Chapter 8. Appendices

Appendix A: Noise and Vibration Analysis

ATSConsulting
acoustics, transportation + strategy

M E M O R A N D U M

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Subject: Noise and Vibration Analysis for the Supplemental EIR No. 2

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1. INTRODUCTION

This memorandum presents a noise and vibration analysis of design refinements that have taken place since the completion of the 2007 Gold Line Phase II Final Environmental Impact Report (FEIR) and the 2011Gold Line Supplemental Environmental Impact Report No. 1 (SEIR 1) were published.

The design refinements addressed in this memorandum are:

- Duarte Eastbound Sound Wall 1: The 2007 FEIR recommends a sound wall in Duarte from station 1129+50 to 1133+00. The noise prediction and thresholds were updated to reflect current conditions. No impact is predicted in that area and no mitigation is necessary to comply with the FTA noise criteria.
- Additional TPSS units: New sites were proposed for TPSS units in the corridor. The Metro Design Criteria for Ancillary Equipment was compared to several noise thresholds. There will be no noise impact from the TPSS units if the Metro Design Criteria is met.
- Relocation of Duarte parking facility: There is a new proposed location for the parking facility in Duarte. The new location is farther from noise sensitive receivers, so there is no noise impact from the relocation. A 24-hour noise measurement was conducted at the nearest noise sensitive receiver to determine the existing noise conditions in that area.
- Azusa Vibration Impact: Predicted vibration levels with mitigation presented in the FEIR and the subsequent analysis ("*Updated Vibration Predictions for Metro Gold Line Phase 2A, Pasadena to Azusa*" dated November 17, 2010 prepared by ATS Consulting) exceed the FTA criteria at one location in Azusa. Mitigation options that would eliminate the impact are discussed. In addition, a 24-hour noise measurement was made to update existing noise conditions in that area.

Consistent with the 2007 FEIR, all analyses in this memorandum use the Federal Transit Administration (FTA) noise prediction procedures and impact criteria[*]. However, the FTA updated the vibration impact criteria in May 2006. The updated criteria specify limits in terms of the maximum vibration level in any 1/3 octave band rather than as an overall vibration limit. This updated criteria is applied to the vibration impact identified in Azusa.

1.1 Background on Environmental Noise

Noise is typically defined as unwanted or undesirable sound, where sound is characterized by small air pressure fluctuations above and below the atmospheric pressure. The basic parameters of environmental noise that affect human response to sound are the following:

1. Intensity or level,
2. Frequency content, and
3. Variation with time.

Intensity is determined by how greatly the sound pressure fluctuates above and below the atmospheric pressure, and is expressed on a logarithmic scale in units of decibels (dB). By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 dB. On a relative basis, a

[*] *Transit Noise and Vibration Impact Assessment*, Report FTA-VA-90-1003-06, May 2006.

3-dB change in sound level generally represents a noticeable change in loudness, whereas a 10-dB change is typically perceived as a doubling (or halving) in the loudness of a sound.

The frequency content of noise is related to the tone or pitch of the sound, and is expressed based on the rate of the air pressure fluctuations in cycles per second called hertz (Hz). The human ear can detect frequencies from about 20 Hz to 17,000 Hz; however, the sensitivity of human hearing varies with frequency. The A-weighting system is commonly used when measuring environmental noise to which humans are most sensitive. Sound levels measured using this weighting system are called "A-weighted" sound levels and are expressed as "dBA."

Figure 1 includes examples of A-weighted sound levels from common indoor and outdoor sounds.

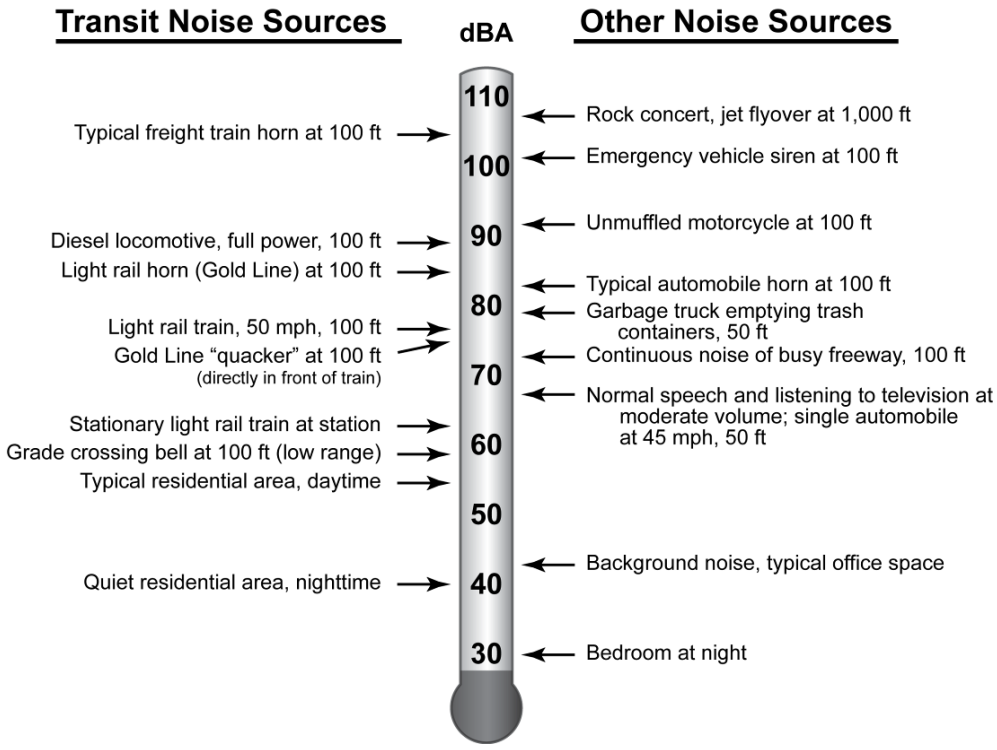

Figure 1: Typical Indoor and Outdoor Noise Levels

Environmental sound constantly fluctuates and can be expressed using many different metrics. The metrics used in this report to characterize varying sound environments are:

- **Maximum Sound Level (Lmax)** is the maximum sound level that occurs during an event such as a train passing.
- **Equivalent Sound Level (Leq)** is the most common means of characterizing fluctuating community noise. Leq represents a constant sound that, over a specified period of time, has the same sound energy as the time-varying sound. Leq is used by the FTA to evaluate noise effects at institutional land uses—such as schools, churches, and libraries—from proposed transit projects.

- **Day-Night Sound Level (**Ldn**)** is basically a 24-hour Leq with an adjustment to reflect the greater sensitivity of most people to nighttime noise. The adjustment is a 10 dB penalty for all sound that occurs between the hours of 10:00 p.m. to 7:00 a.m., which means that any event occurring during the nighttime is equivalent to 10 occurrences of the same event during the daytime. Ldn is the most common measure of total community noise over a 24-hour period and is used by the FTA to evaluate residential noise effects from proposed transit projects.
- **Percent Exceedance Level (LXX)** is the sound level that is exceeded for a certain percentage of the measurement period (e.g., L99 is the sound level exceeded during 99 percent of the measurement period). For a 1-hour period, L99 is the sound level exceeded for all except 36 seconds of the hour. L1 represents typical maximum sound levels, L_{33} is approximately equal to Leq when free-flowing traffic is the dominant noise source, L50 is the median sound level, and L99 is close to the minimum sound level.
- **Sound Exposure Level (SEL)** is a measure of the acoustic energy of an event such as a train passing. In essence, the acoustic energy of the event is compressed into a 1-second period. SEL increases as the sound level of the event increases and as the duration of the event increases. It is often used as an intermediate value in calculating overall metrics such as Leq and Ldn.

1.2 FTA Noise Impact Criteria

The FTA noise impact criteria is a sliding scale that is based on the existing noise exposure at the sensitive receiver. The basic concept of the sliding scale is that more project noise is allowed in areas where existing noise is higher, but the allowable increase above the existing noise exposure decreases as the existing noise exposure increases.

The criteria are shown graphically in Figure 2 for the three land use categories along with an example of how the criteria are applied. The top two graphs show the Category 1 and 3 thresholds, used for nonresidential land uses, where Leq is applied as the noise exposure metric. The bottom left graph shows Category 2 thresholds, used for residential land uses, where Ldn is applied as the noise exposure metric.

The concept of a sliding scale for noise impact can be difficult to grasp and may be clarified by the example illustrated in the bottom right graph of Figure 2. Assume that the existing day-night noise level (Ldn) has been measured to be 60 dBA. This is the total noise from all existing noise sources over a 24-hour period: traffic, aircraft, lawnmowers, birds chirping, etc. Starting at 60 dBA on the horizontal axis, follow the vertical line up to where it intersects with the moderate and severe impact curves. Then refer to the left axis to read off the impact thresholds. As shown in the example, an existing noise level of 60 dBA Ldn gives thresholds of 58 dBA for moderate impact and a 63 dBA for severe impact. If the predicted increase in noise exceeds the moderate threshold, noise mitigation must be considered. If the predicted increase exceeds the severe threshold, noise mitigation must be included in the project unless there are compelling reasons why mitigation is unfeasible.

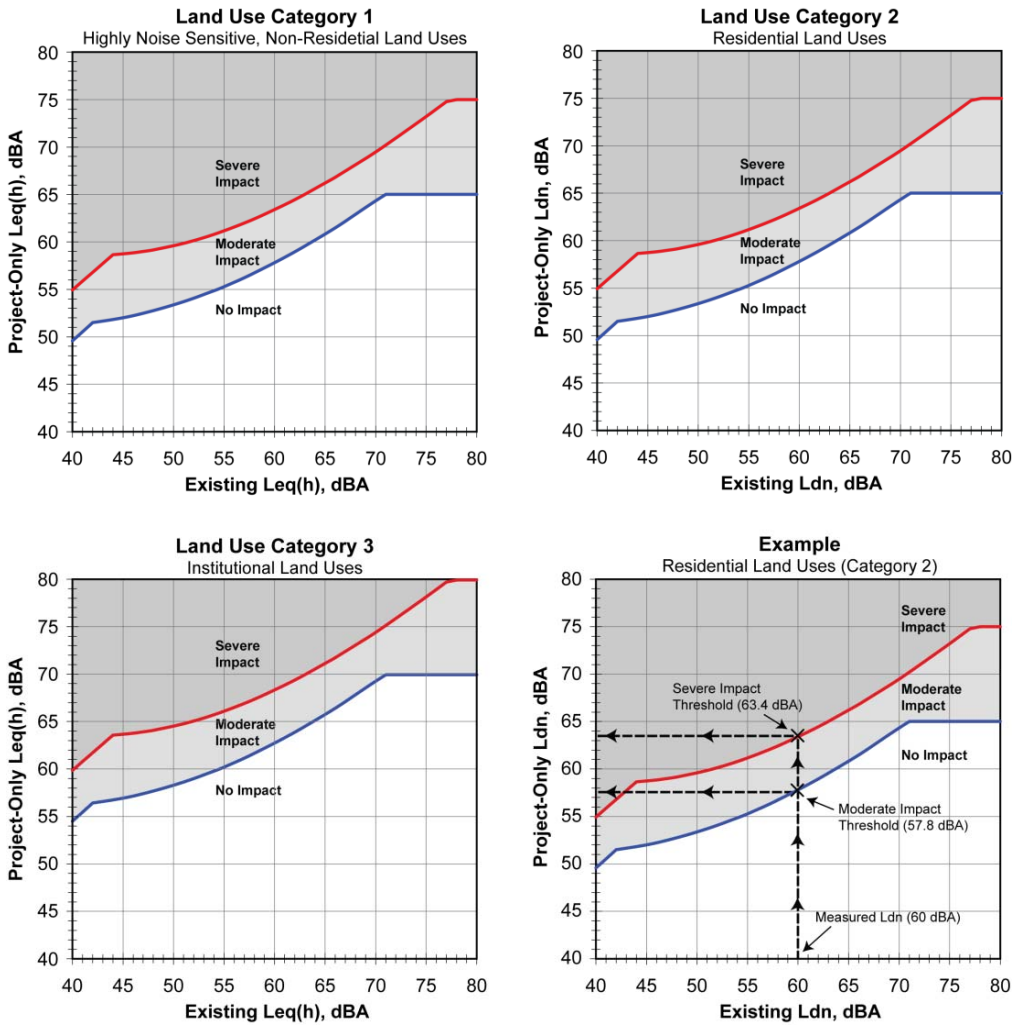

Figure 2: FTA Noise Thresholds

2. DUARTE SOUND WALL

The 2007 FEIR recommends a 350 foot long sound wall along the eastbound track in the city of Duarte from station 1129+50 to 1133+00. Figure 3 shows the location of the proposed sound wall and the nearest residences. The residential cluster used in the 2007 FEIR noise analysis (boxed in red in Figure 3) is labeled as Duarte eastbound group 1 and includes the four single-family residences located closest to the proposed tracks along Duarte Road from Mountain Avenue to Park Rose Avenue. The nearest residence in the group is 120 feet from the centerline of the eastbound track. The dominant existing noise source is the vehicular traffic on Duarte Road, with runs between the residences and the proposed tracks.

The predicted noise level from the 2007 FEIR for the residences in Duarte eastbound group 1 was one decibel below the impact threshold. However, mitigation was recommended in the form of a noise wall. A new noise analysis was conducted to determine if there is noise impact at the residences in Duarte eastbound group 1 and to determine if mitigation measures are necessary to meet the FTA noise criteria.

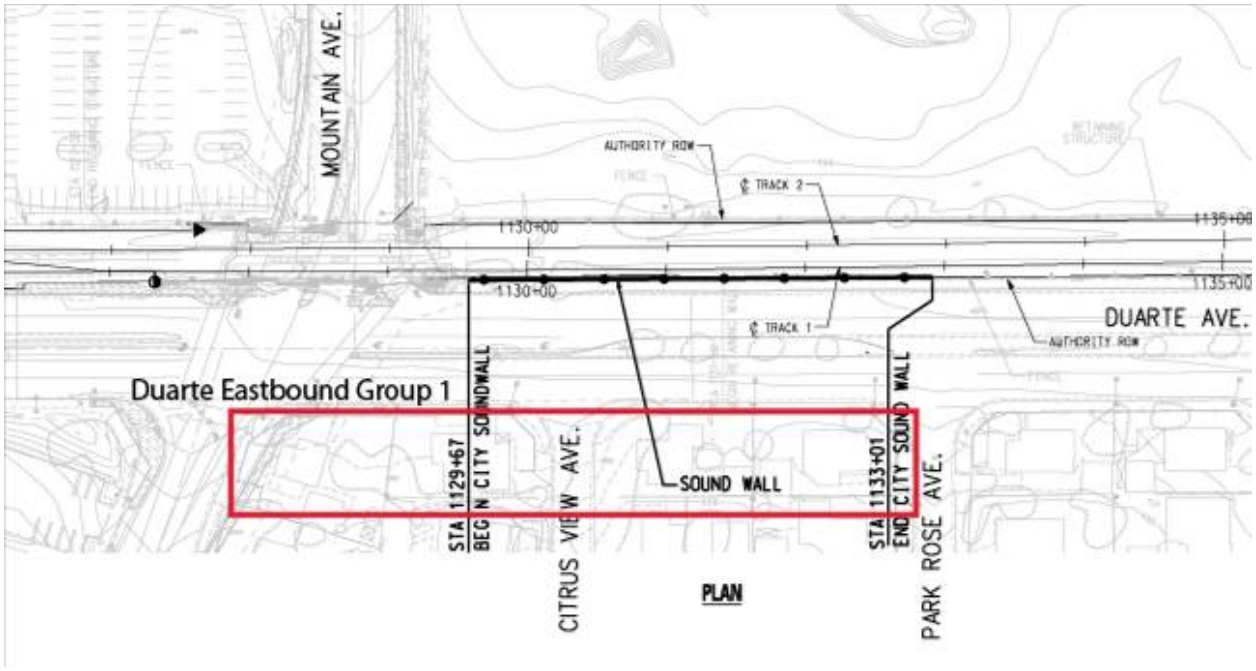

Figure 3: Location of Daurte Eastbound Sound Wall 1

2.1 Noise Impact Assessment

The train noise prediction procedure for this analysis followed the same methodology described in the 2007 *Noise and Vibration Technical Report*. The prediction procedure follows the FTA noise assessment guidelines.

The FTA noise thresholds are based on the existing noise exposure. The 2007 FEIR used a noise measurement taken in 2005 at the intersection of Duarte Road and Broadland Avenue to determine the FTA noise impact threshold for the residences in Duarte eastbound group 1. This measurement was approximately one-half mile east of the residences in Duarte eastbound group 1. An additional 24-hour noise measurement was conducted in July 2011 at the intersection of Duarte Road and Citrus View Avenue to update the noise analysis and determine the appropriate noise threshold. The measured Ldn was 63 dBA. Detailed measurement results are presented in Appendix A. The FTA noise thresholds for a residential land use with an Ldn of 63 dBA are:

- Moderate Impact Threshold: 60 dBA
- Severe Impact Threshold: 65 dBA

The FTA impact thresholds apply to the predicted project noise level. The project noise includes only noise from the light-rail operations and does not include noise from existing sources, such as traffic. As a result, the FTA impact threshold can be less than the measured existing noise level. The FTA moderate impact threshold for Duarte eastbound group 1 is three decibels lower than the existing noise level.

If the predicted project noise level exceeds the moderate impact threshold, FTA guidance is to consider noise mitigation options. If the predicted project noise level exceeds the severe impact threshold, FTA guidance is to include mitigation in the project unless there are compelling reasons why mitigation is unfeasible.

Table 1 shows the assumptions for the noise prediction (train speed and distance from the residences to the track) as well as the threshold and predicted project noise level. The predicted project noise level, which only includes train noise, is 59 dBA, one decibel below the threshold for moderate impact.

Table 1: Noise Prediction for Duarte Eastbound Group 1	
Engineering Station	1128+50-1133+00
Speed:	55 mph
Distance to Near Track:	120 ft
Existing Noise Level (Ldn):	63 dBA
Threshold for Moderate Impact (Ldn):	60 dBA
Predicted Project Noise Level (Ldn):	59 dBA
[1]Ldn is the day-night sound level.	

The 2007 FEIR recommended mitigation for Duarte eastbound group 1, although the predicted noise level in the report did not exceed the moderate impact threshold. The updated noise prediction in Table 2 also approaches, although it does not exceed, the FTA threshold for moderate noise impact. A noise mitigation analysis for the residences is included as part of this updated noise analysis given that the predicted level is only 1 decibel below the impact threshold and mitigation was recommended in the 2007 FEIR.

The installation of a sound barrier north of Duarte Road along the south edge of the project right-of-way would provide a reduction in the project sound level (noise associated with the light-rail operations) of approximately 12 dB (Table 2). The wall; however, would not reduce traffic noise from Duarte Road at the residences.

The predicted future noise level is a combination of the traffic noise and light-rail operations noise. The existing traffic noise at Duarte eastbound group 1 is higher than the predicted train noise with or without a barrier. As a result, the future noise level is dominated by the traffic noise along Duarte Road. The predicted future noise levels with and without a barrier are shown in Table 2. Because the barrier would not reduce traffic noise and the predicted train noise is much less than the existing traffic noise, the introduction of light-rail would only cause a very small increase in noise level. The predicted future noise level with a train but without the barrier increases the existing noise level by 1 dB and the predicted future level with a train with a barrier increases the existing noise level by less than 1 dB.. Humans cannot typically distinguish changes in sound level that are less than 3 dB. Installing a sound barrier would not provide noticeable benefit to the residents.

Table 2: Predicted Future Noise Levels With and Without Mitigation for Duarte Eastbound Group 1		
	without Barrier	**with Barrier**
Existing Noise Level (Ldn)	63 dBA	63 dBA
Predicted Project Noise Level (Ldn) (LRT noise only)	59 dBA	47 dBA
Predicted Future Noise Level[1] (Ldn) (LRT noise and traffic noise)	64 dBA	63 dBA
[1]Predicted future noise level is the decibel sum of the existing noise level and the predicted project noise level.		

3. NOISE FROM TPSS UNITS

The primary noise sources on traction power substation (TPSS) units are transformer hum and noise from cooling systems. The cooling fans are the primary noise source on the TPSS units used on the Metro Gold Line.

A TPSS unit will be added to the project at one of three potential sites at the intersection of the 210 Freeway and Michillinda Avenue. Site options A, B, and C are shown in Figure 4 below. The Construction Authority would acquire the single-family residence on Arboleda Street indicated in Figure 4 to accommodate the TPSS for option A. The nearest noise-sensitive receiver to option A is a single-family residence located adjacent to the proposed parcel, approximately 10 feet from the property line. However, the TPSS unit would be set back farther than 10 feet from the edge of the parcel nearest to the residence.

The Construction Authority would acquire part of the parking lot on the northeast corner of the intersection of Michillinda Avenue and Arboleda Street to accommodate the TPSS for option B, as indicated in Figure 4. The nearest sensitive receiver to the option B site is the single-family residence currently located at the option A site. The residence is approximately 15 feet from the edge of the option B parcel; however, the TPSS would likely be placed on the southern edge of the parcel oriented with the cooling fans facing the street.

TPSS site option C is located south of the 210 Freeway, adjacent to the east off-ramp. The land is currently owned by CalTrans. The nearest noise sensitive receiver is a single-family residence on Quigley Street, approximately 60 feet from the edge of the proposed parcel.

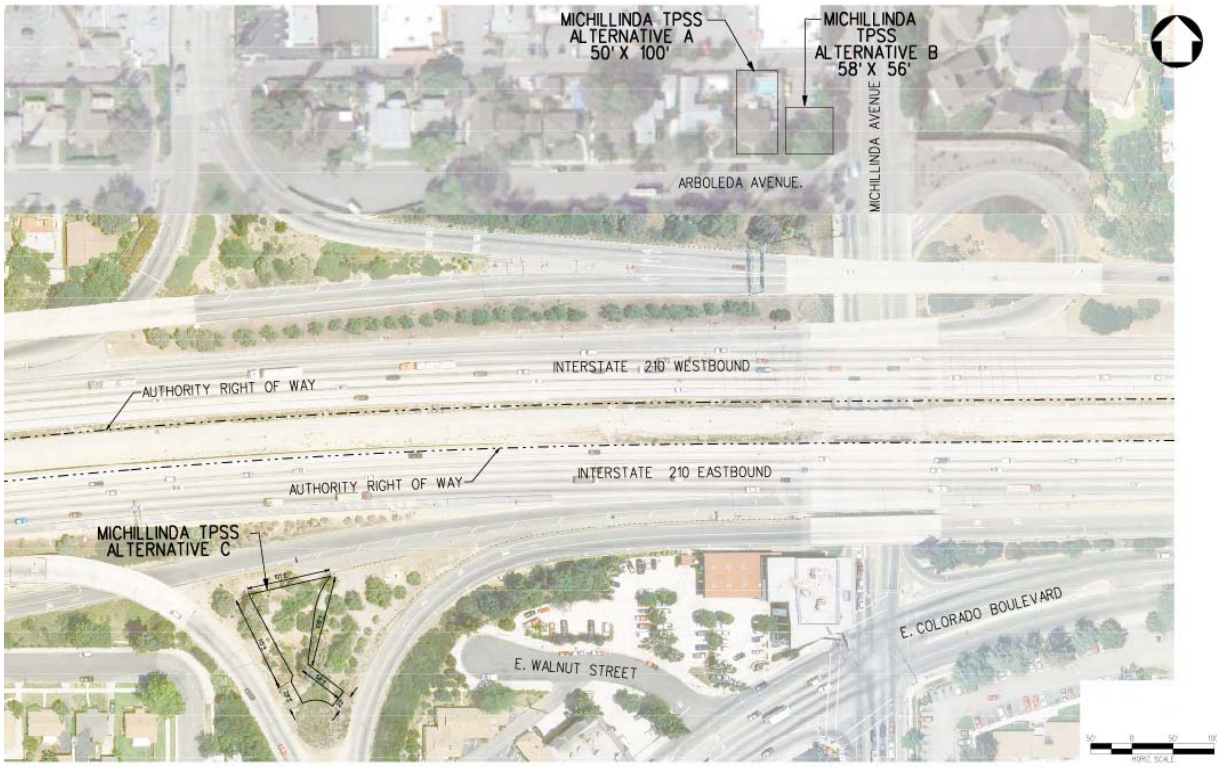

Figure 4: Aerial Photograph of Michillinda Avenue TPSS Option A, B, and C Locations

In Azusa, the TPSS site near Soldano Street has been shifted from the location identified in the 2007 FEIR. The current proposed location for the TPSS is north of the alignment, just west of Soldano Street at station 1385+74. There is a multi-family residential building approximately 42 feet from the proposed TPSS location shown in Figure 5.

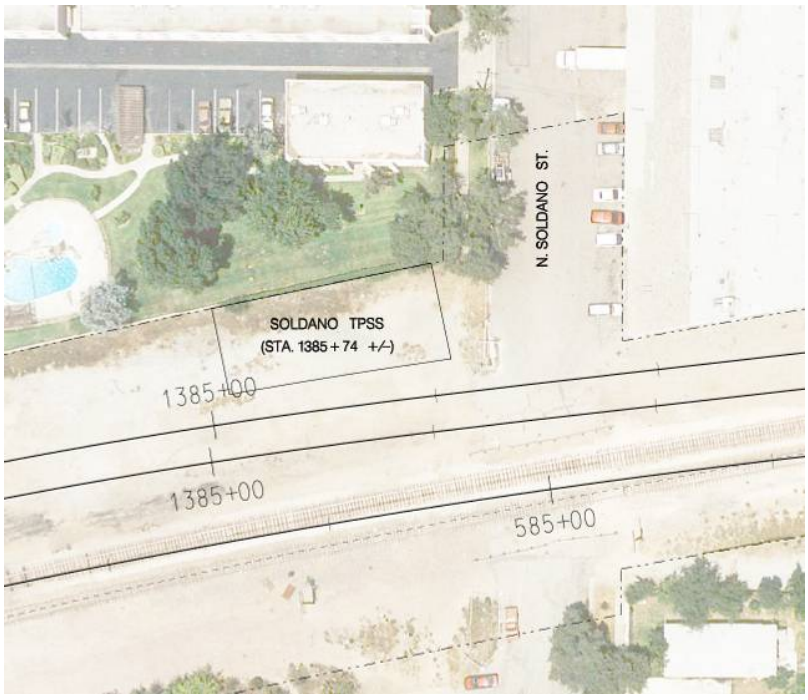

Figure 5: Aerial Photograph of the Soldano Street TPSS Location

3.1 Noise Thresholds for TPSS Units

The FTA Guidance Manual does not include separate thresholds for substation noise. The FTA criteria are geared toward train operations with intermittent sound events throughout the day. The TPSS units, in contrast, are usually running continuously while trains are in operation. As explained in the *2007 Noise and Vibration Technical Report*, noise level goals that are more stringent than the FTA criteria are often applied to noise from TPSS units because they have different sound characteristics than light-rail vehicles. The noise level goal presented in the 2007 FEIR is a limit of 10 dB above the hourly L90, with a minimum limit of 45 dBA at any residence.

As discussed in Section 1.2, the FTA noise criteria are based on the existing noise exposure. Twenty-four hour noise measurements were conducted near the proposed TPSS sites to determine the existing noise exposure. Detailed measurement results are presented in Appendix A. The results were used to determine the FTA criteria at the residences nearest to each TPSS site. The noise measurement results were also used to determine the L90 plus 10 dB noise threshold goal. The noise thresholds based on the measurement data are presented in Table 3 below.

Table 3: Noise Threshold for TPSS Units							
City	**TPSS**	**Eng. Station**	**Dist, ft**	**Existing Ldn**	**FTA Criteria, Ldn**	**Measured L90(hour), dBA**	**Noise Level Goal: L90(hour)+10, dBA**
Pasadena	Michillinda A	864+50	15	66	62	51	61
Pasadena	Michillinda B	865+40	10	66	62	51	61
Pasadena	Michillinda C	859+50	60	57	57	42	52
Azusa	Soldano	1385+74	55	57	57	40	50

In addition to the federal criteria supplied in the FTA Guidance Manual, cities also have noise ordinances that stipulate acceptable noise levels. While these criteria do not apply to noise from the light-rail vehicle operations, they should be considered for TPSS noise because TPSS units are permanently located within the city and run continuously.

The noise criteria from the applicable city ordinances for the three TPSS sites are presented in Table 4 below. In all three cases, the noise criteria from the city ordinances is higher than or equal to the noise level goal of L90 plus 10 dB.

Table 4: City Noise Ordinance Thresholds		
Community Area	**TPSS**	**City Threshold, dBA**
Pasadena	Michillinda Options A and B	61[a]
Pasadena	Michillinda Option C	53[a]
Azusa	Soldano	50
[a] The Pasadena noise threshold is the ambient level plus 5 dB. The lowest ambient 1-hour Leq was used.		

3.2 Predicted TPSS Noise Levels

The TPSS units will be designed to comply with the Metro Design Criteria for noise from transit system ancillary facilities. The Metro Design Criteria are presented in Table 5. The residential areas near the proposed TPSS locations are considered average residential density. The TPSS units are assumed to run continuously. To comply with the Metro Design Criteria, the TPSS units could not exceed a maximum noise level of 45 dBA at a distance of 50 feet from the unit or at the setback line of the nearest building, whichever is closer.

Table 5: Metro Design Criteria for Noise From Transit Ancillary Facilities		
Community Area	**Maximum Noise Level, dBA**	
	Transient	**Continuous**
Low Density Residential	50	40
Average Residential	55	**45**
High-density residential	60	50
Commercial	65	55
Industrial/highway	75	65
Source: Metro Design Criteria, Table 2-9 (Metro 2009)		
[1] Maximum noise level at a distance of 50 feet, or at the setback line of the nearest building, whichever is closer.		

The Metro Design Criteria is presented in terms of an equivalent noise level, or Leq. To compare the design criteria to the FTA noise thresholds, the design criteria is converted to the day-night noise level (Ldn), a measure of noise exposure that weights nighttime noise more heavily than daytime noise. The results of the conversion are presented in Table 6. The predicted TPSS noise does not exceed the FTA criteria at any of the three TPSS locations.

Table 6: Predicted TPSS Noise Levels, Ldn		
TPSS	**FTA Criteria, Ldn dBA**	**Predicted TPSS Noise, Ldn dBA[a]**
Michillinda Option A	62	51
Michillinda Option B	62	51
Michillinda Option C	57	51
Soldano	57	51
[a] The predicted level is based on the Metro Design Criteria of an Leq of 45 dBA at the nearest residence.		

Table 7 presents the Metro Design Criteria noise level as well as the noise criteria stipulated by the cities and the noise goal L90 plus 10 dB. The Metro Design Criteria does not exceed either of the noise thresholds. Applying the Metro Design Criteria to the installation of the TPSS units will ensure that the noise from the units will be less than the FTA noise thresholds, the stricter noise goal of L90 plus 10 dB, and the noise criteria from the respective cities. There would be no noise impact if the TPSS units comply with the Metro Design Criteria.

Table 7: Predicted TPSS Noise Levels, Leq			
TPSS	**Noise Level Goal: L90(hour)+10, dBA**	**City Threshold, dBA**	**Predicted TPSS Noise, Leq dBA[a]**
Michillinda Option A	61	61	45
Michillinda Option B	61	61	45
Michillinda Option C	52	53	45
Soldano	49	50	45
[a] The predicted level is based on the Metro Design Criteria of 45 dBA at the nearest residence.			

4. RELOCATION OF THE DUARTE PARKING FACILITY

The location of the parking facility in Duarte studied for the 2007 FEIR noise analysis (shown in Figure 7) was located west of Highland Avenue, between single-family residences to the west and the GE Aviation building at 1700 Business Center Drive to the east. The current proposed parking facility locations (options A and B) are both east of the GE Aviation building, farther from any noise sensitive receivers. As shown in Figure 7, the current options for the parking facility location are surrounded by commercial land uses.

The FTA noise criteria do not consider commercial land uses as noise sensitive. As a result, there will be no noise impact with the new parking location options. The FEIR parking location is currently being used to store cars for a nearby dealership. When the Duarte Station Parking Options A or B are implemented, the dealership lot will be converted into a parking lot for the GE Building. However, this will not result in a change to the noise environment at the nearest sensitive receivers. No additions or changes to the 2007 FEIR mitigation recommendations are necessary as a result of the relocation of the Duarte Parking Facility.

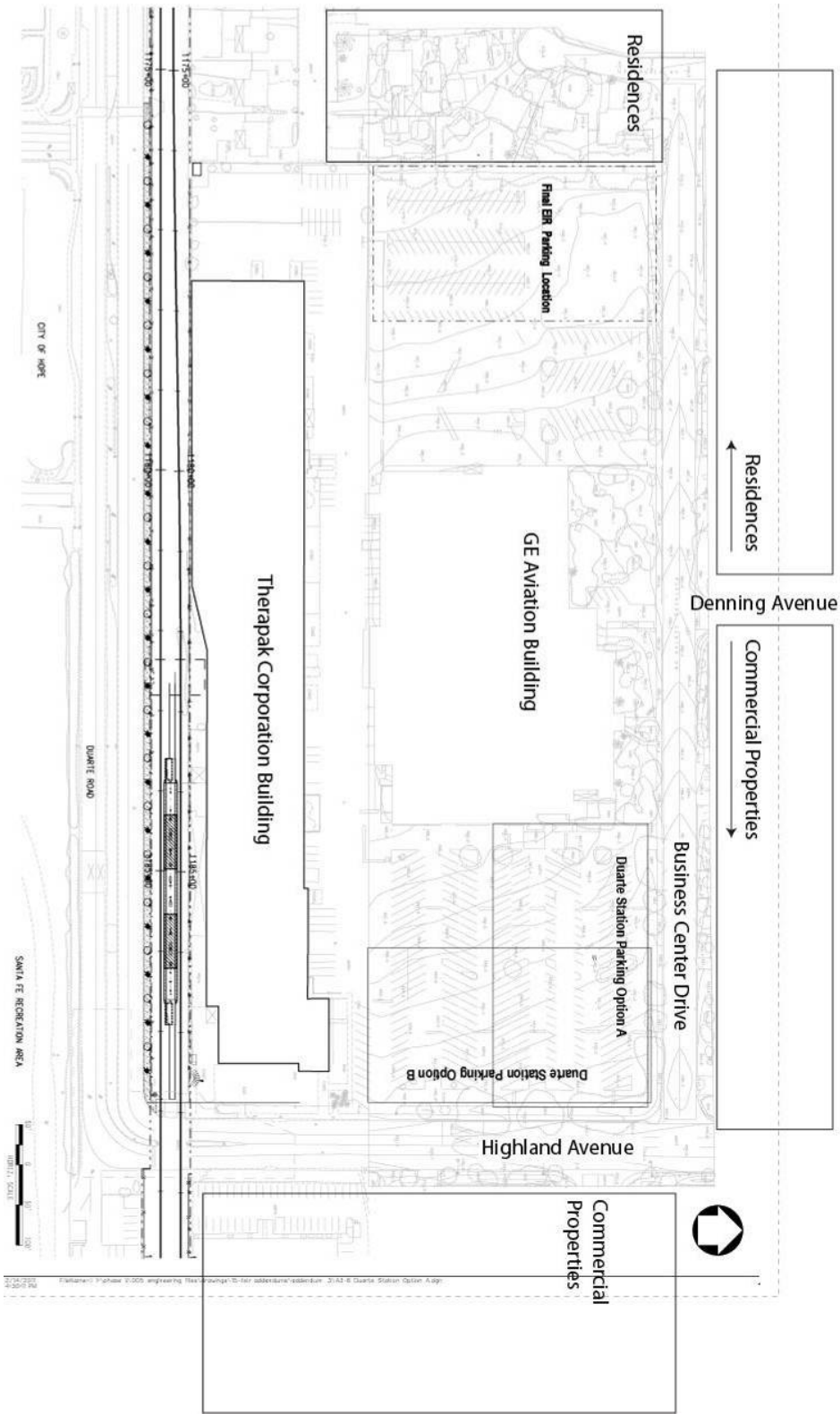

Figure 6: Location of the Proposed Duarte Parking Facility