoor sound exposure level of 96 dBA (at 50 feet) from typical activities from the Main Shop. Such activities included impact wrenches during dissemble and ensemble of train's truck, PA announcements, overhead cranes operation, and steam cleaning.

Projected Cumulative Noise

Operational

The impact assessment for noise is based on the comparison of the increased levels (L_{dn}) associated with BART operations with the impact threshold presented in Figure 5.

Table 6 and Table 7 show the results of the projected cumulative noise levels from BART train operations on the proposed HMC Project for Phase 1 and Phase 2 respectively. Projected noise levels in the tables include the effect of BART train operations on the mainline (future schedule), and BART operations on the new crossovers (including future test track operations). The summary of the results are as follows:

Phase 1 - West Side Improvements

There would be potential for *Moderate Noise Impact* at three single-family residences located on 11th Street due to the increase associated with the proposed crossover P100.

Noise impacts are also projected at about 14 single-family homes that would be located directly opposite to crossover P102 which connects the southbound main line with the southbound dispatch and reception lead. The increase in noise level expected on residences at Alicante Terrace and Carrara Terrace would be 2.0 to 2.7 dBA resulting in *Moderate Impact*.

Phase 2 – East Side Improvements

Operations of BART trains on crossover P100B would result in a *Severe Noise Impact* at nine single-family residences located on La Brea Terrace due to the noise increase associated with the BART trains from crossover P100B and the distance from the crossover to the residences.

Also six single-family homes located on Carrara Avenue would receive a *Moderate Impact* due to crossover P101 that would be connecting the northbound mainline with the test track. There are other homes near this crossover; however noise levels from operations of BART trains on the test track at the crossover P101 would be reduced by the shielding provided from the existing retaining wall. Thus, for the single-family homes at Messina and La Bonita Terrace there would be *No Noise Impact*. Consequently noise mitigation measures would only be considered for the homes on Carrara Avenue.

North of Whipple Road, the project would slightly increase the cumulative noise levels at nearby single-family homes due to trains on the aerial flyover. However, the increase would be below the threshold for Moderate Noise Impact. As a result, *No Noise Impact* is expected from BART operations on the aerial guideway and therefore, no additional mitigation measures would be needed on the aerial guideway.

Table 6 – Projected cumulative noise levels from BART operations on the HMC Expansion (Project) for Phase 1

Location	Land Use	Dist. to nearest track CL (ft)	Amb. Level L_{dn} (except as noted	FTA Criteria: Moderate Impact	FTA Criteria: Severe Impact	No Noise Control: Projected Total[1] L_{dn} or L_{eq} (dBA)	No Noise Control: Increase (dBA)	No Noise Control: Imp. Type	No Noise Control: # of Bldgs with Imp.	With Noise Control: Projected Total[1] L_{dn} or L_{eq} (dBA)	With Noise Control: Increase (dBA)	With Noise Control: Imp. Type	With Noise Control: # of Bldgs with Imp.
11th St btwn Stone St & Boyle St.	SFR	135 xo	60	2.0	5.0	62	2.0	NI	0	---			
11th St and Boyle St.	SFR	140 xo	60	2.0	5.0	63	2.7	MI	3	62	1.7	NI	0
Dry Creek Park	Park	120xo	60[2]	4.6	9.0	63[2]	2.8	NI	0	---			
La Brea Terrace	SFR	75	62	1.7	4.4	64	1.6	NI	0	---			
Alicante Terrace	SFR	75 xo	62	1.7	4.4	65	2.7	MI	7	64	1.7	NI	0
Carrara Terrace	SFR	80 xo	62	1.7	4.4	64	2.0	MI	7	63	1.3	NI	0
Messina Terrace	SFR	85	62	1.7	4.4	63	0.5	NI	0	---			
La Bonita Terrace	SFR	90	63	1.6	4.1	63	0.0	NI	0	---			

Notes:
(1) Include noise levels from future BART train operations on mainline and crossover and the projected existing adjusted ambient noise levels.
(2) Leq is the metric for FTA Category 3 sensitive receptors
xo : crossover switch

SFR: Single-family residence building
NI : No Impact as defined by FTA
MI : Moderate Impact as defined by FTA
SI: Severe Impact as defined by FTA

Source: WIA 2010

Table 7 – Projected cumulative noise levels from BART operations on the HMC Expansion (Project) Phase 2

Location	Land Use	Dist. to nearest track CL (ft)	Amb. Level L_{dn} (except as noted	FTA Criteria		Cumulative Noise Levels No Noise Control				Cumulative Noise Levels With Noise Control			
				Moderate Impact	Severe Impact	Projected Total[1] L_{dn} or L_{eq} (dBA)	Increase (dBA)	Imp. Type	# of Bldgs with Imp.	Projected Total[1] L_{dn} or L_{eq} (dBA)	Increase (dBA)	Imp. Type	# of Bldgs with Imp.
11th St btwn Stone St & Boyle St.	SFR	135 xo	60	2.0	5.0	61	1.4	NI	0	---			
11th St and Boyle St.	SFR	140 xo	60	2.0	5.0	62	1.7	NI	0	---			
Dry Creek Park	Park	120xo	60[2]	4.6	9.0	62[2]	1.8	NI	0	---			
La Brea Terrace	SFR	75 xo	62	1.7	4.4	67	4.7	SI	9	64	1.4	NI	0
Alicante Terrace	SFR	75 xo	62	1.7	4.4	64	1.5	NI	0	---			
Carrara Terrace	SFR	80 xo	62	1.7	4.4	65	2.5	MI	6	63	1.3	NI	0
Messina Terrace	SFR	85 xo	62	1.7	4.4	63	1.4	NI	0	---			
La Bonita Terrace	SFR	90 xo	63	1.6	4.1	63	0.4	NI	0	---			

Notes:
(1) Include noise levels from future BART train operations on mainline and crossover and the projected existing adjusted ambient noise levels.
(2) Leq is the metric for FTA Category 3 sensitive receptors
xo : crossover switch

SFR: Single-family residence building
NI : No Impact as defined by FTA
MI : Moderate Impact as defined by FTA
SI: Severe Impact as defined by FTA

Source: WIA 2010

Table 8 – Projected cumulative noise levels from activities at the proposed east train storage, west side improvements, and traction power substation

Location	Land Use	Range of Typical Dist. (ft)	Amb. Level L_{dn}	FTA Criteria		Projected Total L_{dn} (dBA)	Increase (dBA)	Imp. Type	# Bldgs w/Imp
				Moderate Impact	Severe Impact				
Ithaca Ave between Whipple Road and Troy Place	SFR	630 – 2,900	70	1.0	2.8	70	0.1	NI	0
Carroll Ave between Troy Place and Gressel St	SFR	320 – 1,400	69	1.1	2.9	69	0.3	NI	0
Carroll Ave between Gressel St. and Becker Place	SFR	170 – 1,100	67	1.2	3.1	68	1.1	NI	0
Carroll Ave between Becker Pl. and Fairway Street	SFR	200 – 1,400	67	1.2	3.1	68	1.0	NI	0
Carroll Ave north of Fairways Street	SFR	370 – 2,500	67	1.2	3.1	67	0.2	NI	0

SFR: Single-family residence building
NI : No Impact as defined by FTA

Source: WIA 2010

Hayward Yard (Train Storage, HMC, Traction Power Substation and Enhanced Vehicle Inspection Area)

The assessment of cumulative noise impacts resulting from BART operations on the proposed storage expansion is presented in Table 8. Noise levels in the table account for train movements at lower speed during storage, noise from the traction power substation, operations on the aerial structures for the dispatch flyover, and operations on the new Hayward Maintenance Complex (HMC).

Results of the analysis show that BART operations on the proposed storage tracks and other tracks associated with it would increase the existing ambient conditions of nearby residences by a range between 0.1 and 1.1 dBA. The increase would result in *No Impact* as defined by FTA. Therefore, no noise mitigation measurements would be required.

Noise levels from the traction power substation are projected to be below the criteria for noise impact and therefore, no noise mitigation would be needed. Similarly, operations of the HMC would generate cumulative noise levels below the threshold of impact resulting in *No Impact* as per FTA.

The Enhanced Vehicle Inspection Area will be used to inspect vehicles as they are delivered to the Hayward Yard before going into service on the BART system. It is expected that up to two vehicles per month might be delivered on average. Most of the time the vehicles will be stationary during which time noise generation will be minimal, since most of the inspection work will be conducted inside the vehicle and when outdoors power tools will be used infrequently if at all. Movement of the train will generate low levels of noise considering the low speeds into and out of the Inspection Area. Considering the low levels of noise generated and their infrequent occurrence, *No Noise Impact* is expected for the Enhanced Vehicle Inspection Area.

Mitigation Measures

Based on the results of the noise assessment, there is a potential for noise impact on nearby residences due to implementing the Project. Noise mitigation measures were evaluated for those receptors with *Moderate Impact* and *Severe Impact*

A sound wall is the primary noise mitigation evaluated for reducing cumulative noise impacts from operations associated with the HMC Project. Other measures evaluated included relocation of the crossovers and building sound insulation. Noise mitigation controls for reducing impacts are:

Sound Walls

Project sound walls must typically have a minimum surface density of 4 lb/ft^2 to be considered effective. Implementation of these sound walls would provide approximately 10 dBA but not more than a 15 dBA reduction in overall wayside noise levels. Concrete block masonry, poured-in-place, or pre-cast concrete walls would be acceptable as construction materials. Table 9, Table 10, Figure 8 and Figure 9 shows the approximate location, height and length of sound walls for reducing noise impacts to *No Impact* per FTA criteria for Phase 1 and Phase 2 of the Project.

The recommended height of each sound wall ranges from 9 to 14 feet and would be located at the BART east property line which varies between 65 and 75 feet from the northbound main track. A total of 980 linear feet of sound wall would be required during Phase 1 and 790 feet during Phase 2.

The specific location and height of sound walls would be addressed later in detail during final design when further details about track and receiver elevation, track location and other pertinent information would be available.

Table 9 – Summary of minimum recommended sound wall mitigation for the HMC Project Phase 1

Sound Wall ID	Location	SW [1] Height (feet)	SW length (feet)
	11th St between Stone St & Boyle St.	---	---
SW-01	11th St and Boyle St.	10	320
	La Brea Terrace	---	---
SW-02	Alicante Terrace	10	320
SW-02	Carrara Terrace	13	340
	Messina Terrace	---	---
	La Bonita Terrace	---	---

Note:
(1) Approximate height from BART top-of-rail

Source: WIA 2010

Table 10 – Summary of minimum recommended sound wall mitigation for the HMC Project Phase 2

Sound Wall ID	Location	SW [1] Height (feet)	SW length (feet)
	11th St between Stone St & Boyle St.	---	---
	11th St and Boyle St.	---	---
SW-03	La Brea Terrace	9	380
	Alicante Terrace	---	---
SW-04	Carrara Terrace	14	410
	Messina Terrace	---	---
	La Bonita Terrace	---	---

Note:
(1) Approximate height from BART top-of-rail

Source: WIA 2010

Building Sound Insulation

For those noise sensitive receptors at ground level where the outdoor noise from HMC train operations can be mitigated with a feasible height sound wall to achieve the FTA Criteria, but the sound wall is not tall enough to mitigate noise levels at upper stories, possible physical improvement to building exterior-to-interior sound insulation may be necessary and should be evaluated after construction of the project is completed. The interior noise levels for stories above ground level at the Innovation Homes facing the BART ROW could potentially be exposed to noise that is in excess of the FTA criterion even with the recommended sound walls. These residences should be evaluated to determine if improved building noise insulation may be needed as additional mitigation beyond the recommended sound walls.

This additional type of mitigation (improving sound insulation) has been used around freeways and airport projects, but not yet implemented on a BART project, although this approach to noise impact mitigation has been included in the Warm Springs Extension project as well as in the Silicon Valley Rapid Transit project (now referred to as the Berryessa Extension project). The VTA Capitol Corridor LRT project implemented a formal process that evaluated the need for improving building insulation on a case-by-case basis as noise mitigation where sound walls were not the preferred option.

Improving individual building insulation can be evaluated on a case-by-case basis using the generally accepted criterion (i.e., California State and local building codes) of a maximum interior noise for residences of 45 dBA L_{dn}. Generally speaking windows are the building element that determines whether or not a building exterior provides the amount of exterior-to-interior noise reduction to achieve an interior noise level of 45 dBA L_{dn} or lower. In general, windows must provide a Sound Transmission Class (STC) rating of greater than 27 for this to be achieved. The greater the exterior noise level is, the higher the window STC rating required. Based on visual observations in the field, the current construction elements of the buildings at the Innovation Homes should provide a STC rating higher than 27. Therefore, future train operations from the HMC Project should achieve an L_{dn} of 45 dBA interior or less. Consequently improving building insulation by replacing the existing windows on a case-by-case basis may not be necessary. However, it is not possible to verify this condition at the present time, and therefore it is recommended to that this should be evaluated on a case-by-case basis once the HMC Project has been completed and trains are operating.

Figure 8 – Location and minimum recommended extent of sound wall for Phase 1

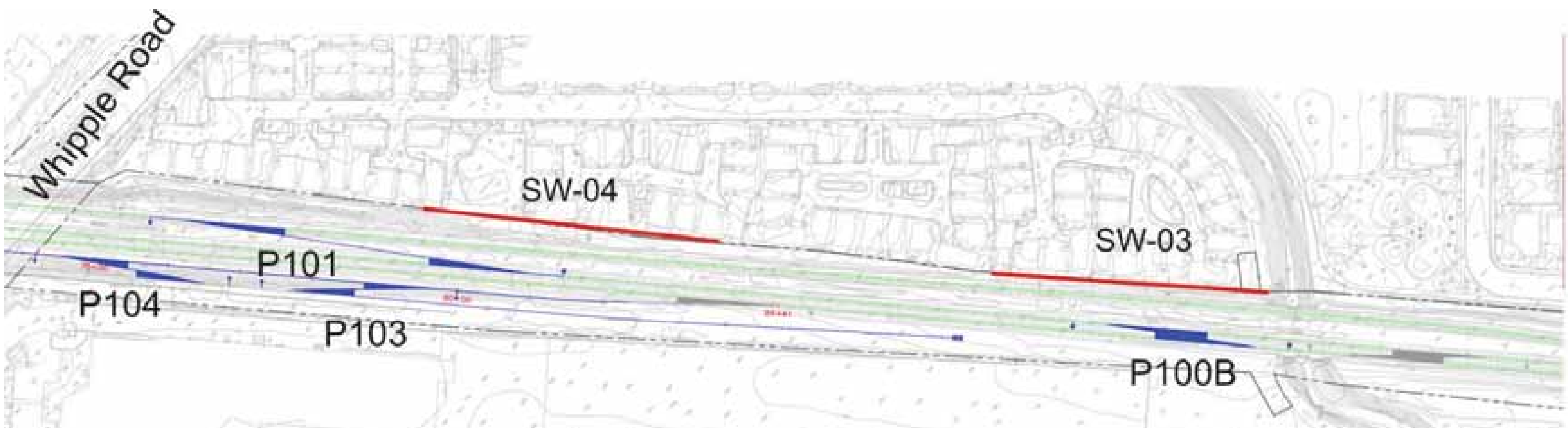

Figure 9 - Location and minimum recommended extent of sound wall for Phase 2

Vibration Assessment

Methodology

BART Operational Vibration Analysis

To assess the potential for ground-borne vibration impact, results of the curves derived from the measured ground vibration at the four sites were compared against the FTA criteria presented in Table 5. The methodology to assess the potential for vibration impacts for the Hayward Maintenance Complex Project is identical to the General Assessment presented in the FTA Guidance Manual. The General Assessment method uses only an overall level and applies adjustments to account for different vibration factors. The analysis presented herein uses a locally derived ground vibration curve obtained by field measurements instead of a generalized one. Adjustments to the curves were made to account for train speed at the east storage tracks, the elevated guideway, and increases due to building vibration response (BVR), which generally amplifies ground-borne vibration for residential buildings.

For practical reasons, vibration measurements in the area of the project were performed on the ground surface outside residential homes. To establish interior vibration levels, an adjustment of +3 VdB was applied to account for the general response of wood-framed residential structures such as those observed at all receptors in the area of the project. This adjustment is sometimes referred to as the building vibration response (BVR).

The BVR represents the response of a particular building, type or class of building structures relative to the vibration observed at the ground's surface at the building façade closest to the tracks. The response of the building includes the foundation coupling loss, floor-to-floor attenuation and resonant amplification of vibrating room surfaces (floors/ceilings and walls) that may apply to a specific receiving area. Generic building response data are contained in a report by Nelson and Saurenman[6], and in *State-of-the-Art Review: Prediction and Control of Ground-borne Noise and Vibration from Rail Transit Trains*[7]. WIA also maintains a database of measured building vibration responses for similar building construction on several rail transit projects in the Bay Area and southern California.

Speed adjustments to the curves obtained from field measurements were applied to BART trains on the storage and lead tracks. The speed adjustment is $20 \times \log\left(Speed / Speed_{ref} \right)$, with 70 mph as the reference speed. For the analysis herein, the maximum speed at the east storage and lead tracks were assumed to be 30 mph.

Separate analyses were conducted for each alternative evaluated and compared against the applicable criteria. Operations of BART trains on the mainline can be categorized as *Frequent Events* per the

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[6] Nelson, J. T. and H. J. Saurenman, *A Prediction Procedure for Rail Transportation Groundborne Noise and Vibration*, Transportation Research Record 1143, Presented at the January 1987, A1F04 Committee Meeting of the Transportation Research Board.

[7] U.S. Dept. of Transportation, *State-of-the-Art Review: Prediction and Control of Groundborne Noise and Vibration from Rail Transit Trains*, UMTA-MA-06-0049-83-4, December 1983.

FTA guidelines. Based on the information provided by BART [8] current dispatch activities at the Hayward Yard (60 trains) would continue to originate out of the west side of the facility. Yard operations for the analysis were estimated at 80 train movements during daytime and 40 during nighttime hours. For the purpose of modeling, we have assumed that half of the train movements would be originated from the west side and half from the east side of the facility.

Projected Ground Vibration

Operational

The impact assessment for vibration is based on the overall vibration levels associated with BART operations projected to the location of vibration sensitive receptors. When vibration levels exceed the criteria shown in Table 5, then a *Vibration Impact* is identified. Vibration mitigation measures have been evaluated to reduce the vibration to the level of *No Impact*.

Phase 1 – West Side Improvements

Table 11 shows the results of the assessment during Phase 1. As presented in the table, there would be no *Vibration Impacts* from train operations on the proposed single crossover P100 along 11th Street. Vibration sensitive receptors would be located far enough away such that the vibration levels would be below the 72 VdB criterion. Therefore, no vibration mitigation measures would be needed.

BART trains crossing the switch P102 would generate a *Vibration Impact* at approximately six residential homes located on Alicante Terrace and four homes located on Carrara Terrace. The vibration levels are projected 6 to 7 VdB over the FTA criteria and primarily due to the proximity between the receptors and the crossover P102 (85 to 90 feet). Mitigation measures would be needed at the location of crossover P102 to reduce the level of impact to *No Impact*.

Phase 2 – East Side Improvements

In the vicinity of crossover P101 vibration levels associated with trains crossing the crossover frog would be 8 to 12 VdB in excess of the FTA criterion resulting in *Vibration Impact* at 15 residences on La Bonita and Carrara Terrace (eight single-family homes at La Bonita Terrace and seven at Carrara Terrace). Four of the seven single-family residences on Carrara identified with a *Vibration Impact* would be impacted as discussed above for Phase 1. Mitigation measures are recommended to reduce the level to *No Impact*.

In addition, vibration impact is expected at those receptors located within 130 feet from the turnout P100B. The overall vibration criteria would be exceeded with this option by up to 4 VdB on residences located on La Brea Terrace (9 single-family homes) resulting in *Vibration Impact*. Vibration mitigation measures for the crossover P100B would be required to reduce the level of impact to *No Impact*.

Vibration levels from BART train operation on crossovers P103 and 104 would be below the FTA criterion. Consequently, no vibration mitigation measures would be necessary. Lower vibration levels are due to the distance to/from residences and the slower train operational speed on the dispatch track.

[8] Data Request for the Hayward Yard Project. Provided by BART – Data_Request2.doc

Hayward Yard

Activities from BART trains at the proposed East Storage area would be below the FTA criterion. Train movements are expected to occur at a lower speed and although the vibration would be higher than those on tangent track, based on the measured data for the crossover at the Hayward Yard, the adjusted vibration (adjusted for speed) would be below the FTA criterion resulting in *No Vibration Impact*. Consequently, no mitigation measures would be required.

Vibration Mitigation Measures

As discussed above, results of the vibration assessment for the HMC Project shows that vibration levels expected from BART operations on crossover switches would exceed the FTA criteria resulting in potential for *Vibration Impact*. Vibration mitigation measures are recommended to reduce the Project impact to *No Impact*.

The location of the mitigation measures under the track such as tire-derived aggregate (TDA) or floating slab track (FST) is presented in Table 13. The mitigation control should extend a minimum of 75 feet on both sides of the crossover frog to account for the length of one BART car. However, the actual extent of the mitigation control would be determined during final design. In addition to tire-derived aggregate and floating slab track, new measures to mitigate vibration may arise from new technology and may be found to be appropriate mitigation.

Tire-Derived Aggregate (TDA)

The use of shredded scrap tires as a vibration-isolating medium for rail is a relatively recent technology. TDA as a vibration reduction medium consists of construction with a compacted layer of shredded tires approximately 12 inches thick located below the sub-ballast and ballast layers of track. This system has been installed at selected locations on two transit systems, on the San Jose VTA Vasona Line and at Denver's TREX light rail line. Recent investigation indicates that the performance is more effective than a ballast mat, but less effective, particularly at lower frequencies when compared to the performance of a floating slab track-bed system.

The schematic of the typical extent recommended for TDA mitigation on the crossovers is shown in Figure 10. As indicated in the figure, vibration mitigation would be required on both frogs, and the minimum recommended is 100 feet before the point of switch. On the turnout P102, the minimum extent is 100 feet from the point of switch to the south and 100 feet to the north on both the main southbound track and the turnout track. The schematic of the vibration mitigation is indicated in Figure 11.

Floating Slab Tracks

This approach basically consists of a massive concrete slab supported on elastomeric elements, normally natural rubber. Several designs have been successfully used for heavy rail transit systems such as in Washington DC, Atlanta, Boston, Toronto and on the BART system. This specific design consists of precast concrete slabs that are normally 6-feet long and supported vertically on four natural rubber pads per slab. Each slab is held in place in the lateral direction by natural rubber "side pads" that bear against a curb constructed in a concrete bathtub (shallow retained cut). In the longitudinal direction, natural rubber pads separate adjacent slabs. All of the horizontal (lateral and longitudinal) restraint pads are pre-compressed during installation. One of the most significant design parameters of the floating slab track-bed is the fundamental natural frequency of the track-bed in the vertical direction. The appropriate floating slab natural frequency depends on the ground-borne vibration frequencies, which require reduction. Floating slab track-bed designs to date have been in the 8 to 16 Hz range.

Table 11 – Projected vibration levels from BART trains operations on the HMC for Phase 1

Location	Land Use	Dist. to closest XO (ft)	FTA Criterion	GBV from XO	Impact	# of Rec. with Impact
11th St between Stone St & Boyle St.	SFR	200	72	62	NI	0
11th St and Boyle St.	SFR	150	72	68	NI	0
La Brea Terrace	SFR	170	72	65	NI	0
Alicante Terrace	SFR	85	72	79	I	6
Carrara Terrace	SFR	90	72	78	I	4
Messina Terrace	SFR	---	72	----	NI	0
La Bonita Terrace	SFR	---	72	---	NI	0

Notes:
xo : crossover switch
GBV: Groundborne Vibration — NI : No Impact as defined by FTA
SFR: Single-family residence building — I : Impact as defined by FTA
Source: WIA 2010

Table 12 – Projected vibration levels from BART trains operations on the HMC for Phase 2

Location	Land Use	Dist. to closest XO (ft)	FTA Criterion	GBV from XO	Impact	# of Rec. with Impact
11th St between Stone St & Boyle St.	SFR	---	72	---	NI	0
11th St and Boyle St.	SFR	---	72	---	NI	0
La Brea Terrace	SFR	100	72	76	I	9
Alicante Terrace	SFR	220	72	59	NI	0
Carrara Terrace	SFR	80	72	80	I	7
Messina Terrace	SFR	120	70	70	NI	0
La Bonita Terrace	SFR	60	72	84	I	8

Notes:
xo : crossover switch
GBV: Groundborne Vibration — NI : No Impact as defined by FTA
SFR: Single-family residence building — I : Impact as defined by FTA
Source: WIA 2010

Table 13 – Recommended location of vibration mitigation for the HMC Project

Crossover #	Phase 1	Phase 2

P100B	No	Yes[1]
P100	No	No
P101	No	Yes [1]
P102	Yes[1]	No
P103	No	No
P104	No	No

Notes:
(1) Mitigation extent will be determined during final design.

Source: WIA 2010

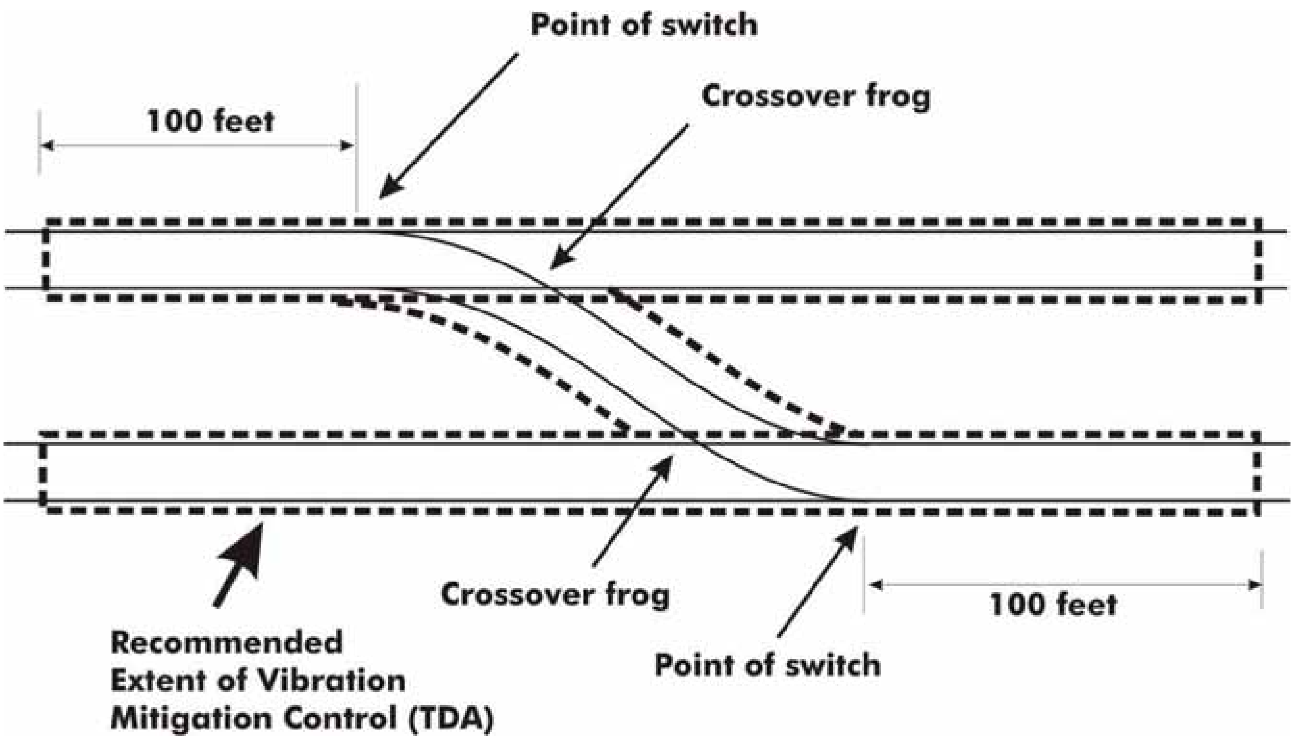

Figure 10 – Schematic of the vibration mitigation extent for Tire-Derived Aggregate (TDA) on crossover track

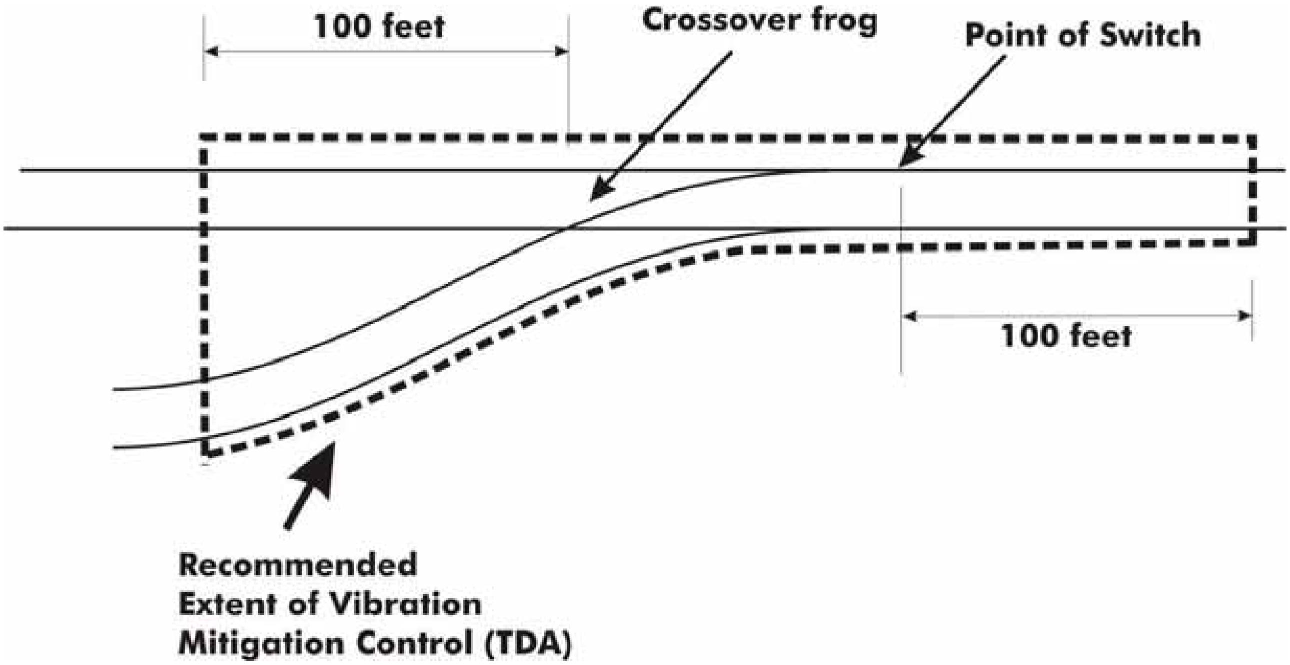

Figure 11 - Schematic of the vibration mitigation extent for Tire-Derived Aggregate (TDA) on crossover P102

Construction Noise and Vibration Impact Assessment

Construction of the BART HMC Project is proposed in two phases. Phase 1 construction includes all improvements related to the west side of the Hayward Yard. This would include demolition of one warehouse, replaced by a new Overhaul Shop, and construction of new tracks to connect the west side improvements to the BART mainline. Phase 1 would include some basic civil construction, such as grading, installing utilities, track work, and rail turnouts required for the storage tracks at both the west side of the Yard and south of Whipple Road. Of the switches south of Whipple Road, switches P100 and P102 would be installed in Phase 1. Phase 2 construction would include all improvements related to the east side of the Yard and the new east side storage tracks. This would include construction of the storage tracks, connecting tracks between the new storage tracks and the BART mainline tracks, third rail power, train control and one or both flyovers. Switches P100B, P101, P103 and P104 would be installed during Phase 2. Further, construction activities which involve the mainline tracks would be conducted during nighttime hours (10 pm to 7 am) to minimize interference with revenue train operations, while other construction activities, including preparation for construction involving mainline tracks, would generally be conducted within the daytime hours (7 am to 10 pm).

The primary variables and assumptions that were used for the noise and vibration construction models include:

- Phase 1 construction includes all work related to the west side of the Hayward Yard, including the new Overhaul Shop and associated crossovers and trackwork and a non-rail vehicle storage area.
- Phase 2 construction would implement work related to the east side of the Hayward Yard, including at least one flyover, new storage tracks, associated crossovers and trackwork and third rail power, communications, and train control systems.
- Construction work on the test track and storage areas would be performed during daytime hours. Construction work involving mainline tracks would be done during nighttime hours and weekends. Thus, new switch installation and flyover construction would typically be done during nights and weekends (Phase 1 and Phase 2). However, preparation for construction involving mainline tracks would be performed during daytime hours.
- There would be two staging areas, one located at the northeast end of the Hayward Yard and another at the southeast end of the Yard (currently used as a secured storage area).
- Construction areas north of Whipple Road would be accessed through the current Hayward Yard entrance on Whipple Road and through the driveway from Whipple Road to the four warehouse on the west side. Additionally, there would be three construction access points considered for construction activities south of Whipple Road: through the industrial property west of the BART mainline (south of Whipple Road), by the service road along the north side of Dry Creek, and from F Street.

Noise and Vibration Policies

BART criteria for assessing noise and vibration impact from construction activities are based on the FTA guidelines. FTA guidelines are presented in Table 14. The criteria are specified in terms of 8-hour equivalent noise level (L_{eq}) for residential, commercial and industrial land uses. The criterion for most land uses near the Project would be 80 dBA for daytime construction and 75 dBA for nighttime construction. The FTA guidelines also recommend that for urban areas with high ambient noise levels, such as the area in the vicinity of the Project, the construction noise should not exceed ambient noise +10 dBA.

Table 14 – Guidelines for Assessing Construction Noise Impact by FTA

	8-hour L_{eq} (dBA)	
Land Use	**Day**	**Night**
Residential	80	75
Commercial	85	80
Industrial	90	85

Source: FTA, May 2006.

The criteria for evaluating groundborne vibration due to construction activities are those specified in the FTA guidelines. The criteria have been divided into two categories: interference with human activity (annoyance) and building damage. The guidelines presented by FTA indicate that building damage would be the primary concern for evaluating construction activities, primarily due to the temporary nature of the activity. Nonetheless, both annoyance and potential building damage are evaluated herein. For evaluating potential annoyance due to construction vibration activities, the applicable criteria are the levels presented in Table 5 for the corresponding FTA land use category (e.g., Category 2 for residential homes).

Humans are sensitive to groundborne vibration at much lower levels than that which may cause structural damage or even cosmetic damage. Consequently, vibration levels associated with potential building damage are significantly higher than those used in assessing annoyance.

The FTA criteria relating to potential cosmetic cracking due to building vibration are presented in Table 15. The criteria are applicable in four categories, considering different building structures. Based on visual observation by WIA during the noise and vibration survey, most buildings could be included in the Category II as listed below in Table 15 with a threshold of 0.3 in/sec. No historic structures, which could be subject to Category IV criteria, have been identified in the vicinity of the Project.

Table 15 – FTA Construction Vibration Damage Criteria

Building Category	Peak Particle Velocity (PPV)
I. Reinforced-concrete, steel or timber (no plaster)	0.5 in/sec (12.7 mm/s)
II. Engineered concrete and masonry (no plaster)	0.3 in/sec (7.6 mm/s)
III. Non-engineered timber and masonry buildings	0.2 in/sec (5.1 mm/s)
IV. Buildings extremely susceptible to vibration damage	0.12 in/sec (3 mm/s)

Source FTA, 2006

Noise and Vibration Methodologies

Construction noise varies depending on the construction process, type of equipment involved, location of the construction site with respect to sensitive receptors, the schedule proposed to carry out each task (e.g., hours and days of the week) and the duration of the construction work. The assessment of potential significant noise effects due to construction of the BART HMC Project is based on the standards and procedures described in the FTA Guidance Manual and the Federal Highway Administration (FHWA) RCNM model[9]. This analysis of construction noise assumes that noise will decrease at a rate of 6 dB per doubling of the distance from the construction site.

There would be a number of noise sources associated with the proposed Project. Some of the equipment involved during construction of Phase 1 and Phase 2 of the project would include the use backhoes, pile drivers, mounted jack hammer (hoe ram), excavators, dozers, compactors, and vibratory rollers. Construction activities associated with track installation would include the use of cranes, rail saws, compressors, pumps, generators, a ballast regulator, and ballast tamper. Phase 2 would require the use of a pile driver for construction of the flyover(s).

Maximum noise levels and use factors presented in Table 16 were applied to estimate the potential negative effects due to construction activities. The table also shows the project phase where the equipment was assumed to be used.

Table 16 – Construction Equipment Noise Levels and Use Factor

Equipment	Acoustical Use Factor for Noise (percentage)	Typical Maximum Noise Level (L_{max}) at 50 feet from Source, dBA	Phase involved
Backhoe	40	78	1 & 2
Pile driver (sonic)	20	96	2
Compactor	20	83	1 & 2
Excavator	40	81	1 & 2
Dozer	40	82	1 & 2
Mounted Jack Hammer (hoe ram)	20	88	1
Pneumatic Tool	50	85	1 & 2
Concrete Pump Truck	20	81	1 & 2
Ballast Equalizer, Tamper	20	82 – 83	1 & 2
Rail saw	20	90	1 & 2
Vibratory Concrete Mixer	20	80	1 & 2
Crane	16	81	1 & 2

Sources: FHWA RCNM, January 2006 and FTA, May 2006, WIA 2010.

[9] Federal Highway Administration – *FHWA Roadway Construction Noise Model*. Final Report January 2006.

The analysis herein includes the noise effects from staging areas. Noise from construction staging areas is likely to be generated by trucks, cranes and other mobile and stationary equipment. There would be three staging areas, one located at the northeast end of the Hayward Yard, another at the southeast of the Yard, currently used as a secured storage area, and the third located at the undeveloped outdoor area near the new M&E shop.

The projected levels of noise generated by construction activities and construction staging areas were compared against the criteria presented in Table 15. Noise control measures were investigated and proposed for those areas where noise from construction activities is expected to exceed the recommended criteria.

The assessment of potentially significant impact due to construction-induced vibration for the Project is based on the standard procedures described in the FTA Guidance Manual. Construction vibration varies according to the construction procedure, type of equipment involved and location of the construction site with respect to sensitive receptors. Buildings in the vicinity of the construction activities respond to vibration differently depending primarily on their structural characteristics.

As for the noise analysis, the assessment for vibration impacts separately evaluates the use of heavy equipment during construction and the specialized equipment expected during track installation.

Table 17 shows the equipment assumed for this analysis. Vibration reference levels are presented in terms of the peak-particle velocity (PPV) and their approximate vibration level (i.e., in VdB), at a reference distance of 25 feet. The table only shows the equipment expected to have the greatest impact.

Vibration levels associated with each piece of equipment presented in Figure 12 were projected as a function of distance following the equation $PPV_{equip} = PPV_{ref} \times (25/D)^n$ in inch/sec, where D is the distance from the equipment (in feet) and n is a value related to the vibration attenuation rate through the ground. A value of n equal to 1.5 was used in the analysis.

Table 17 – Construction equipment vibration levels

Equipment	PPV at 25 feet (in/sec)	Approximate Vibration Velocity Level at 25 feet, VdB
Pile Driver (sonic)	0.730	105
Vibratory Roller	0.200	94
Hoe Ram	0.089	87
Large Bulldozer	0.090	87
Caisson Drilling	0.089	87
Jack Hammer	0.035	79

Source: FTA, May 2006 and WIA archives

In assessing interference with human activity (annoyance) due to construction, the vibration is characterized by the root-mean-square (r.m.s.) vibration level. The expected levels of vibration were projected by using the equation $L_v(D) = L_v(25ft) - 30\log(D/25)$ in VdB (ref: 1 micro-in-sec), where $L_v(25ft)$ is the reference vibration level measured at 25 feet, and D is the distance from the equipment in feet.

The projected levels of vibration generated by construction activities were compared to the applicable criteria. Generic forms of vibration control measures are presented in those areas where vibration from construction activities is expected to exceed the applicable criterion.

Figure 12 shows the expected PPV with distance for each method/piece of equipment evaluated. Similarly, Figure 13 shows the expected vibration levels as a function of distance for the equipment involved during construction.

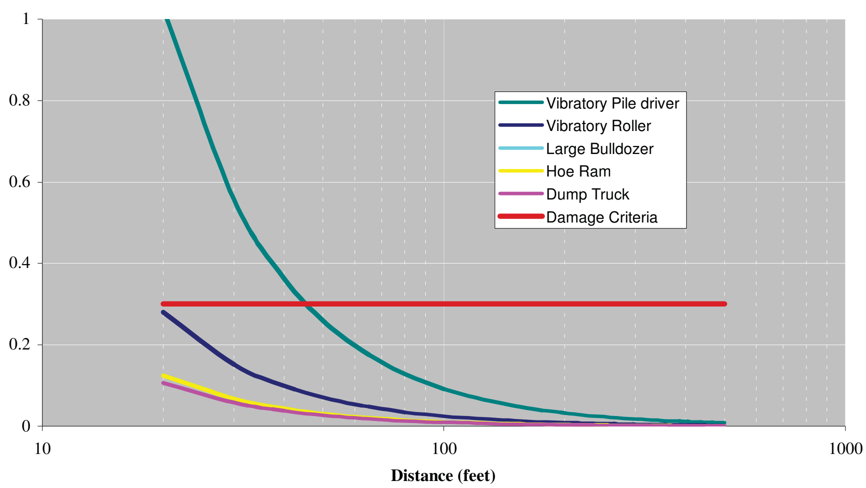

Figure 12 – Expected Ground Vibration (PPV) due to Construction Activities for the BART HMC Project

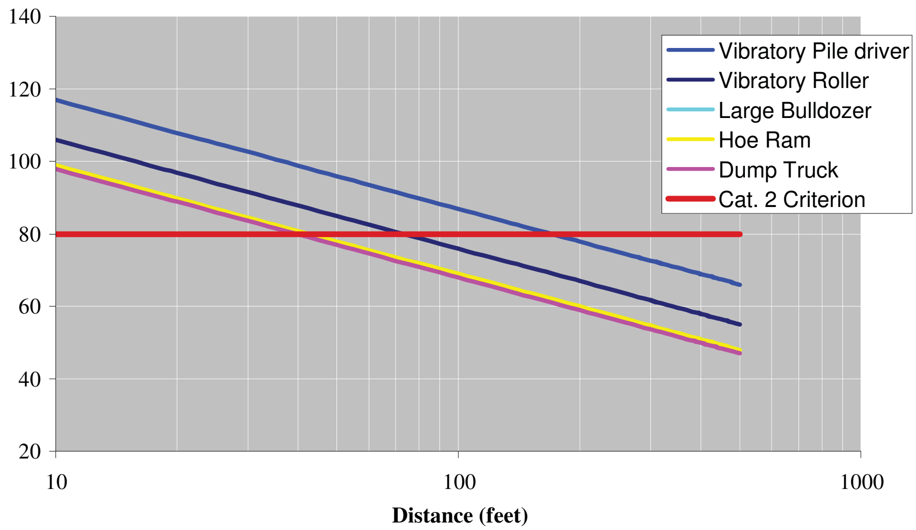

Figure 13 – Expected Vibration Levels (VdB) versus Distance due to Construction Activities for the BART HMC Project Vibration Impact Assessment

Projected Construction Noise and Vibration

Noise

Based on this preliminary analysis, noise levels during Project construction with the use of heavy equipment would typically range between 61 to 85 dBA, depending on the distance of the construction activity to the noise sensitive receptor.

Table 18 and Table 19 show the projected range of noise levels expected from the use of heavy equipment during construction and track installation for Phase 1 and Phase 2, respectively. The tables present the range of noise levels expected for each group of receptors. The expected effect of existing sound barriers at the Innovation Homes complex has been included for the noise calculations.

Heavy Equipment

Results of the analysis show that residential receptors located within 75 feet of heavy equipment would be exposed to a *Noise Impact* during daytime construction, assuming an unobstructed line of sight. This distance would be extended to 110 feet (unobstructed) if construction activities are executed during nighttime.

During Phase 1 construction, the typical noise levels from heavy equipment would range from 54 to 72 dBA at nearby sensitive receptors. As presented in Table 18, with the existing sound walls at Innovation Homes, *No Noise Impact* is expected. Residences located along 11th Street would receive *No Noise Impact* during construction of Phase 1.

During Phase 2, *No Noise Impact* is expected at the Innovation Homes development, again due to the effects of the existing sound wall. Residences located along Ithaca Street and Carroll Avenue would have *No Noise Impact* from heavy equipment.

Track Installation

The use of ballast tamping and ballast regulators would generate a *Noise Impact* for residences within 100 feet of daytime construction activities or within 190 feet of nighttime track-laying activities, including crossover switch installation.

During Phase 1, there would be *Noise Impact* at 3 homes on 11th Street and 17 homes at the Innovation Homes development during nighttime construction. These homes would experience noise levels up to 77 dBA and 75 dBA respectively.

For Phase 2, track installation activities would cause a nighttime Noise Impact for 32 homes at the Innovation Homes development during the nighttime hours where noise levels could reach 78 dBA even with the existing sound wall. Noise control measures are discussed for these homes. The East Storage tracks would not affect mainline operations, and thus track installation work would only be conducted during the daytime, with no noise impact for homes on Ithaca Street or Carroll Avenue.

Flyover Construction

One or both flyovers would be constructed during Phase 2 of the project, and the estimated noise from pile driving for the aerial structure is also shown in Table 19. We have assumed for the analysis herein, that the construction would use sonic or vibratory pile drivers, which in general produce lower noise levels than an impact pile driver. However, while vibratory pile drivers do not produce peak noise levels as high as impact pile drivers, they can generate high levels of noise if not shielded properly.

Pile driving is expected to exceed the FTA noise criteria for residential receptors only within 140 feet of operation. If pile driving is schedule at night, after 10 pm or earlier than 7 am, the area of *Noise Impact* could be extended up to 240 feet from the alignment right-of-way.

Pile driving would be expected to occur only during the daytime (which is the most likely situation). Moreover, based on the current alignment for the flyover option, pile driving would happen 400 feet or farther from the residential homes resulting in *No Noise Impact*.

Staging Areas

There would be a staging area proposed to the north and south of the Hayward Yard. Noise projected from the staging area would potentially cause a *Noise Impact* for sensitive receptors (e.g., single family homes) within 70 feet from the staging area’s property line during daytime hours and 110 feet during nighttime. The closest homes to either staging area would be located at least 150 feet from the nearest property line resulting in *No Noise Impact*.

Other Considerations

Trucks would be required to transport equipment, and supplies. The California Vehicle Code limits vehicle noise emission levels of new highway trucks built after 1987 to 80 dBA at a distance of 50 feet from the centerline of travel under any condition of operation, including acceleration and deceleration, in any gear. Older, noisier trucks may still be in use, but a reasonable approach to construction equipment noise control would be to specify that the contractor's trucks meet current regulations for new trucks.

For construction activities occurring north of Whipple Road, trucks would be accessing the Project area at the current access to the Hayward Yard on Whipple Road, which is approximately 150 feet from residences along Ithaca Street. Noise levels at residences could potentially reach up to 63 dBA resulting in *No Noise Impact*. For the purpose of calculations we have assumed about 20 trucks per hour (1 minute each).

Three construction access points are under consideration for activities occurring south of Whipple Road or for equipment that would be too large to go under the Whipple Road Bridge. The truck traffic considered from any of the three access points would be very low, on the order of 5 to 6 trucks per day. Noise levels at residences located north of the Dry Creek would experience the highest noise levels from truck traffic for the three access points in consideration. However, hourly noise levels would be on the order of 57 dBA or lower resulting in *No Noise Impact*. If the access option from F Street is selected, a temporary access road may need to be constructed along the west side of the BART mainline. The distance to the nearest sensitive receptors would be 50 feet or farther from truck operation, resulting in a noise level below 50 dBA and therefore *No Noise Impact*.

As a practical matter, new diesel trucks produce markedly lower noise levels during normal operation than those allowed by the Vehicle Code. Trucks would also idle as they are loaded and unloaded. We have assumed that trucks would idle for no more than 5 minutes (a more restrictive time limit may be imposed for air quality); trucks that sit in place for longer than 5 minutes should turn off their engines.

Audible backup alarms on moving equipment may generate neighborhood complaints because the sound of the alarm is tonal, since it is meant to be heard and to attract attention. Backup alarms for haul trucks must be audible above the surrounding ambient noise level at a distance of up to 200 feet[10]. In areas of high ambient noise or congested traffic, a motion-detected braking system or administrative controls such as flaggers/observers may be used in lieu of an audible alarm[11]. The characteristics of the alarm tone means that backup alarms are often designed to be higher than the ambient, typically by at least 5 dBA. Many alarms are preconfigured to be higher than a worst-case construction/industrial operating environment by 10 to 15 dBA. Thus, since the construction noise environment at 50 feet behind any piece of moving machinery may be as high as 70 to 90 dBA, backup alarms are typically designed to emit a sound as loud as 85 to 115 dBA. Some alarm devices measure the ambient noise level and adjust their output accordingly. One example is a "smart alarm" which adjusts the alarm level so that it is 5 dBA above the ambient, with a range of 77 to 97 dBA. An alarm level of 97 dBA would correspond to a noise level of 63 dBA at a distance of 200 ft[12]. If truck operations are proposed during the nighttime hours, alternative measures such as strobe lights or administrative controls (i.e. Flag person) can be used to replace audible backup alarms. The contractor should be precluded from using audible backup alarms at night, if at all feasible.

[10] California Occupational Safety and Health Administration, Title 8, Section 1592(a)
[11] Cal-OSHA, Title 8, Section 1592(b)
[12] SAE J994-2003 Standard specifies that alarm noise levels are measured at a distance of 1.2 m (4 ft).

Vibration Construction Assessment

Two types of potential construction-induced vibration effects were evaluated for the BART HMC Project: *Annoyance* and *Building Damage*. The criterion used in assessing annoyance is contained in the FTA guidance manual and presented in the operational analysis section. The criteria relating to potential cosmetic damage (i.e., cracking) due to building vibration is 0.3 in/sec PPV based on the FTA guidelines.

Annoyance from construction activities would likely occur at 55 sensitive receptors in the vicinity of the Project (34 of which occur for both Phase 1 and Phase 2 of the Project), that are located within 100 feet of any heavy equipment. Specifically, vibration annoyance would be expected during installation of crossover P100 and P102 at residences located on La Brea Terrace, Alicante Terrace, and Carrara Terrace (26 homes, Phase 1), and installation of crossover P100B, P101, P103 and P104 at residences located on La Brea, Carrara Terrace, Messina Terrace, and La Bonita Terrace (29 homes, Phase 2).

The use of heavy equipment during construction of the Project would generate peak velocity levels that would be well below the threshold of cosmetic damage. Consequently, construction of the Project would result in *No Vibration Impact* from equipment or activities that would potentially cause building damage. Refer to Table 20 and Table 21.

Flyover Construction

Vibration velocity levels during pile driving (vibratory pile driver) would be 0.02 in/sec PPV or lower at all residences in the vicinity of the project. The use of a pile driver during construction of the north and south elevated structures (flyovers) could potentially generate annoyance to receptors located within 220 feet of the activity. A similar vibration magnitude is also expected from heavy, dropped objects or handling of heavy plates in the work areas, although these would be very infrequent. Potential for building damage would be expected from pile driving activities located 50 feet or closer to any building. It is expected that the closest distance between pile driving and homes would be 300 feet. Table 21 shows the expected vibration levels from construction activities using heavy equipment for Phase 2. The highest PPV is expected during vibratory compaction at a level that would be 0.04 in/sec PPV which is well below the 0.3 in/sec criterion. Consequently, there would be no potential for building damage from construction of the flyover option, resulting in *No Vibration Impact.*

Construction Noise and Vibration Control Measures

This section discusses recommended noise and vibration control measures to reduce impacts due to the Project. Control measure recommendations are presented separately for each source and/or phase of the project.

As presented in the previous section, due to the duration of construction activities for the Project, a *Vibration Impact* would be expected only where construction activities exceed the threshold for building damage. However, some vibration control policies are recommended to be implemented by the contractor to minimize the potential annoyance on nearby residential properties.

Noise

To eliminate construction noise impacts, construction activities should be performed in accordance with the criteria presented in Table 14 of this report. However, as discussed in this analysis, it may not be possible to comply with the criteria with the use of typical construction equipment. A noise barrier, as discussed below, would eliminate the construction noise impact for homes on 11th Street (Phase 1 nighttime track installation), but additional control measures would be required for the Phase 2 nighttime track installation impacts at the Innovation Homes complex; for these homes, the nighttime noise could exceed the criterion, but these measures would mitigate the effects of the noise. The following noise control measures are recommended for incorporation into the construction phase of Project:

- Where feasible, require the Contractor to comply with a Performance Standard of 80 dBA 8-hour Leq during the daytime and 75 dBA 8-hour Leq during the nighttime at the property line of the sensitive receptor.
- Prior to construction, require the Contactor to prepare a Noise Control and Monitoring Report, in which the contractor indicates what noise levels they expect to generate, noise control measures they intend to implement, and how they intend to monitor and document construction noise and complaints.
- Locate noisy equipment as far as possible from noise sensitive receptors. In addition, the use of temporary barriers should be employed around the equipment.
- Use temporary noise barriers along the working area and or project right-of-way. Barriers/curtains must achieve a Sound Transmission Class (STC) of 30 or greater in accordance with ASTM Test Method E90 and be constructed from material having a surface density of at least 4 lb/sq. ft. to ensure adequate transmission loss.
- When nighttime or 24-hour construction will be required, BART and the contractor shall coordinate with residents to ensure that the affected residents are fully informed about the upcoming construction. Residents will be given the option of sleeping in hotel rooms at BART expense for the duration of the nighttime construction in areas where construction is expected to exceed the FTA criterion. Residents that work nights and sleep days in locations where construction noise is expected to exceed the FTA criterion will be given the same option.
- Require ambient sensitive (“smart”) backup alarms, SAE Class D, or limit to SAE Class C (97 dB) for vehicles over 2.5 cubic yard haulage capacity, or Cal-OSHA/DOSHA-approved methods that avoid backup noise for vehicles under 2.5 cubic yard haulage capacity.
- Fit silencers to combustion engines. Ensure that equipment has effective, quality mufflers installed, in good working condition.
- Switch off engines or reduce to idle when not in use.
- Lubricate and maintain equipment regularly. Well-maintained equipment is normally quieter than a non-maintained one.
- Construction-related truck traffic should be re-routed along roadways that would produce the least disturbance to sensitive receptors.

Vibration

No permanent vibration impacts have been indicated, but the construction could cause temporary annoyance during construction activities when heavy equipment is used. To avoid vibration-induced annoyance due to construction activities, the vibration associated with these activities should be kept below the annoyance criteria. The contractor should be encouraged to select equipment and methods that would reduce potential for building damage and also annoyance to nearby residents. Some recommended vibration controls include:

- Require the Contractor to comply with a Performance Standard of 0.3 in/sec PPV any building at any time.
- Encourage the Contractor to minimize vibration annoyance by maintaining vibration levels at 80 VdB or less at any building at any time.
- Prior to construction, require the Contactor to prepare a Vibration Control and Monitoring Report, in which the contractor indicates what vibration levels they expect to generate, vibration control measures they intend to implement, and how they intend to monitor and document construction vibration and complaints.
- Avoid the use of impact pile drivers. Instead favor the use of sonic or vibratory impact driver. It is also encouraged to use “quiet” or “silent” piling technologies, if it is possible to implement.
- When nighttime or 24-hour construction will be required BART and the contractor shall coordinate with residents to ensure that the affected residents are fully informed about the upcoming construction. Residents will be given the option of sleeping in hotel rooms at BART expense for the duration of the nighttime construction in areas where construction is expected to exceed the FTA criterion. Residents that work nights and sleep days in locations where construction vibration is expected to exceed the FTA criterion will be given the same option.
- Monitor vibration during construction to ensure compliance with the criterion for building damage for buildings within 40 feet from construction activities. Conduct a pre-construction crack survey at these structures.
- Plan routes for hauling material out of the Project site that would cause the least annoyance.
- High amplitude vibration methods such as vibratory pile driving and soil compaction using large truck-mounted compactors should be restricted to areas beyond 50 feet and 20 feet respectively of residential structures or wood-framed buildings. Otherwise, temporary accommodations away from construction should be coordinated between BART and the residents.

Table 18 – Projected Noise Levels and Impacts from Using Heavy Equipment during Phase 1 Construction (West Side and New Shop)

					Expected Noise Levels from Heavy Equipment Construction and Track Installation Without Noise Control, L_{eq} (dBA)									
	Dist. to Const. (ft)		Criteria		Heavy Equipment					Track Installation				
							Impact Type					Impact Type		
Location	Nearest	Farthest	Day	Night	Nearest	Farthest	Day	Night	# Impacts	Nearest	Farthest	Day	Night	# Impacts
11th between D & Stone St	500	500	80	75	62	62	NI	NI	0	66	66	NI	NI	0
11th between Stone St & Boyle St	400	400	80	75	64	64	NI	NI	0	68	68	NI	NI	0
11th between and Boyle St	150	300	80	75	72	66	NI	NI	0	77	71	NI	I	3
La Brea Terrace	170	550	80	75	64	54	NI	NI	0	69	59	NI	NI	0
Alicante Terrace	85	550	80	75	70	54	NI	NI	0	75	59	NI	I	9
Carrara Terrace	85	500	80	75	70	55	NI	NI	0	75	60	NI	I	8
Messina Terrace	120	250	80	75	67	61	NI	NI	0	72	66	NI	NI	0
La Bonita Terrace	150	350	80	75	65	65	NI	NI	0	70	63	NI	NI	0
Ithaca Street between Whipple Rd and Carroll Ave	540	650	80	75	61	59	NI	NI	0	66	64	NI	NI	0
Carroll Ave between Troy Place and Gressel St.	540	650	80	75	61	59	NI	NI	0	66	64	NI	NI	0
Carroll Ave between Gressel St. and Becker Place	540	650	80	75	61	59	NI	NI	0	66	64	NI	NI	0
Carroll Ave between Becker Place and Fairway Street	660	660	80	75	59	59	NI	NI	0	64	64	NI	NI	0
Carroll Avenue north of Fairway Street	660	660	80	75	59	59	NI	NI	0	64	64	NI	NI	0

Notes
Day: from 7 am to 10 pm
Night: from 10 pm to 7 am.
I : Impact
NI: No Impact.

Source: WIA 2010

Table 19 – Projected Noise Levels and Impacts from Using Heavy Equipment during Phase 2 Construction (East Side and Flyovers)

					Expected Noise Levels from Heavy Equipment Construction and Track Installation Without Noise Control, L_{eq} (dBA)														
	Dist. to Const. (ft)		Criteria		Heavy Equipment									Track Installation					
							Impact Type					Impact Type				Impact Type			
Location	Nearest	Farthest	Day	Night	Nearest	Farthest	Day	Night	# Impacts	Dist. to pile driving	Level	Day	Night	Nearest	Farthest	Day	Night	# Impacts
11th between D & Stone St	500	500	80	75	62	62	NI	NI	0	2600	55	NI	NI	66	66	NI	NI	0
11th between Stone St & Boyle St	320	320	80	75	66	66	NI	NI	0	2400	55	NI	NI	70	70	NI	NI	0
11th between and Boyle St	350	500	80	75	65	62	NI	NI	0	2200	56	NI	NI	69	66	NI	NI	0
La Brea Terrace	75	250	80	75	71	61	NI	NI	0	1500	59	NI	NI	76	66	NI	NI	0
Alicante Terrace	180	300	80	75	64	59	NI	NI	0	1300	61	NI	NI	69	64	NI	I	9
Carrara Terrace	80	300	80	75	71	59	NI	NI	0	1000	63	NI	NI	76	64	NI	I	8
Messina Terrace	60	300	80	75	73	59	NI	NI	0	600	67	NI	NI	78	64	NI	I	7
La Bonita Terrace	60	250	80	75	73	61	NI	NI	0	400	71	NI	NI	78	66	NI	I	8
Ithaca Street between Whipple Rd and Carroll Ave	150	400	80	75	72	64	NI	NI	0	400	71	NI	NI	77	68	NI	n/a*	0
Carroll Ave between Troy Place and Gressel St.	150	350	80	75	72	65	NI	NI	0	400	71	NI	NI	77	69	NI	n/a*	0
Carroll Ave between Gressel St. and Becker Place	200	300	80	75	70	66	NI	NI	0	300	73	NI	NI	74	71	NI	n/a*	0
Carroll Ave between Becker Place and Fairway Street	150	400	80	75	72	64	NI	NI	0	350	72	NI	NI	77	68	NI	n/a*	0
Carroll Avenue north of Fairway Street	150	350	80	75	72	65	NI	NI	0	1400	60	NI	NI	77	69	NI	n/a*	0

Notes
Day: from 7 am to 10 pm
Night: from 10 pm to 7 am
I : Impact
NI: No Impact.
n/a*: Not Applicable. Since track installation activities in this area would not affect the mainline and would thus be conducted during the daytime, no nighttime noise impact has been evaluated.

Source: WIA 2010

Table 20 – Summary of Vibration Induced by Heavy Equipment during Phase 1 Construction

Location	Distance (feet)	Land Use	Vibration Criteria		Projected Maximum Vibration during Heavy Equipment Construction				
			Building Damage (in/sec)	Annoyance VdB, re: 1 micro-in/sec	Bldg Damage			Annoyance	
					PPV (in/sec)	Impact Type	# of Imp.	Vibration Level, VdB	Exceed Criterion
11th between D & Stone St	500	SFR	0.3	80	< 0.01	NI	0	58	No
11th between Stone St & Boyle St	400	SFR	0.3	80	< 0.01	NI	0	61	No
11th between and Boyle St	150	SFR	0.3	80	< 0.01	NI	0	74	No
La Brea Terrace	170 – 550	SFR	0.3	80	≤ 0.03	NI	0	57 – 72	Yes
Alicante Terrace	85 – 550	SFR	0.3	80	≤ 0.03	NI	0	57 – 81	Yes
Carrara Terrace	85 – 500	SFR	0.3	80	≤ 0.03	NI	0	58 – 81	Yes
Messina Terrace	120 – 250	SFR	0.3	80	≤ 0.02	NI	0	67 – 77	No
La Bonita Terrace	150 – 350	SFR	0.3	80	≤ 0.01	NI	0	63 – 74	No
Ithaca Street between Whipple Rd and Carroll Ave	540 – 660	SFR	0.3	80	< 0.01	NI	0	55 – 57	No
Carroll Ave between Troy Place and Gressel St.	540 – 660	SFR	0.3	80	< 0.01	NI	0	56 – 57	No
Carroll Ave between Gressel St. and Becker Place	540 – 660	SFR	0.3	80	< 0.01	NI	0	55 – 57	No
Carroll Ave between Becker Place and Fairway Street	660	SFR	0.3	80	< 0.01	NI	0	54	No
Carroll Avenue north of Fairway Street	660	SFR	0.3	80	< 0.01	NI	0	45	No

Notes
SFR: Single-family residence
NI : No Impact as per FTA
I : Impact as per FTA

Source: WIA 2010

Table 21 – Summary of Vibration Induced by Heavy Equipment during Phase 2 Construction

Location	Distance (feet)	Land Use	Vibration Criteria		Projected Maximum Vibration during Heavy Equipment Construction				
					Bldg Damage			Annoyance	
			Building Damage (in/sec)	Annoyance VdB, re: 1 micro-in/sec	PPV (in/sec)	Impact Type	# of Imp.	Vibration Level, VdB	Temporary Exceedance
11th between D & Stone St	500	SFR	0.3	80	≤ 0.02	NI	0	58	No
11th between Stone St & Boyle St	320	SFR	0.3	80	≤ 0.02	NI	0	64	No
11th between and Boyle St	350 – 500	SFR	0.3	80	≤ 0.02	NI	0	58 – 63	No
La Brea Terrace	75 – 250	SFR	0.3	80	≤ 0.04	NI	0	65 – 83	Yes
Alicante Terrace	180 – 300	SFR	0.3	80	≤ 0.01	NI	0	65 – 71	No
Carrara Terrace	80 – 300	SFR	0.3	80	≤ 0.03	NI	0	65 – 82	Yes
Messina Terrace	60 – 300	SFR	0.3	80	0.01 – 0.05	NI	0	67 – 86	Yes
La Bonita Terrace	60 – 250	SFR	0.3	80	0.01 – 0.05	NI	0	67 – 86	Yes
Ithaca Street between Whipple Rd and Carroll Ave	150 – 400	SFR	0.3	80	≤ 0.01	NI	0	61 – 74	No
Carroll Ave between Troy Place and Gressel St.	150 – 350	SFR	0.3	80	≤ 0.01	NI	0	63 – 74	No
Carroll Ave between Gressel St. and Becker Place	200 – 300	SFR	0.3	80	≤ 0.01	NI	0	65 – 70	No
Carroll Ave between Becker Place and Fairway Street	150 – 400	SFR	0.3	80	≤ 0.01	NI	0	61 – 74	No
Carroll Avenue north of Fairway Street	150 – 350	SFR	0.3	80	≤ 0.01	NI	0	63 – 74	No

Notes
SFR: Single-family residence
NI : No Impact as per FTA
I : Impact as per FTA

Source: WIA 2010

Appendix A Long-term Noise Survey Plots

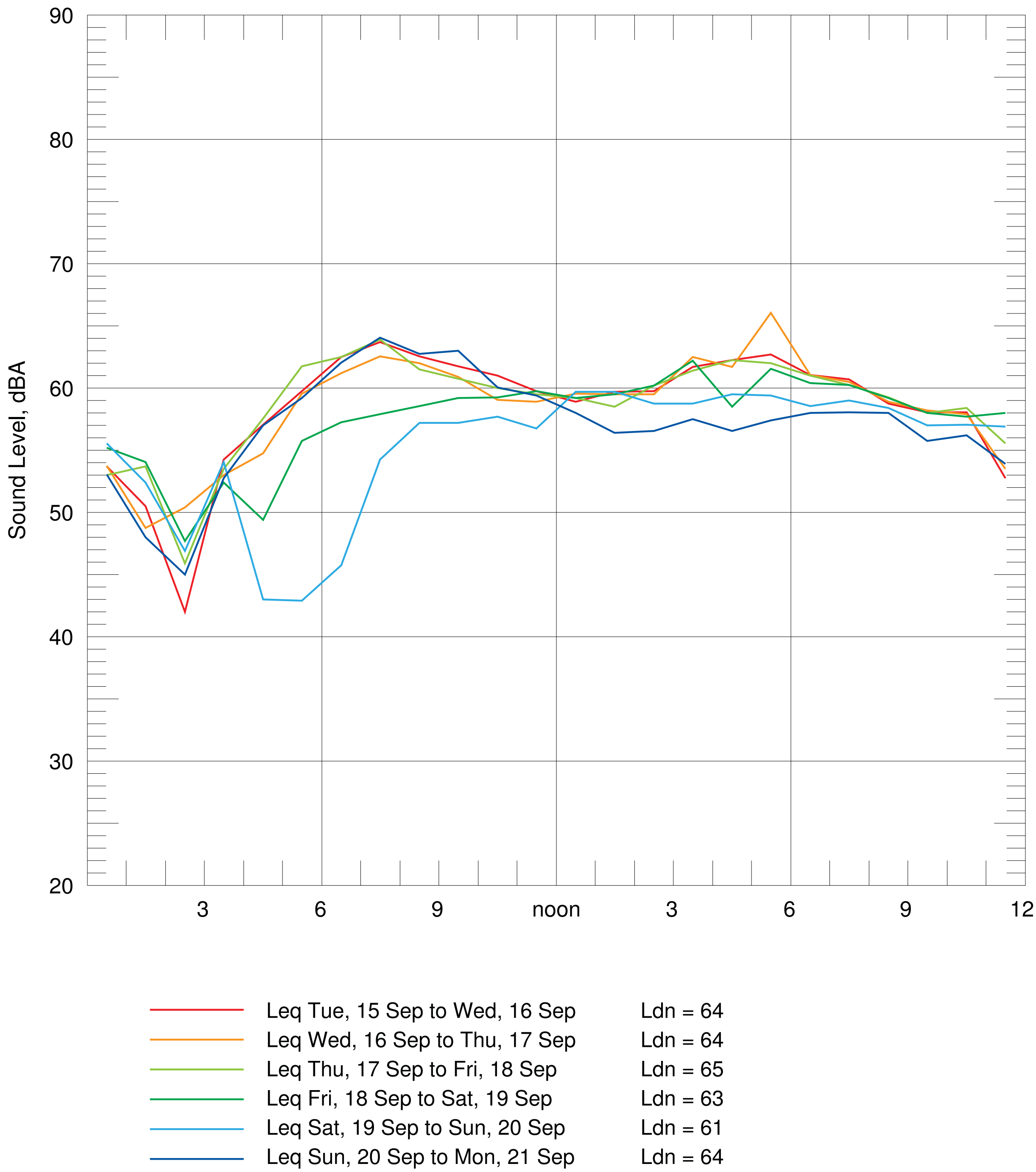

Figure A- 1 – Summary of the hourly equivalent noise level obtained at location N1 for six consecutive days.

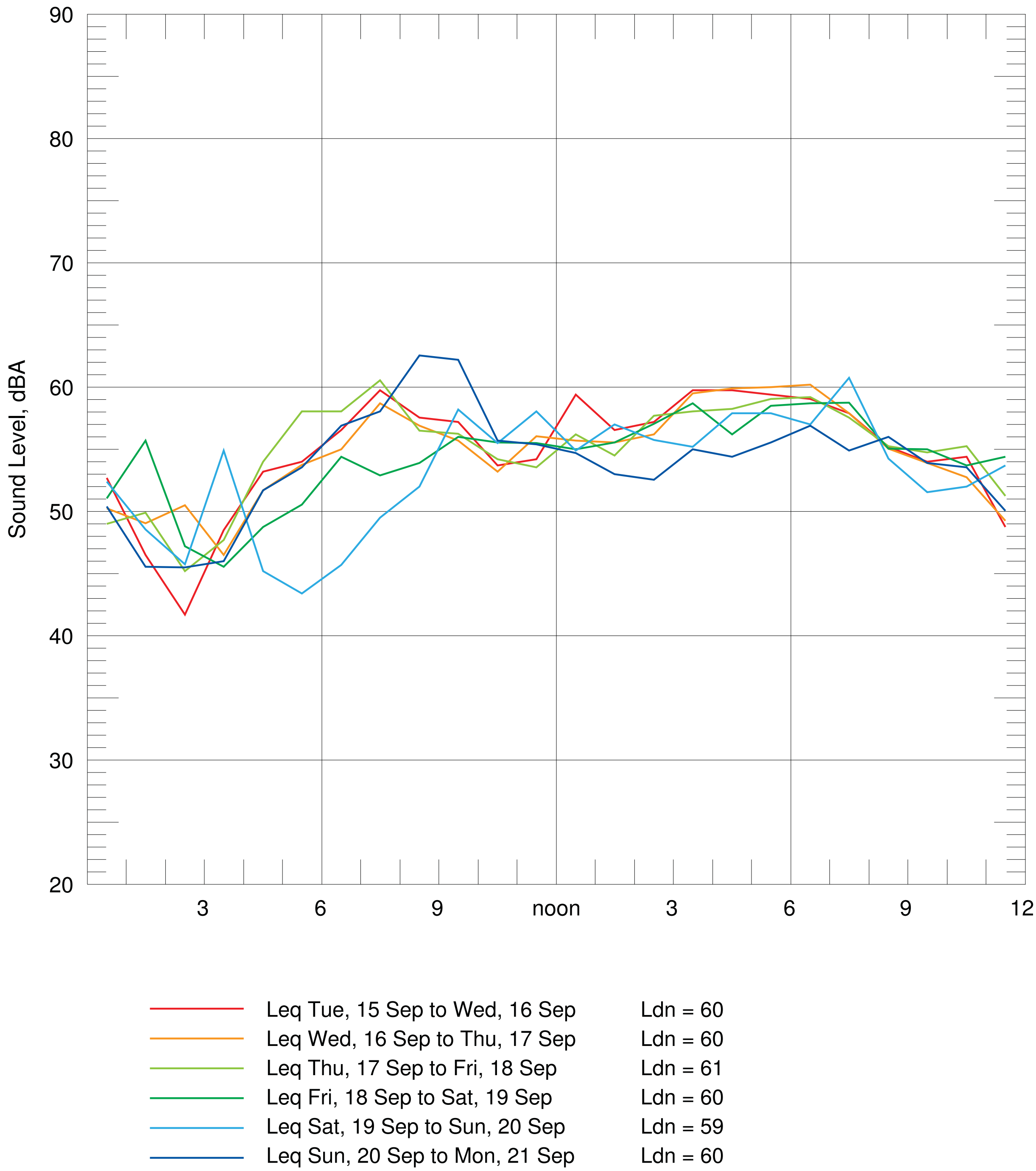

Figure A- 2 – Summary of the hourly equivalent noise level obtained at location N2 for six consecutive days.

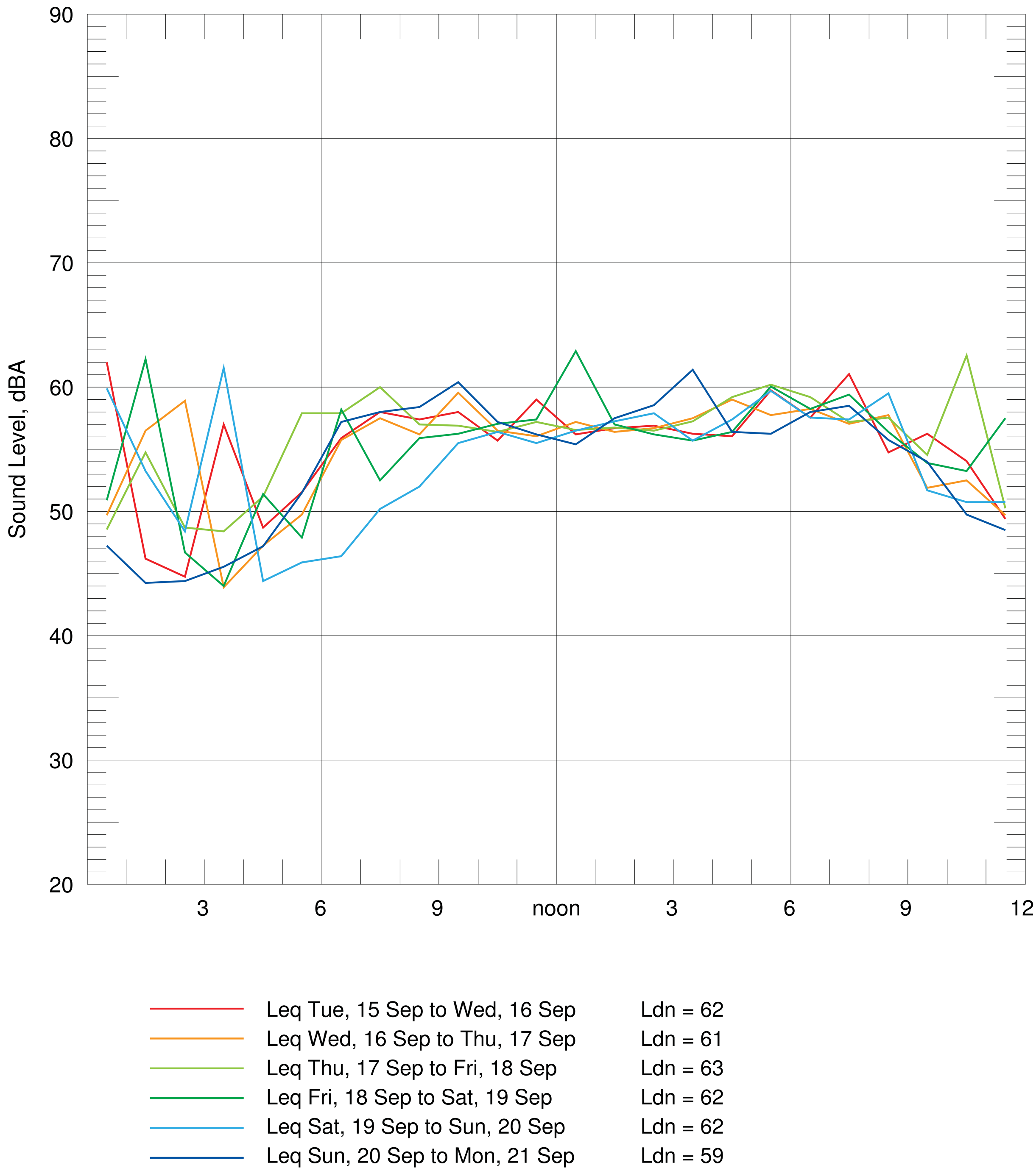

Figure A- 3 – Summary of the hourly equivalent noise level obtained at location N3 for six consecutive days.

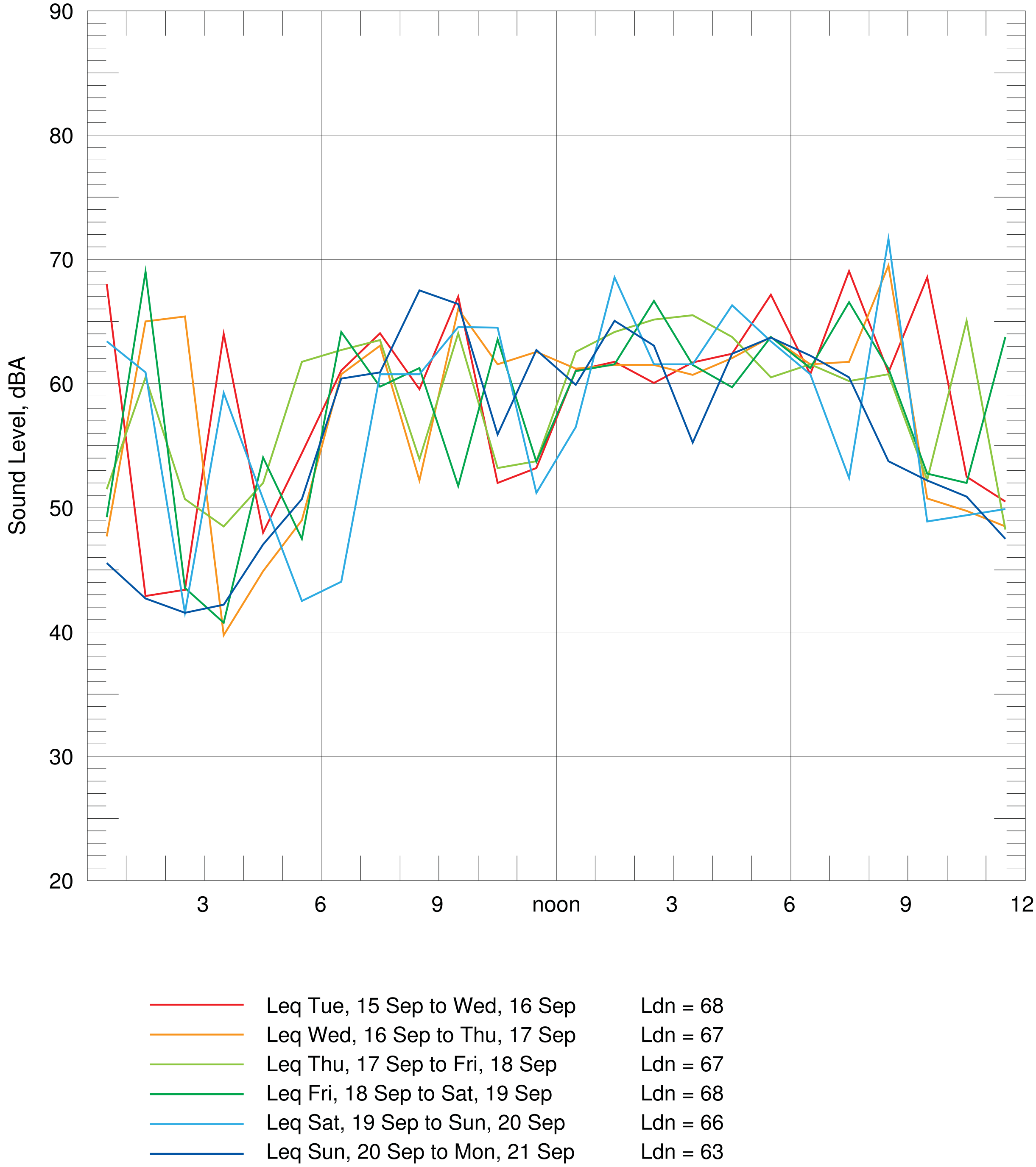

Figure A- 4 – Summary of the hourly equivalent noise level obtained at location N4 for six consecutive days.