Appendix O

Vibration Technical Report for the East-West Connector Project

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VIBRATION TECHNICAL REPORT

for the

EAST-WEST CONNECTOR PROJECT

(DRAFT)

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1 EXECUTIVE SUMMARY

The East-West Connector Project (Project or proposed project) is a 3.0-mile roadway project that would provide improved east-west access between Interstate 880 (I-880) on the west and Mission Boulevard (State Route 238) on the east in south Alameda County by widening existing roadways and constructing a new roadway segment. This report presents the results of the vibration study that was conducted for the project. The report has been prepared in support of environmental review for the project pursuant to the California Environmental Quality Act (CEQA). The Alameda County Transportation Authority is the lead agency for the project and is preparing an Environmental Impact Report (EIR) to comply with CEQA.

The evaluation criteria in this analysis address the potential for disturbance from vibration during nighttime (10 p.m. to 7 a.m.) construction activities (0.083 in/sec PPV), and the potential for cosmetic building damage (0.2 in/sec PPV).

This analysis has determined that there would be potentially significant impacts from the following:

- Construction activities such as pile driving which would potentially generate vibration exceeding 0.2 in/sec PPV at homes within 200 feet of pile driving.

- Construction activities such as vibratory compacting would potentially generate vibration exceeding 0.3 in/sec PPV at one commercial building within 20 feet of compacting.

- New lane construction requiring vibratory compacting would potentially generate vibration exceeding 0.3 in/sec PPV at commercial buildings on Decoto Road.

- Train operations on either UPRR track during the nighttime hours (10 p.m. to 7 a.m.) on the shoofly would potentially exceed the nighttime disturbance criterion and would increase the train vibration over existing. Operations of trains on shooflies would exceed the nighttime disturbance criterion at one residential building within 40 feet of the UPRR Oakland tracks and up to twenty-three residential buildings within 60 feet of the UPRR Niles tracks.

Control measures have been recommended to limit or reduce the potential vibration impacts. These measures include the following:

- Vibration limits in the construction specifications: Vibration at all residential and non-engineered wood frame buildings should be limited to 0.2 in/sec PPV. Vibration at commercial, concrete, and engineered buildings should be limited to 0.3 in/sec PPV.

- Pre-Construction survey of existing structures homes within the following areas: within 50 feet of the vibratory compacting activities (new lanes, shoofly), within 200 feet of vibratory pile driving activities, or within 400 feet of impact pile driving activities.

- Exclusion of impact or vibratory pile driving or vibratory compaction methods within 50 feet of residential or wood-framed structures.

- Advance notice and community outreach regarding projected vibration for neighbors within 400 feet of pile driving activities or 100 feet of vibratory compaction. For buildings within these zones, the Project should encourage neighbors to remove precious and fragile items from shelves and walls for the duration of nearby construction activities.

- The contractor should limit the speed of large equipment to 15 mph on site, and reduce the occurrence of potholes and large bumps (e.g., portable curbs) for trucks which would move at a higher speed.

- Modify shoofly alignments to maintain a distance to nearby residences greater than 40 feet from track centerline (UPRR Oakland) or 60 feet (UPRR Niles).

- Use Tire-Derived-Aggregate (TDA) as a substrate layer below the ballast and sub-ballast to reduce vibration transmitted into the ground.

- Advance notice and community outreach regarding projected vibration for neighbors within 100 feet of UPRR shoofly alignments. For buildings within these zones, the Project should encourage neighbors to remove precious and fragile items from shelves and walls for the duration of nearby construction activities.

2 INTRODUCTION

The East-West Connector Project (Project or proposed project) is a 3.0-mile roadway project that would provide improved east-west access between Interstate 880 (I-880) on the west and Mission Boulevard (State Route 238) on the east in south Alameda County by widening existing roadways and constructing a new roadway segment. The project would also provide bike lanes along its entire length, and when completed, it would provide a continuous bike corridor from just east of I-880 to Mission Boulevard. (Figure 1).

This report presents the results of the vibration study that was conducted for the project. The report has been prepared in support of environmental review for the project pursuant to the California Environmental Quality Act (CEQA). The Alameda County Transportation Authority is the lead agency for the project and is preparing an Environmental Impact Report (EIR) to comply with CEQA.

Within this report, the environmental setting section presents the fundamentals of environmental vibration and presents the results of vibration measurements conducted at the site. The regulatory setting section provides a discussion of policies and standards applicable to the project. A summary of the results of vibration modeling conducted for the project and an evaluation of the potential impacts resulting from the project are presented in the impacts analysis section. Mitigation measures are presented to reduce potentially significant vibration impacts.

2.1 PROJECT DESCRIPTION

The 3.0-mile project alignment extends between a location northeast of the I-880 and Decoto Road ramps on the west and the intersection of Mission Boulevard and Appian Way on the east. The proposed project includes constructing a new 1.3-mile-long roadway on the east portion of the alignment (between Paseo Padre Parkway and Mission Boulevard), widening 1.7 miles of existing roadways (Decoto Road and Paseo Padre Parkway), and making other improvements along the alignment. Other improvements include signalizing existing intersections, modifying intersection lane configurations, widening Fremont Boulevard and Mission Boulevard near their intersections with the project's main roadway alignment, and realigning Quarry Lakes Drive. The general study area and project alignment are depicted in Figure 2-1.

Two options are being considered for the Quarry Lakes Drive realignment, Realignment Option 1 and Realignment Option 2, both of which would move the road southwest of its existing route. Quarry Lakes Drive Realignment Option 1 would move the road southwest of the existing residence located just off Quarry Lakes Drive (35261 Alvarado Niles Road), resulting in the roadway's edge being approximately 220 feet southwest of the house. Quarry Lakes Drive Realignment Option 2 would keep the road on the northeast side of the residence, but would move it closer to the residence than under current conditions, resulting in the roadway edge being approximately 60 feet north of the house's northern face.

Construction of the new roadway segment would require construction of an underpass beneath the existing Bay Area Rapid Transit District (BART) tracks and the Union Pacific Railroad (UPRR) tracks. During construction of this segment, a shoofly (temporary realignment of the

railroad tracks) would be installed adjacent to the existing tracks to ensure rail operation is not interrupted.

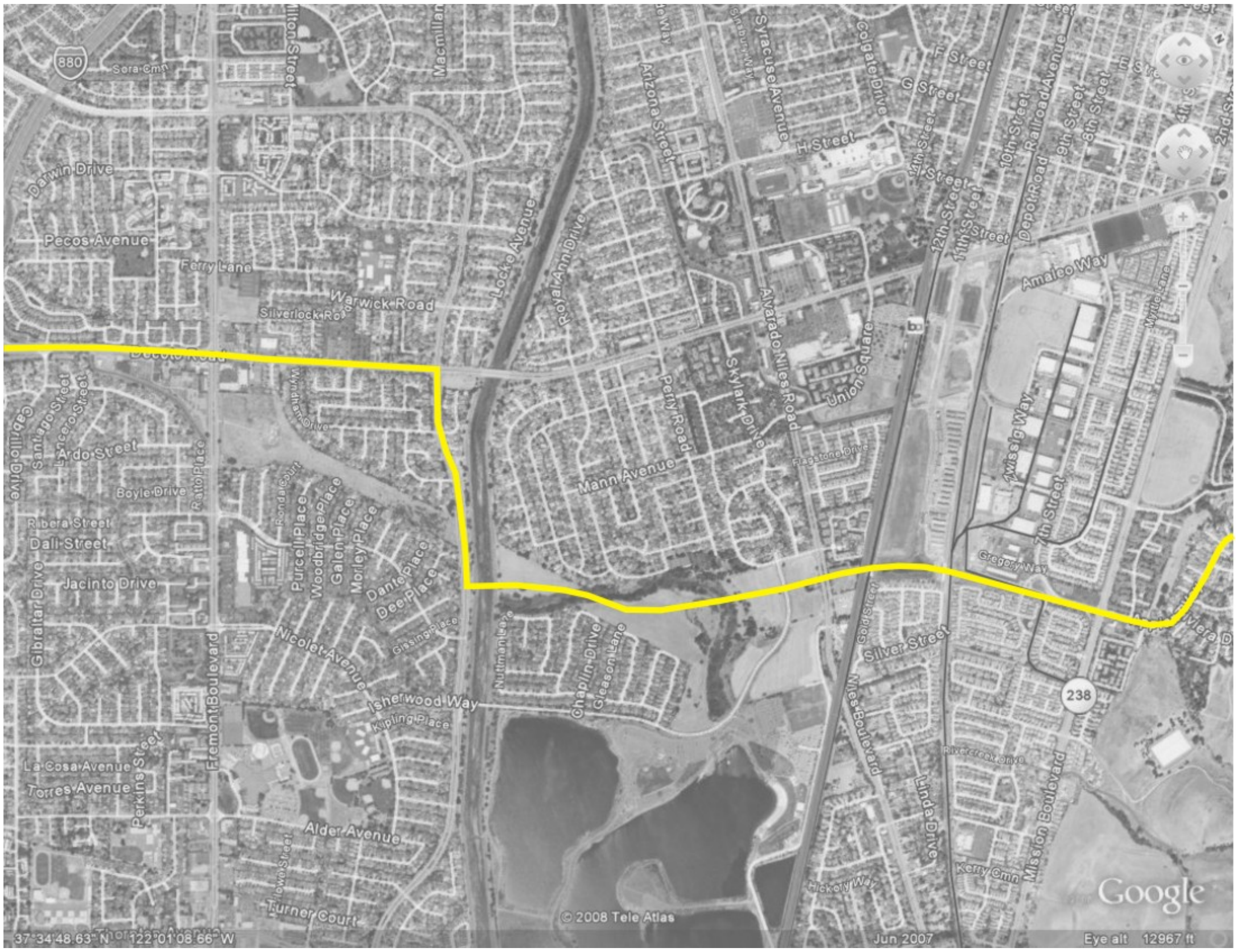

Figure 2-1 Project Area and Alignment Corridor

3 EXISTING VIBRATION ENVIRONMENT

3.1 PROJECT LOCATION

3.1.1 Existing Roadway Segments

This portion of the project alignment would extend along 1.7 miles of existing roadways, Decoto Road and Paseo Padre Parkway, within the City of Fremont. Both roadways would be widened to six lanes.

- The project alignment includes a 0.9-mile segment of Decoto Road, and this entire stretch of Decoto Road has been developed, primarily with residential and commercial land uses. The Church of Jesus Christ of Latter Day Saints is located on the west side of the street across from Brookmill Street

- The project alignment includes a 0.8-mile segment of the Paseo Padre Parkway. This stretch of Paseo Padre Parkway has been developed with single family residential homes on the southwesterly side of the street.

3.1.2 New Roadway Segments

This portion of the project alignment would create 1.3 miles of new roadway, extending from Paseo Padre Parkway on the west to the Mission Boulevard on the east, through a corridor that is primarily undeveloped because it has been reserved for a roadway. Additionally, the proposed alignment traverses right-of-way currently owned by Bay Area Rapid Transit District (BART) and Union Pacific Railroad (UPRR).

- From Paseo Padre Parkway to Alvarado-Niles Road, the undeveloped area includes the Alameda Creek Flood Control Channel (Alameda Creek) and Old Alameda Creek. The undeveloped land is surrounded by single-family residential development to the north (in Union City) and single-family residential development to the south (in Fremont).

- Between Alvarado-Niles Road and Mission Boulevard, the alignment extends through undeveloped land. Additionally, the project roadway alignment also crosses two sets of UPRR tracks (Oakland and Niles Subdivisions), BART tracks, Green Street bridge, and the Chesapeake Drive culvert. BART operations typically provides over 260 trains in both directions per day at a nominal speed of 70 to 80 mph in this area. Currently, the UPRR Oakland subdivision can experience up to four trains (freight only) per week[1], and the UPRR Niles subdivision typically experiences 16 trains (10 freight and 6 passenger/commuter) per day at speeds of up to 79 mph. Surrounding land uses include a multi-family development on the north side of the alignment near Alvarado-Niles Road, existing single-family residential development on both sides, planned commercial development on the north side, industrial uses (Union City corporation yard) on the north side, and a dog park on the north side.

3.2 VIBRATION BACKGROUND AND TERMS

Vibration can be interpreted as energy transmitted in waves through the ground. These energy waves generally dissipate with distance from the vibration source (e.g., truck hitting a pothole, or pile driving). Because energy is lost during the transfer of energy from one particle to another, vibration becomes less perceptible with increasing distance from the source. Vibration attenuates at a rate of approximately 50 percent for each doubling of distance from the source. This approach only takes into consideration the attenuation from geometric spreading; since there additional factors that reduce vibration, including damping from soil condition, this approach tends to underestimate attenuation and therefore, provides a “worst-case” estimate of vibration at the receptor.

Vibration is an oscillatory motion that can be described in terms of the displacement, velocity, or acceleration. Vibration is typically described by its peak amplitude and its root-mean-square

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[1] Anecdotally, based on work performed by WIA for an unrelated project slightly south of the Project, very few, if any, trains currently use the Oakland Subdivision, and those infrequent trains typically travel at speeds of 50 mph or less.

(RMS) amplitude. The RMS value can be considered an average value over a given time interval. In this analysis, any data reported in RMS will be the maximum RMS value, unless otherwise indicated. The peak vibration velocity is the same as the "peak particle velocity" (PPV), and we have used the designation PPV to refer to the peak vibration in units of inches per second (in/sec). Peak particle velocity is defined as the maximum instantaneous positive or negative peak of the vibration signal, and PPV is used to assess the potential for damage to buildings and structures; it can also be used for assessing annoyance (Dowding, 1996)[2]. The RMS amplitude is usually used for assessing human annoyance.

For this analysis, unless otherwise indicated, we have applied a crest factor of four to account for the relationship between peak particle velocity and RMS velocity[3]. This factor is typical for random vibration sources such as tunnel trains and excavators. Thus, given the RMS velocity, the peak particle velocity can be estimated by multiplying the RMS velocity by a factor of four. Conversely, the RMS velocity can be estimated from the peak particle velocity by dividing the peak particle velocity by a factor of four.

Responses of human receptors and structures are influenced by a combination of factors, including soil or rock type, distance, duration, and the number of perceived events. Energy transmitted through the ground as vibration can reach levels that can cause structural damage, however, humans are very sensitive, and the vibration amplitudes that can be perceived by humans are well below the vibration which could potentially cause architectural or structural damage.

Common background sources of vibration in the study area include truck traffic, trains, and occasional earthquakes. Figure 3-1 illustrates typical amplitudes of vibration in terms of peak particle velocity and typical human response. In this report, both the peak and RMS velocities are given in inches per second (in/sec). For example, a freight train passing 100 feet from an observer can cause vibrations of 0.1 in/sec PPV, while a strong earthquake can produce vibrations in the range of 10 in/sec PPV. The threshold of human perception for continuous vibration is approximately 0.006 in/sec PPV measured at the surface on which the person is lying, sitting, or standing. Studies have been conducted that indicate that people are less aware of short-duration events (Dowding 1996) than events of longer duration. Transient vibration with duration of 30 seconds or less is barely perceptible at 0.03 in/sec PPV whereas short duration vibrations of 0.13 in/sec PPV are distinctly perceptible. A glossary of common acoustical terms

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[2] Vibration levels can also be expressed in decibels (**dB**). The decibel scale is a logarithmic scale of a particular sound or vibration amplitude relative to a reference value. For purposes of this report, vibration expressed in decibels will be referenced as vibration decibels (VdB) to differentiate vibration levels from sound levels. In mathematical terms in this analysis, the vibration level is equal to 20 times the logarithm of the ratio of the time varying vibration velocity (inch/sec) to a reference velocity of 1 *micro*-inch/second.

[3] The root-mean-square (**RMS**) amplitude of a sound or vibration is the square root of the time average of the square of the instantaneous amplitude over a specified time interval, usually one second ("slow" weighting). The RMS amplitude is described as an "energy average" of the time-varying amplitude. To distinguish this from an arithmetic average (e.g., the arithmetic average of 40, 50 and 60 is 50). The energy average of 40, 50 and 60 dB is 55.6, which favors the higher amplitude levels. The RMS vibration level, or vibration level, is the level in decibels (VdB) of the RMS vibration. Unless otherwise stated, the RMS vibration levels in this report are for a one-second RMS averaging time; or a "slow" meter response.

is included in Appendix A. Terms that are used extensively in this report are described and discussed below.

Vibration propagated through soil and building structures is referred to as **Groundborne Vibration**. In this analysis vibration is discussed in terms of the speed (velocity) at which the ground would move in units of inches/second.

Noise caused by vibration propagated through soil and building structures is **Groundborne Noise**. It is normally radiated by the ground in open air and by walls, floors and ceilings inside a building as a result of groundborne vibration.

3.2.1 Groundborne Noise

Groundborne noise in buildings is generated when interior surfaces (walls and floors) are vibrated, or "excited", into motion by ground vibration transmitted into the structure. For example, ground vibration could cause windows to rattle or items on shelves to move. The construction features of a building's foundation, structure, and walls determine the building's response to incident ground vibration. Groundborne noise can be calculated in the building based on the projected RMS vibration of the ground surface at the building.

Groundborne noise is less of a concern in the presence of airborne noise, because the airborne noise usually dominates the groundborne noise at locations where there is surface activity; the airborne noise is louder than groundborne noise and thus, airborne noise control (if necessary) is the limiting factor. Groundborne noise is typically of concern for highly sensitive and isolated buildings (e.g., recording studio) or for projects which involve underground construction at night where there is little or no project airborne noise component and when airborne noise levels are less (i.e., less traffic noise). No criteria are presented to evaluate groundborne noise and no analysis has been conducted to determine the predicted groundborne noise levels.

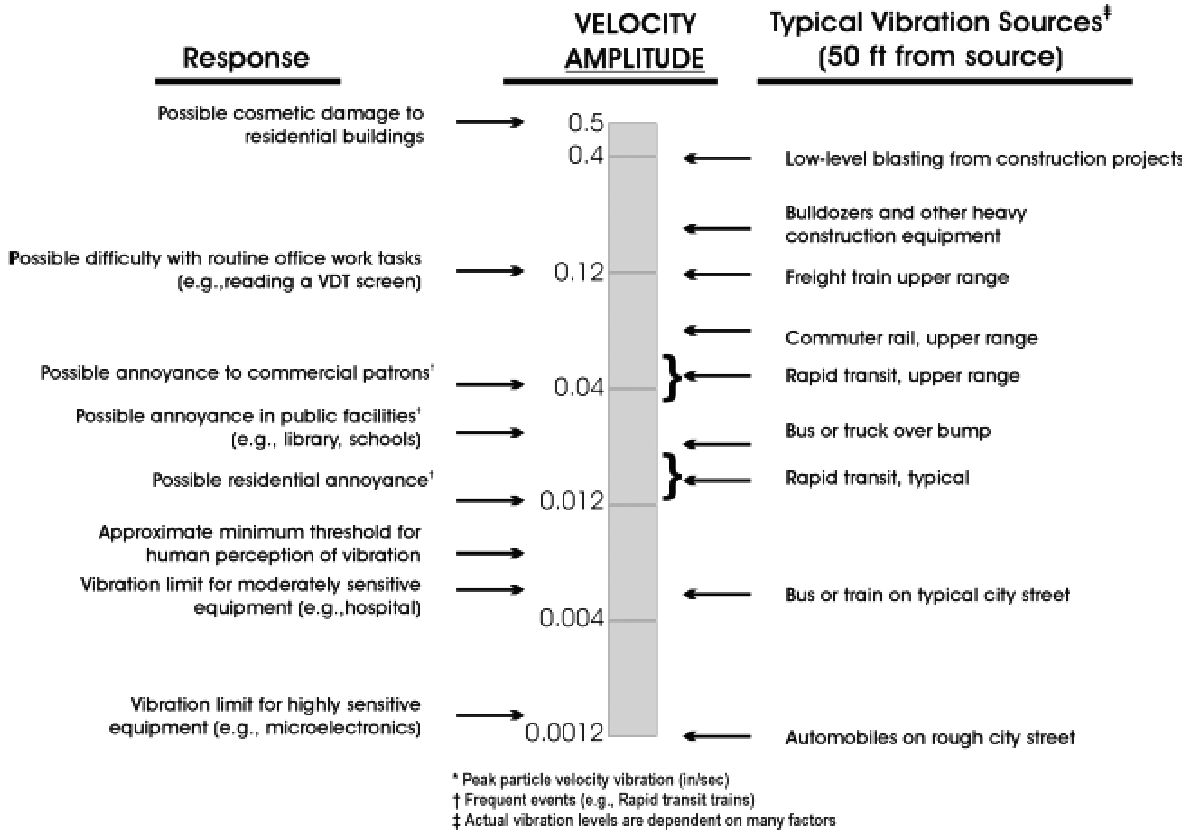


Figure 3-1 Typical Environmental Vibration Magnitudes and Responses

3.3 VIBRATION SURVEY

3.3.1 Description of Noise and Vibration Measurement Locations

Vibration measurements were conducted to establish existing vibration environments at the project site and to support the impact analysis. The vibration measurements typically lasted for several minutes each. The locations where the measurements were taken are shown in Figure 3-2 , and the locations and observations are noted below:

V1: near residences on Decoto Road and Sea Cliff Terrace. The measurement was conducted on July 1, 2008 at two positions: one at the property set-back line and the other on the curb of Decoto Road. Traffic, both cars and trucks, on Decoto Road dominates the vibration environment. 260 cars were counted in a 5-minute period.

V2: near residences on Paseo Padre Parkway and Cornish Drive. The measurement was conducted on July 1, 2008 at two positions: one at the property set-back line and the other on the curb of Paseo Padre Parkway. Traffic, primarily cars, on Paseo Padre Parkway dominates the vibration environment.

V3: near residences at Runckel Lane and Dominici Drive, close to the proposed roadway alignment and south of Old Alameda Creek. The measurement was conducted on July 1, 2008 to obtain vibration levels in a quiet environment. There are distant vibration sources on Paseo Padre Parkway.

V4: near residences on Skylark Drive (at Osprey Drive and at Alvarado-Niles Road). The measurement was conducted on June 27, 2008 on the sidewalk near single-family residences. Traffic, primarily cars on Alvarado-Niles Road, dominates the vibration environment.

V5: near residences on Gold St. and Platinum St. The measurement was conducted on June 27, 2008 on the sidewalk near single-family residences. BART trains are the primary source of vibration, since the UPRR activity on the Oakland subdivision is low. Distant train movements also contribute to the vibration environment.

V6 near residences on Mission Blvd. and Chesapeake Drive. The measurement was conducted on June 27, 2008 at two positions: one at the property set-back line and the other on the curb of Mission Blvd. During a five-minute interval, 180 vehicles were counted, from about 3:59 to 4:04 p.m.

V6A: near residences and industrial uses on 7th St. near Mission Blvd. The measurement was conducted on July 1, 2008 to observe traffic noise, particularly from trucks, on 7th St. Only a few trucks passed by during the vibration recording.

3.3.2 Existing Vibration

Table 3-1 summarizes the existing vibration at each measurement location. Both peak particle velocity (PPV) and maximum root-mean-square particle velocity (RMS) are listed[4]. These measurements indicate that the existing vibration velocity in the project vicinity is below 0.025 in/sec PPV, which is typically less than the level of perceptibility for short-duration events such as a vehicle passby. The vibration measurements, in conjunction with a visual survey of the existing environment, confirms that the traffic on local roadways generates low vibration, and other than trains, there are no existing sources of vibration perceived in these areas. Vibration generated by traffic on Mission Boulevard and Decoto Road approaches but does not exceed the threshold of human perceptibility at the curb of each respective street. The generated vibration levels drop to well under the perceptibility threshold at the property setback distances, further away from the street. Thus, the project area is not substantially impacted by existing vibration. As listed in Table 3-1, the vibration measurements indicate that the existing vibration levels are typical of local traffic-dominated environments. No freight trains or passenger trains operating on the UPRR rail lines were measured during the survey, however, existing freight/commuter train traffic on the UPRR tracks is likely to be perceptible[5]. Trains on UPRR Niles could be expected to reach 0.083 in/sec PPV at the nearby homes on Klondike Drive (60 feet from track centerline) or 0.052 in/sec PPV at homes on Green Street (95 feet from track centerline). For homes near the UPRR Oakland tracks, the existing freight vibration could reach 0.063 in/sec PPV for homes on Platinum or Gold Streets (50 feet from track centerline).

Table 3-1 Existing Vibration

Measurement Location	Typical Range (in/sec) RMS	Typical Range (in/sec) PPV[1]	Primary Vibration Source
V_1 (curb) Decoto Road	0.0001 to 0.008	0.0025 to 0.0225	Traffic on Decoto
V_1 (property setback) Decoto Rd	0.0003 to 0.01	<0.03 (estimated)	Local traffic on side street
V_2 (curb) Paseo Padre Pkwy	0.0001 to 0.005	0.0025 to 0.007	Traffic on Paseo Padre
V_2 (property setback) Paseo Padre	0.0001 to 0.003	<0.009 (estimated)	Traffic on Paseo Padre
V_3 Runckel Lane	<0.0001	<0.003 (estimated)	none
V_4 Skylark/Osprey	<0.00018	<0.0007 (estimated)	Traffic on Alvarado-Niles
V_5 Gold Street	0.00003 to 0.004	0.0025 to 0.009 0.063 (estimated freight)[2]	BART/UPRR[2]
V_6 (curb) Mission Boulevard	0.0003 to 0.015	0.003 to 0.025	Traffic on Mission

[4] In some cases the peak particle velocity values were estimated based on the relationship between RMS and PPV noted at other locations.

[5] Based on FTA (2006) general data for freight train vibration, presented in Section 5.

V_6 (property setback) Mission Blvd	0.0006 to 0.007	0.003 to 0.009	Traffic on Mission
V_6A Seventh Street	0.00003 to 0.002	0.0025 to 0.004	Traffic on Seventh

Note 1: The estimated PPV values are based on the observed relationships between RMS and PPV at other locations. While random vibration can result in a crest factor of 4 between RMS and PPV, the measured results indicate a moderate crest factor of up to 2.8

Note 2: Data measured for BART only. UPRR trains estimated as none were measured during the survey.

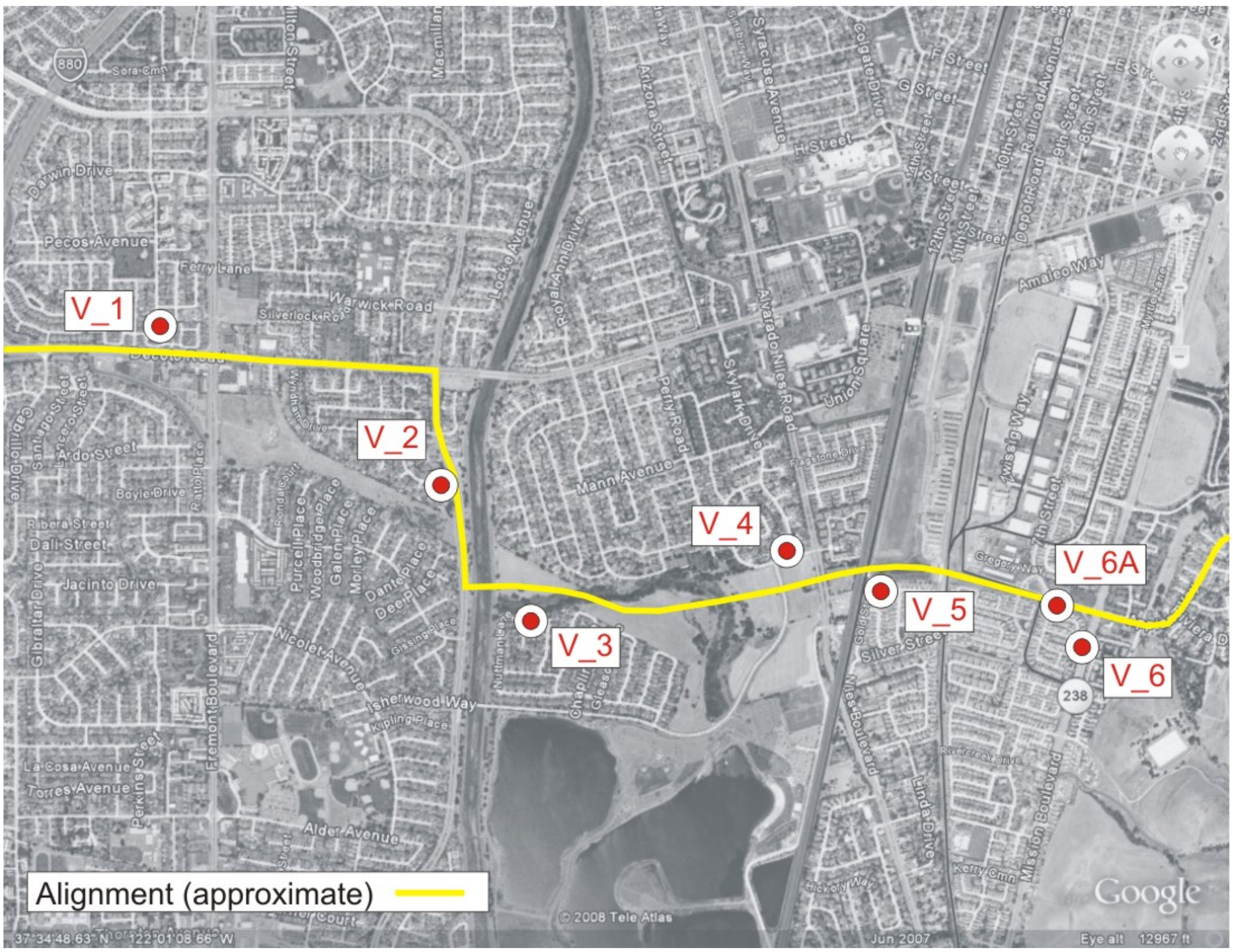


Figure 3-2 Project Area and Vibration Measurements

4 VIBRATION STANDARDS

4.1 GROUNDBORNE NOISE AND VIBRATION STANDARDS

The City of Fremont and Union City include some mention of vibration limits in their local standards. To augment this information, we have included criteria for vibration damage to buildings from construction which have been developed by state and federal agencies. These criteria are appropriate to apply to the Project to determine impacts associated with vibration from construction and are discussed below

4.1.1 State Regulations: California Environmental Quality Act

CEQA contains the following guidelines to evaluate the significance of noise impacts attributable to a proposed project. Based on the CEQA Guidelines, a proposed project would have a significant impact on the noise environment if it would:

a. Expose persons to or generate noise levels in excess of standards established in a local general plan or noise ordinance or applicable standards of other agencies;

b. Expose persons to or generate excessive ground borne vibration or ground borne noise levels;

c. Result in a substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project;

d. Result in a substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project;

e. Be located within an airport land use plan area or, where such a plan has not been adopted, within 2 miles of a public airport or public use airport and expose people residing or working in the project area to excessive noise levels; or

f. Be located in the vicinity of a private airstrip and expose people residing or working in the project area to excessive noise levels.

Of these guidelines, items (a) and (b) are applicable to the proposed project and were considered in the vibration analysis presented in this report. Guidelines (c) and (d) are addressed in a separate report. Guidelines (e) and (f) are not applicable because the project is not located in the vicinity of any public airport or private airstrip.

4.1.2 Local Municipalities

4.1.2.1 City of Fremont

The City of Fremont Municipal Code (2005) sets a limitation on construction hours. For projects located within 500 feet of residences, the construction hours are limited to:

- Monday-Friday: 7 a.m. to 7 p.m.
- Saturdays/Holidays: 9 a.m. to 6 p.m.

- Sundays: construction is not allowed.

For projects located beyond 500 feet from residences, the construction hours can be expanded to:

- Monday-Friday: 6 a.m. to 10 p.m.
- Weekend/Holidays: 8 a.m. to 8 p.m.

Fremont does not have any requirements which would limit vibration from construction or the operation of a new roadway.

4.1.2.2 Union City

The Union City Municipal Code (Section 9.40.053) establishes allowable construction hours:

> *Notwithstanding any other provision of this chapter, between the hours of eight a.m. and eight p.m. daily except Saturday, when the exemption herein shall apply between nine a.m. and eight p.m. and Sundays and holidays, when the exemption herein shall apply between ten a.m. and six p.m., construction, alteration, or repair activities which are authorized by valid City permit shall be allowed if they meet at least one of the following noise limitations:*
>
> *A. No individual piece of equipment shall produce a noise level exceeding eighty-three dBA at a distance of twenty-five feet. If the device is housed within a structure on the property, the measurement shall be made outside the structure at a distance as close to twenty-five feet from the equipment as possible.*
>
> *B. The noise level at any point outside the property plane of the project shall not exceed eighty-six dBA. (Ord. 275-86 § 1 (part), 1986)*

Union City does not have any requirements which would limit vibration from construction or the operation of a new roadway.

4.1.3 Building Damage Criteria

The American Association of State Highway and Transportation Officials provides guidelines for recommended practice regarding earthborne vibration from construction (AASHTO, 2004), and they describe three categories of vibration damage that can occur, from Threshold Damage to Minor or Architectural Damage to Major Damage. These guidelines indicate that Threshold Damage can be avoided with criteria less than 0.75 in/sec PPV for residential buildings using drywall and 0.5 in/sec PPC for residential buildings use plaster. The term “threshold cracking” is defined as the highest vibration amplitude at which no cosmetic, minor, or major damage occurs. This may include “threshold cracks” as hair-sized cracks in room walls that occur at the lowest vibration amplitudes.

The Federal Transportation Administration (FTA, 2006) Construction Vibration guidelines, more stringent than the AASHTO criteria, are summarized in Table 4-1. As shown previously, humans are sensitive to groundborne vibration at much lower levels than that which may cause structural damage or even cosmetic damage. This should be taken into consideration when notifying the public about the potential vibration from construction activities. Public outreach and education are key to acceptance by the Project neighbors, as long as building damage does not occur.

The vibration sensitivity of historical structures is dependent on several factors, including construction type and quality, local geologic and soil conditions, and historical context. Older buildings and monuments with a demonstrated historical significance can be sensitive to the slightest cosmetic damage. The Peterson Farm House (ca. 1884) is located adjacent to Quarry Lakes Drive, and has been identified as potentially eligible for inclusion in the federal and state registers. This house was documented as a stud-wall, wood-frame construction building on a perimeter foundation (Ward Hill, 1994). This building would fall under Category III, as listed below in Table 4-1. At this time, no historic structures subject to Category IV are located in the vicinity of the site.

Table 4-1 Recommended Vibration Limits For Threshold Damage

Building Category	**Peak Particle Velocity**
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

4.1.4 Utility Damage Criteria

The AASHTO Standard (AASHTO, 2004) includes references for underground utility criteria, citing studies that indicate that vibration under the ground surface is lower than that measured at the ground surface. One major utility has adopted a criterion of 4.0 in/sec (100 mm/s) for underground optical fiber cables. Underground or restrained concrete structures can withstand vibration of 10.0 in/sec (254 mm/s) before the appearance of threshold cracks. Thus, the underground utilities are less sensitive than surface structures.

4.1.5 Vibration Criteria for Interference with Human Activity

The FTA Manual (FTA, 2006) indicates that a threshold of 0.015 in/sec PPV can be used to evaluate the potential for annoyance from frequent or continuing vibration. Similarly, commercial patrons might be annoyed with vibration at 0.05 in/sec PPV, and vibration on the order of 0.15 in/sec PPV can interfere with working on a computer or reading a computer screen.

As mentioned in Section 3, studies have been conducted that indicate that people are less aware of short-duration events than events of longer duration. Vibration with a duration of 30 seconds or less is barely perceptible at 0.03 in/sec PPV, and vibration at 0.13 in/sec PPV is distinctly perceptible. Based on information presented in Section 5, homes within 200 feet of the UPRR Oakland tracks or 300 feet of the UPRR Niles tracks are already exposed to vibration which exceeds 0.015 in/sec PPV (up to 0.083 in/sec PPV along Klondike).

Daytime vibration impacts which occur intermittently or for a few days (e.g., less than two weeks) at residences and offices would be considered temporary, and would not require control measures. Since the existing environment from trains operating on UPRR tracks is estimated to be on the order of 0.083 in/sec PPV, Project-related vibration which occurs during the nighttime hours from the shooflies (train operations) which exceeds the expected existing vibration (0.083 in/sec PPV) would be considered a (temporary) vibration impact.

4.1.6 Groundborne Noise Guidelines

There are no standards which have been specifically developed to assess the impact of groundborne noise from construction activity. As noted above in Section 3.2.1, groundborne noise is generally less of a concern in the presence of airborne noise, because the airborne noise usually dominates the groundborne noise at locations where there is surface construction activity. Groundborne noise is more of a concern at night, when airborne noise levels are less (i.e., less traffic noise).

5 PROJECT GROUNDBORNE VIBRATION

5.1 PROJECT COMPONENTS

For discussion purposes, the proposed project has been divided into existing roadway segments (the western portion of the project) and the new roadway segment (the eastern portion of the project). A brief description of the setting for the proposed alignment is presented below.

5.1.1 Roadway Improvements

5.1.1.1 Existing: Decoto Road

The 0.9-mile segment of the Decoto Road, from its intersection with Cabrillo Court to Paseo Padre Parkway, would be widened to six lanes. The proposed improvements would require minor right-of-way acquisition at various locations to widen the existing right-of-way. The acquisition would generally run along the length of the alignment. The width of the acquisition varies between six to ten feet in general with the exception of a commercial establishment at 35041 Fremont Boulevard, for which the width of the acquisition would be approximately twenty four feet.

5.1.1.2 Existing: Paseo Padre Parkway

The 0.8-mile segment of Paseo Padre Parkway, from Decoto Road on the north to Isherwood Way on the south, would be widened to six lanes. The proposed roadway improvements would be constructed within the existing right-of-way.

5.1.1.3 New Roadway: Paseo Padre to Mission Boulevard

The 1.3 miles of new roadway would extend from Paseo Padre Parkway in the west to the Mission Boulevard in the east. The new four-lane roadway would meet the local design standards of Fremont and Union City and would not be designed as a freeway or expressway.

The four-lane roadway would be approximately 84 feet wide and consist of a 13 foot and a 12 foot vehicle lane in each direction, a landscaped median between the eastbound and westbound lanes, and eight-foot bike lane/outside shoulders in each direction.

5.1.2 Bridges

5.1.2.1 Alameda Creek Flood Control Channel Bridge

From Paseo Padre Parkway, the new roadway would cross the Alameda Creek Flood Control Channel. The crossing would be a concrete slab bridge that is supported by six bents, each with approximately 24 concrete piles, in the channel.

5.1.2.2 Old Alameda Creek Bridges

The project alignment would cross Old Alameda Creek at two locations. The bridges would be constructed using cast-in-place concrete box girder.

5.1.3 Quarry Lakes Drive Realignment

Quarry Lakes Drive (QLD) crosses the new roadway alignment west of Alvarado-Niles Road. The project proposes to realign QLD approximately 450 feet to the southwest to increase the distance between the two intersections on the new roadway for better traffic operations.

Two options are being considered for the QLD realignment, QLD Realignment Option 1 and QLD Realignment Option 2. Both of the potential alignments would move Quarry Lakes Drive southwest of its existing alignment. Under Option 1, QLD would terminate at the new roadway and not extend through the new roadway. Under Option 2, QLD would extend through the new roadway and connect to Osprey Drive.

5.1.4 Rail/Road Underpass

The new roadway alignment would extend beneath (from west to east) BART tracks, UPRR Oakland Subdivision (UPRR Oakland) tracks, Green Street, and UPRR Niles Subdivision (UPRR Niles) tracks. Green Street is situated on a bridge just west of the UPRR Niles tracks, and the project would pass beneath this bridge and the fronting tracks via a single grade-separation structure. Similarly, the BART and UPRR Oakland tracks parallel each other further to the west, and the project would pass beneath these two sets of tracks with two separate grade-separation structures.

While the underpass is being constructed, temporary rail tracks ("shoofly") would be installed adjacent to the existing tracks to minimize impacts on the operations of ACE, Amtrak, BART, and UPRR during project construction. The shooflies for the impacted tracks would be constructed within existing railroad right-of-way to allow for the removal of the existing tracks and the construction of the grade separation structures while maintaining the existing rail operations. There would be a minimum distance of 15 feet between the centerline of the shoofly track and adjacent residential soundwalls. The shoofly would likely be constructed parallel and be adjacent to the excavation for the grade separation structures, and temporary shoring would be required to support the excavation. Once the permanent grade-separation structures are completed, the BART and UPRR tracks would be restored to their existing locations onto the newly constructed structures. In the case of the UPRR Oakland Subdivision, the trains may run on shoofly in various configurations in order to provide a staging area for the BART structure construction. More information on these alternatives is provided in the Appendix.

5.1.5 Construction Schedule

At the present time, it is anticipated that the construction will be implemented in at least three separate packages with a total construction duration of around 42 months.

Package 1: Widening of Decoto Road and Paseo Padre Parkway

Widening of the existing roadway segments on Decoto Road and Paseo Padre Parkway is expected to take approximately 18 months. Construction activities would generally occur Monday through Friday, between 8 a.m. and 6 p.m.. At busy intersections, the work may be performed outside of these hours in order to minimize disruption to traffic.

Package 2: New Roadway between Paseo Padre Parkway and Alvarado-Niles Road

Construction of the new roadway segment, between Paseo Padre Parkway on the west and Alvarado-Niles Road on the east is expected to take 24 months. Construction of the bridges over the Alameda Creek Flood Control Channel and the Old Alameda Creek will be timed to minimize potential impacts to biological resources. Construction activities would generally occur Monday through Friday, between 8 a.m. and 6 p.m. At busy intersections, the work may be performed outside of these hours in order to minimize disruption to traffic. Pile driving activities for the Flood Control Bridge would potentially last a few weeks.

Package 3: New Roadway between Alvarado-Niles Road and Mission Boulevard and Intersection Improvements on Mission Boulevard

Construction of the new roadway segment, between Alvarado-Niles Road in the west and Mission Boulevard in the east is expected to take up to 36 months. Construction of the grade separation bridges would require close coordination with BART and UPRR. To minimize disruption to ongoing services, there would be a need to construct shooflies, which would result in a longer construction period. The duration of grade-separation and shoofly operations could last up to 36 weeks. Pile driving activities for the bridges would potentially last several weeks.

Construction activities would generally occur Monday through Friday, between 8 a.m. and 6 p.m. However, during switchover of railroad operations for the BART and UPRR shooflies, work will be performed outside of these hours, with potential nighttime work for limited periods of time.

5.2 GROUNDBORNE VIBRATION PREDICTION METHODOLOGY AND REFERENCE DATA

The Project would introduce new sources of vibration along the new roadway segment, with some minor changes in lane location along the existing roadway. For this analysis, the current mix of vehicles (automobiles, medium trucks and heavy trucks) has been assumed to remain the same, and the current road condition (relatively smooth, paved, no potholes) also has been assumed to remain the same for the project. As indicated by the existing vibration measurements shown in Table 3-1, the existing vibration is typically in the range of 0.009 to 0.03 in/sec PPV or less at the setback of existing residences along the existing roadways. Figure 5-1 illustrates the expected maximum vibration from vehicular and truck traffic along the proposed Project as a function of distance from the measurement location to the center of the primary source direction (e.g., centerline of east bound traffic). Also shown is the expected peak vibration from rubber tired vehicles at 30 mph (FTA 2006). Note that the observed vibration as shown in Figure 5-3 indicates a potentially higher vibration amplitude from traffic, possibly due to the presence of heavy trucks along the Project alignment.

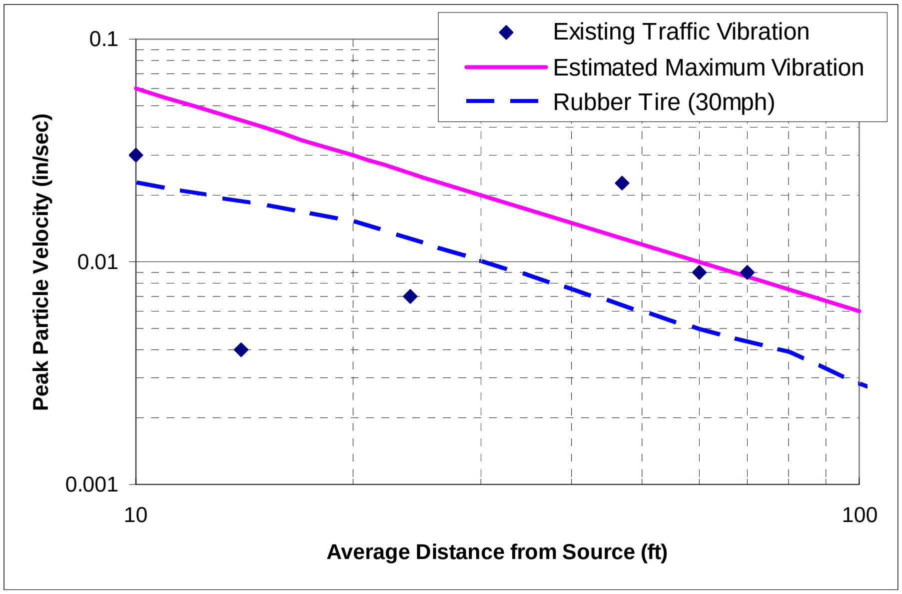
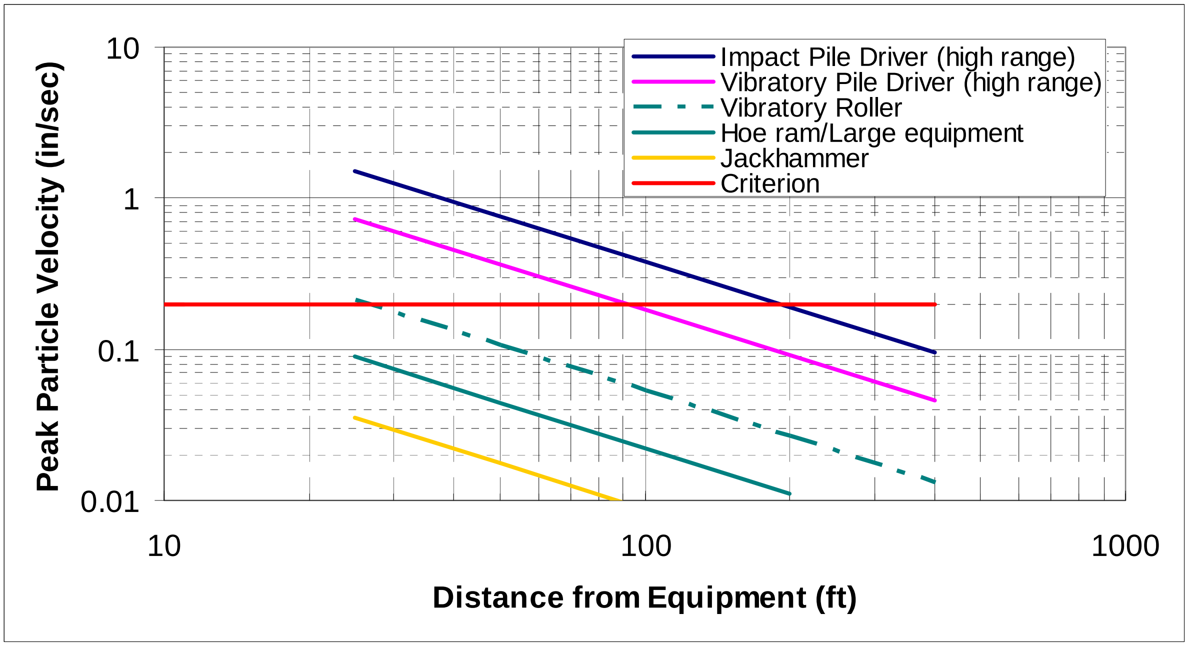


Figure 5-1 Existing Traffic Vibration in Project Area

Construction activities for this Project would involve use of some heavy construction equipment, soil compaction using vibratory methods and possibly impact pile driving. The propagation of vibration is dependent upon the soil characteristics, but we can conservatively estimate vibration would attenuate by 50% with each doubling of distance as described above in Section 3.

Reference vibration data for some construction equipment and the expected attenuation with distance are presented in Figure 5-2. The corresponding vibration amplitude at receptors near the proposed Project was then predicted based on the approximate distance between the nearest receptors and the work sites. In comparing Figure 5-1 and Figure 5-2, we can see that the vibration from construction equipment would potentially be much greater (orders of magnitude) than the existing low amplitudes of vibration generated by trucks and automotive vehicles.

Of the vibration-generating construction equipment, the highest vibration amplitudes would be generated by vibratory compactors, pile drivers and heavy equipment movements. Figure 5-2 illustrates the maximum predicted vibration from the highest amplitude activities. Based on the information in Figure 5-2, vibration from construction activities using impact pile drivers would generate vibration exceeding 0.2 in/sec PPV at distances less than 200 feet from the vibration source; vibration of this magnitude could also be generated from heavy, dropped objects or handling of heavy plates in the road work areas.



Source: FTA 2006

Figure 5-2 Predicted Maximum Vibration from Construction Activities

Finally, Figure 5-3 presents typical transportation vibration (FTA 2006) for railroad, rapid transit and rubber tired vehicles. For comparison, the measured maximum vibration from BART is shown. Vibration amplitudes are proportional to speed of a vehicle, and thus, a BART train operating at about half speed, or 36 mph would generate a vibration of 0.0045 in/sec PPV at 125 feet distance. Conversely, a train traveling at 75 mph would generate a higher amplitude of vibration, about a factor 1.5 times greater than the curve shown at 50 mph for UPRR trains. Further, it is apparent from Figure 5-3 that freight rail vibration can be higher than BART. This difference is primarily due to the poor condition of freight train wheels (and to a lesser extent the condition of commuter or Amtrak train wheels).

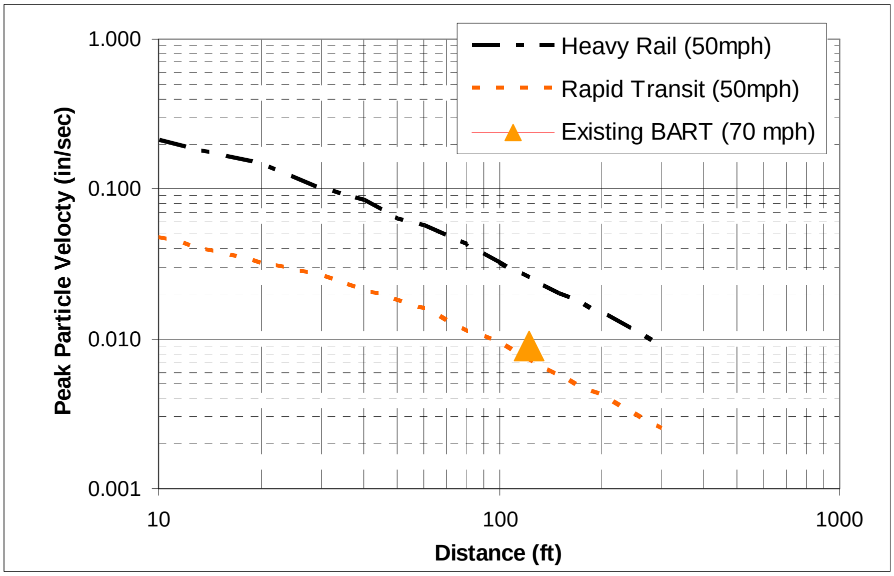


Figure 5-3 Typical Rail Transportation Vibration Sources

5.3 VIBRATION ESTIMATES

5.3.1 Lane Relocation, Paving and New Road

Road widening and new road construction will require some preparation of the subsoil conditions, which will typically require vibratory compaction (roller). Heavily loaded trucks (large equipment) may also be required to transport excavated soils, asphalt and other supplies. Table 5-1 summarizes the expected vibration that would be generated from road paving and new road construction. Also shown in this table is the expected vibration from local traffic on the newly modified or constructed segments. For most buildings, the construction vibration would be potentially perceptible, exceeding 0.03 in/sec PPV. In a few commercial areas along Decoto Road, the construction vibration would potentially exceed the building damage criterion of 0.3 in/sec PPV for commercial structures, depending on the activity and proximity to buildings.

Table 5-1 Expected Vibration from New Road Construction and Operation

Representative Receiver Area[1]	Nearest Existing Survey Receptor	Distance (ft)		Expected Vibration (PPV, in/s)		
		Construction	New Lane	Heavy Trucks	Ground Compaction	Local Traffic
Decoto near Canal Terrace (WB direction)	V_1	125	45	0.018	0.042	0.013
Decoto near Ozark River Way (WB direction)	V_1	100	25	0.022	0.053	0.023
Decoto near Seal Cliff Terrace (WB direction)	V_1	100	25	0.022	0.053	0.023

Representative Receiver Area[1]	Nearest Existing Survey Receptor	Distance (ft)		Expected Vibration (PPV, in/s)		
		Construction	New Lane	Heavy Trucks	Ground Compaction	Local Traffic
Amour and Silverlake off Decoto (near WB direction)	V_1	NA	35	NA	NA	0.016
Church	V_1	NA	40	NA	NA	0.014
Decoto near Gladstone (WB direction)	V_1	NA	25	NA	NA	0.023
Decoto between Cabrillo and Ozark (EB direction) - Commercial	V_1	13	13	0.171	**0.404**	0.044
Decoto between Ozark and Fremont Blvd (EB direction) - Commercial	V_1	25	25	0.089	0.210	0.023
Decoto near Fremont (EB direction) - Commercial	V_1	20	20	0.111	0.263	0.029
Decoto (Brookmill) between Fremont and Paseo Padre (EB Direction)	V_1	NA	35	NA	NA	0.016
Cornish and residences off Paseo Padre	V_2	NA	35	NA	NA	0.016
Begonia Street (WB Direction)	V_3	85	85	0.026	0.062	0.007
Chaplin Street/Conovan Lane (near EB Direction)	V_3	30	30	0.074	0.175	0.019
Conovan Lane (far EB Direction)	V_3	95	95	0.023	0.055	0.006
Osprey Drive at Towhee Court	V_4	285	285	0.008	0.018	0.002
Alvarado Niles and Project Roadway	V_4	275	275	0.008	0.019	0.002
Monterra Terrace closer to Project Roadway (near BART and UPRR)	V_5	75	75	0.030	0.070	0.008
Monterra Terrace closet to railroads (near BART and UPRR)	V_5	105	105	0.021	0.050	0.005

Representative Receiver Area[1]	Nearest Existing Survey Receptor	Distance (ft)		Expected Vibration (PPV, in/s)		
		Construction	New Lane	Heavy Trucks	Ground Compaction	Local Traffic
Platinum Street and Gold St (near UPRR_	V_5*	85	85	0.026	0.062	0.007
Platinum Street and Green St (near UPRR)	V_5*	85	85	0.026	0.062	0.007
Sanburg Drive and Klondike Drive (near UPRR)	V_5*	70	70	0.032	0.075	0.008
Chesapeake Drive and Project Roadway	V_6A	45	45	0.049	0.117	0.013
Cascades Circle near Arroyo Drive	V_6A	55	55	0.040	0.095	0.010
Chesapeake Drive and Mission Blvd	V_6	NA	30	NA	NA	0.019

*: These locations are likely to experience somewhat higher existing vibration than Location V_5 due to higher speed of train operations on the UPRR Niles track compared to the UPRR Oakland track.
NA: No demolition or repaving work anticipated. Only re-striping of the existing road.
Note 1: Residential receptors unless otherwise noted
Bold entries indicate where vibration would exceed the 0.3 in/sec PPV criterion for commercial buildings

5.3.2 Bridge and Shoofly Construction

As indicated above, the bridge structure construction at the flood control channel and the railroads (BART and UPRR) will require installation of piles for the bridge. If impact or vibratory methods are used to drive piles, substantial vibration could be generated at nearby homes. Table 5-2 summarizes the expected vibration from pile driving activities. Also shown are the expected vibration amplitudes from compaction activities for the rock ballast and subsoil conditions. As shown in Table 5-2, the vibration compaction for the shoofly would generate some perceptible vibration exceeding 0.03 in/sec PPV. Pile driving for the bridge structures would potentially generate substantial vibration, and since the piles could be located less than 200 feet from residences, impact pile driving would potentially exceed the 0.2 in/sec PPV criterion for cosmetic building damage at three areas.

Table 5-2 Expected Vibration from Bridge Structure and Shoofly Construction

Receiver	Distance (ft)		Expected Vibration (PPV, in/s)			
	Distance to Construction		Ballast/Ground Compaction		Pile Driving	
	Nearest	Farthest	Nearest	Farthest	Nearest	Farthest

Alameda Creek Flood Control Bridge						
Ballantine Dr and Dee Ct	250	500	NA	NA	0.2	0.10
UPRR (Oakland) and BART Undercrossing						
Osprey Drive at Towhee Court	1400	1515	<<0.01	<<0.01	0.03	0.03
Alvarado Niles and Project Roadway	595	760	0.01	0.01	0.06	0.05
Monterra Terrace	240	395	0.02	0.01	0.16	0.10
Monterra Terrace closest to BART	115	235	0.05	0.02	**0.33**	0.16
Platinum Street and Gold St	120	245	0.04	0.02	**0.32**	0.15
UPRR (Niles) Undercrossing						
Platinum Street and Green St	780	910	0.01	0.01	0.05	0.04
Sanburg Drive and Klondike Drive	65	185	0.11	0.08	**0.58**	**0.21**
Chesapeake Drive and Project Roadway	985	1005	0.01	0.01	0.04	0.04
Cascades Circle near Arroyo Drive	1340	1350	0.01	<<0.01	0.03	0.03
Bold entries indicate potential exceedance over 0.2 in/sec PPV criterion						

5.3.3 Vibration from Trains on Shoofly

As indicated above, the bridge structure construction at the railroads (BART and UPRR) would require construction of shooflies to divert rail traffic during construction. Generally speaking, these temporary tracks will be closer to homes than existing tracks, but in some cases the shooflies will be farther away. The UPRR (Niles) shoofly has three different timing/scheduling options, and the worst case distances for the shoofly have been used in this analysis. See the Appendix for more information on these shoofly construction options. Table 5-3 compares the expected existing train vibration levels with the expected vibration for BART operating on a shoofly at 36 mph. It has been assumed that the BART and UPRR shooflies would be constructed with welded rail joints, similar to the existing constructions, and that the tie-ins between each shoofly and the existing tracks will also use welded rail, not rail switches. The UPRR trains would remain at their current speed (nominally 79 mph on UPRR Niles and around 50 mph on UPRR Oakland). As shown in Table 5-3, BART operations on the shoofly at most locations would be less than the existing conditions due to the combined factors of increased distance and slower speed. The exception would be homes near the intersection of Platinum and

Gold Streets, which would experience a slight increase in vibration from BART operations on the shoofly. For trains on the UPRR tracks, operations on shooflies for the Oakland or Niles Subdivisions would be higher at most residences. For the UPRR Oakland alignment, vibration at one residence (within 40 feet of the shoofly) would exceed the nighttime disturbance criterion of 0.083 in/sec PPV. For the UPRR Niles alignment alternatives, residential buildings within 60 feet of the shoofly track centerline would be impacted:

- Alternative 1: no impacts
- Alternative 2: 15 homes on Klondike Dr., 1 home on Platinum St., and 2 homes on Terrazo Ct.
- Alternative 3: 15 homes on Klondike Dr., 1 home on Platinum St., 1 home on Silver St., and 6 homes on Terrazo Ct. /Saltillo Pl.

Table 5-3 Expected Train Vibration - Existing and with Shoofly

Location	Distance (ft)		Vibration (in/sec PPV)		Distance (ft)		Vibration (in/sec PPV)	
	BART existing	BART shoofly	BART Existing[1]	BART Shoofly[1]	UPRR existing	UPRR Shoofly	UPRR existing[2,3]	UPRR Shoofly[3]
BART and UPRR (Oakland)								
Monterra Terrace closest to BART	50	112	0.027	0.003	125	90	0.025	0.035
Platinum Street and Gold St	110	50	0.006	0.013	50	25	0.063	**0.110**
UPRR (Niles) – Alternative 1 (worst case distances)								
Platinum Street and Green St	NA	NA	NA	NA	95	65	0.052	0.077
Sanburg Drive and Klondike Drive	NA	NA	NA	NA	60	75	0.083	0.066
Residential Under Construction	NA	NA	NA	NA	100	75	.0050	0.066
UPRR (Niles) – Alternative 2 (worst case distances)								
Platinum Street and Green St	NA	NA	NA	NA	95	55	0.052	**0.090**

Sanburg Drive and Klondike Drive	NA	NA	NA	NA	60	40	0.083	**0.118**
Residential Under Construction	NA	NA	NA	NA	100	70	0.050	0.071
UPRR (Niles) – Alternative 3 (worst case distances)								
Platinum Street and Green St	NA	NA	NA	NA	95	50	0.052	**0.100**
Sanburg Drive and Klondike Drive	NA	NA	NA	NA	60	25	0.083	**0.118**
Residential Under Construction	NA	NA	NA	NA	100	70	0.050	0.071

Note 1: Existing Operational Speed of 75 mph assumed and 36 mph for Shoofly
Note 2: Existing vibration based on FTA freight train curve, adjusted for speed
Note 3: Existing and Shoofly operational Speed of 50 mph assumed on UPRR Oakland, and 79 mph on UPRR Niles
Bold vibration values indicate potential exceedance over nighttime disturbance criterion of 0.083 in/sec PPV

6 IMPACTS AND CONTROL MEASURES

6.1 VIBRATION IMPACTS

6.1.1 Consistency with Local Codes

Neither the Fremont nor Union City ordinances contain limits for vibration, thus there are no consistency issues with local codes.

6.1.2 Excessive or Increased Vibration

- As indicated above in Table 5-1, the vibration from new lane construction could exceed 0.3 in/sec PPV at a commercial building within 20 feet of the construction.
- The bridge structure construction at the flood control channel and the railroads (BART and UPRR) would require installation of piles for the bridges. If impact or vibratory methods are used, the vibration impact would be potentially significant at homes within 80 feet of vibratory pile driving or within 200 feet of impact pile driving (three areas). Table 5-2 summarizes the expected vibration from pile driving activities. Also shown are the expected vibration amplitudes from compaction activities for the rock ballast and subsoil preparations.

- Table 5-3 summarizes the estimated vibration impacts from temporary shoofly operations for BART or UPRR during the construction period. Train vibration at up to twenty-four homes near the UPRR tracks would exceed the existing train vibration and the nighttime disturbance criterion of 0.083 in/sec PPV (one home along UPRR Oakland and up to twenty-three homes along UPRR Niles).

- Vibration from traffic on the Project Roadway would generally be consistent with the existing vibration. The exception would be the one commercial building on Decoto (13 feet from the new road), which would increase by a factor of 2 over existing conditions. However, the operational increase at this location would not result in vibration exceeding 0.3 in/sec PPV, as received at this building; therefore, this permanent vibration impact is not significant.

6.2 RECOMMENDED VIBRATION CONTROL MEASURES

- *Construction specifications shall include the following vibration limits: Vibration at all residential and non-engineered wood frame buildings should be limited to 0.2 in/sec PPV. Vibration at commercial, concrete, and engineered buildings should be limited to 0.3 in/sec PPV.*

- *Prior to construction, the structural condition of existing structures should be thoroughly documented for homes within the following areas: within 50 feet of the vibratory compacting activities (new lanes, shoofly), within 200 feet of vibratory pile driving activities, or within 400 feet of impact pile driving activities. This survey would serve the purpose of recording the presence and condition of existing cosmetic and structural cracks or defects.*

- *High amplitude vibration methods such as vibratory sheet pile driving and soil compaction using large truck mounted compactors should be restricted to areas beyond 50 feet of residential structures or wood-framed buildings or 20 feet of commercial buildings. Soil compaction within 50 feet of residential structures should be performed with small (hand operated) vibratory rollers, if feasible.*

    - *If it is infeasible to limit the equipment as indicated above, then construction vibration monitoring should be conducted to document the actual vibration generated at the closest representative buildings, or representative distance. If the vibration methods do not exceed the criteria, then the activities may be allowed without restriction.*

    - *If it is not possible to restrict the equipment usage or document usage within allowable limits, then the Project would generate a potentially unmitigable impact.*

- *Advance notice and information regarding projected vibration should be provided to neighbors within 400 feet of pile driving activities or 100 feet of vibratory compaction. For buildings within these zones, the Project should encourage neighbors to remove precious and fragile items from shelves and walls for the duration of nearby construction* *activities. Some suggestions for information to include in the notice are discussed in the Appendix.*

- *The contractor should limit the speed of large equipment to 15 mph on site, and reduce the occurrence of potholes and large bumps (e.g., portable curbs) for trucks which would move at a higher speed.*
- *Modify shoofly alignments to maintain a distance to nearby residences greater than 40 feet from track centerline (UPRR Oakland) or 60 feet (UPRR Niles).*
- *Use tire-derived aggregate (TDA) as a substrate layer below the ballast and sub-ballast to reduce the vibration transmitted into the ground. While this technology has not yet been proven for freight or heavy rail applications, it has been used as vibration-reducing underlayment for light rail operations at the Valley Transportation Authority (VTA) and the Transportation Expansion project (TREX) in Denver, CO.*
- *Advance notice and community outreach regarding projected vibration for neighbors within 100 feet of UPRR shoofly alignments. Some suggestions for information to include in the notice are discussed in the Appendix.*
- *Limit UPRR track operations on shooflies to daytime hours only (7 a.m. to 10 p.m.), (this may only be possible to achieve along UPRR Oakland given the current low level of train activity)*

7 CUMULATIVE IMPACTS

There are no evaluation methods or criteria to determine the additive, or cumulative effects of vibration. Since the existing vibration and the vibration from the proposed project are not constant and continuous, each vehicle or train passby is treated as an individual random event, and the peak vibration is not additive for these kinds of vibration sources. Thus, there would be no cumulative impacts.

REFERENCES

American Association of State Highway Transportation Officials (AASHTO), "Evaluation of Transportation-Related Earthborne Vibrations," R 8-96 (2004).

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Federal Transit Administration, "Transit Noise and Vibration Impact Assessment" (DTA-VA-90-1003-06), May 2006.

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8 APPENDIX A: GLOSSARY OF ACOUSTICAL TERMS RELEVANT TO ENVIRONMENTAL PROJECTS

Accelerometer: A vibration sensitive transducer that responds to the vibration acceleration of a surface to which it is attached. The electronic signal generated by an accelerometer is directly proportional to the surface acceleration.

Acceleration Level: Also referred to as “vibration acceleration level. The acceleration level is 20 times the logarithm to the base 10 of the ratio of the acceleration to a reference acceleration. The commonly accepted reference acceleration is 10-6 g (10-5 m/sec).

Acceleration: The rate of change of velocity with respect to time

A-Weighted Sound Level (dBA): The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Airborne Sound: Sound that travels through the air, as opposed to structure-borne sound.

Ambient Sound (Noise) or Vibration: The prevailing general sound and noise or vibration existing at a location or in a space, which usually consists of a composite of sounds or vibration sources from many sources near and far.

Background Sound (Noise) or Vibration: The general composite non-recognizable sound and noise or vibration from all distant sources, not including nearby sources or the source of interest. Generally background noise or vibration consists of a large number of distant noise or vibration sources and can be characterized by L90 or L99.

Community Noise Equivalent Level (CNEL): The Leq of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to sound levels between 7 p.m. and 10 p.m. and a 10 dB penalty applied to sound levels between 10 p.m. and 7 a.m.

Crest Factor: The ratio of the peak amplitude to the root-mean-square (RMS) amplitude. The crest factor can be assumed to be 4 for random vibration.

Day-Night Equivalent Level (Ldn): The Leq of the A-weighted sound level over a 24-hour period with a 10 dB penalty applied to sound levels between 10 p.m. and 7 a.m.

Decibel (dB): The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, and sound intensity) with respect to a standardized quantity.

Displacement: The distance a particle moves as a result of vibration.

Energy Equivalent Level (Leq): The level of a steady sound which would have the same energy as the fluctuating noise level integrated over the time period of interest. Leq is widely used as a single-number descriptor of environmental noise. Leq is based on the logarithmic or energy summation and it places more emphasis on high sound level periods than does L50 or a straight arithmetic average of noise level over time. This energy average is not the same as the average sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

Frequency (Hz): The number of oscillations per second of a periodic noise (or vibration) expressed in Hertz (abbreviated Hz). Frequency in Hertz is the same as cycles per second.

Groundborne Noise: Noise caused by vibration propagated through soil and building structures. It is normally radiated by the ground in open air and by walls, floors and ceilings inside a building as a result of vibration which, after being produced by a source some distance away, travels through the soil in the form of elastic waves.

Groundborne Vibration: Vibration propagated through soil and building structures. The vibration travels through the soil in the form of elastic waves.

Octave Band - 1/3 Octave Band: One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz. An octave band is a frequency range that is one octave wide. A standard series of octaves is used in acoustics, and they are specified by their center frequencies. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1/3 octave bands, where each octave is divided into three 1/3 octave bands.

Pascal: One Newton per square meter

Peak Acceleration: The maximum excursion of instantaneous vibration acceleration amplitude from zero.

Peak Displacement: The maximum excursion of instantaneous vibration displacement amplitude from zero.

Peak Particle Displacement: (See Peak Displacement)

Peak Particle Velocity: (See Peak Velocity)

Peak Velocity: The maximum excursion of instantaneous vibration velocity amplitude from zero.

Root Mean Square (RMS): The square root of the average over a period of time of the square of the amplitude.

Root Mean Square Velocity: The square root of the average over a period of time of the square of the velocity amplitude.

Sound Pressure Level (SPL): The sound pressure level of sound in decibels is 20 times the logarithm to the base of 10 of the ratio of the RMS value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 *micro*-Pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels".

Statistical Distribution Descriptors (L1, L10, L50, L90, etc): Also called Exceedance Levels, they represent the level of the sound (A-weighted for environmental studies) or vibration which is exceeded a percentage of the duration of the measurement period, as denoted by the subscript. So, for instance, L10 is the level of the sound or vibration exceeded for 10 percent of the measurement period (usually 1 hour in long-term environmental studies)

> **L99** and **L90** are descriptors of the typical minimum or "residual" background sound (or vibration) levels observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. Generally, the prevalent source of this residual sound is distant street traffic noise. L90 and L99 are not strongly influenced by occasional local motor vehicle passbys. However, they can be influenced by stationary sources such as air conditioning equipment.
>
> **L50** represents a long-term statistical median sound level over the measurement period and does reveal the long-term influence of local traffic noise.
>
> **L10** describes typical levels or average for the maximum sound levels occurring, for example, during nearby passbys of trains, trucks, buses and automobiles, when there is relatively steady traffic noise. Thus, while L10 does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicle passbys at most locations.
>
> **L1**, the sound level exceeded for 1 percent of the time is representative of the occasional, isolated maximum or peak level which occurs in an area. L1 is usually strongly influenced by the maximum short-duration noise level events which occur during the measurement time period and are often determined by aircraft or large vehicle passbys.

Structure-Borne Sound: Generated by vibration traveling through the structure and causing the floors, ceiling and/or walls to vibration and re-radiate sound.

Velocity: The rate of change of displacement with respect to time.

Velocity Level: Also referred to as the “vibration velocity level.” The velocity level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the velocity to a reference velocity. In this report the reported vibration velocity levels are all referenced to 10-6 in/sec.

Vibration: In this context, the motion of an object (e.g., the ground) in response to random or harmonic excitation. Vibration can be measured in terms of acceleration, velocity or displacement.

9 APPENDIX B: BUILDING DAMAGE CRITERIA

AASHTO R8-96 (2004) "Evaluation of Transportation-Related Earthborne Vibrations" describes three general categories of damage to buildings:

- Threshold Cracking. The manifestation of cosmetic damage; the formation of the most superficial interior cracking which occurs in all homes due to various environmental factors and household activities. Safe vibration limits are set to avoid these types of cracks.

- Architectural or Minor Damage. Non-structural damage that does not affect the strength or function of a structure, such as cracked plaster, cracked or broken windows, or hairline cracks in masonry walls.

- Major Damage. Damage resulting in serious weakening of a structure; for example, substantial settlements or shifting of foundations, distortion or weakening of the superstructure, large cracks in foundation or bearing walls, or walls out of plumb.

These AASHTO guidelines indicate that Threshold Damage can be avoided with criteria less than 0.75 in/sec PPV for residential buildings using drywall and 0.5 in/sec PPC for residential buildings use plaster, based on work conducted by the US Bureau of Mines.

The determination of the significance of construction vibration induced cracking must be made in the context of cracking caused by other environmental and domestic factors. Dowding (1985) identifies many causes of cosmetic cracking, including 1) differential thermal expansion, 2) structural overloading, 3) chemical changes in mortar, bricks, plaster, and stucco, 4) shrinkage and swelling of wood, 5) fatigue and aging of wall coverings, and 6) differential foundation settlement. These cracks develop over time, regardless of vibration, and require patching and painting as a matter of normal maintenance. The assessment of cracks related to construction of vibration must be made against this background crack rate, and the differentiation of blast-induced cosmetic cracks from naturally occurring cosmetic cracks can be extremely difficult and time-consuming.

Siskind (2000) indicates that field data suggests a probability of 5 percent for cosmetic damage or threshold damage at 0.5 in/sec peak particle velocity. However, Siskind indicates that the occurrence of threshold cosmetic damage disappears below 0.5 in/sec peak particle velocity, indicating that applying a lower criterion for threshold damage would be excessively conservative for residential buildings of normal construction and historical/political significance.

An active family may produce strains in walls and ceilings that are comparable with those produced by blast vibration at 0.1 to 0.5 in/sec PPV (Dowding 1985). Moreover, the strains produced by thermal variations over a 24 hour period may greatly exceed those produced by vibration from controlled detonation of this order. Thermal cracking of new stucco, for example, can be mistaken for architectural damage due to construction-related vibration.

The Federal Transit Administration (FTA) has recommended vibration criteria for construction-related earthborne vibration. (FTA, 2006). These criteria are summarized in Table B-1.

Table B-1 FTA Construction Vibration Criteria

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

10 APPENDIX C: SHOOFLY CONSTRUCTION OPTIONS

A shoofly is a temporary railroad track. To minimize impacts on the operations of ACE, Amtrak, BART, and UPRR during project construction, shooflies for the impacted tracks would be constructed within existing railroad right-of-way to allow for the removal of the existing tracks and the construction of the grade separation structures while maintaining the existing rail operations. There would be a minimum distance of 15 feet between the centerline of the shoofly track and adjacent residential soundwalls. The shoofly would likely be constructed parallel and be adjacent to the excavation for the grade separation structures, and temporary shoring would be required to support the excavation. Once the structures are completed, the BART and UPRR tracks would be restored to their existing locations onto the newly constructed structures. Attached figures illustrate the construction sequences for each rail corridor. For BART and the UPRR Oakland Subdivision, the construction sequence would be as follows:

a. Construct UPRR shoofly #1 25 feet north of existing UPRR

b. Construct BART shoofly 70 feet north of existing BART

c. Construct south portion of underpass structure (Project Roadway)

d. Reconstruct BART tracks in original location, but now on top of new underpass structure

e. Construction UPRR shoofly #2 onto new underpass 42 feet south of existing UPRR

f. Construction north portion of underpass structure

g. Reconstruct UPRR at original location

In the case of the UPRR Niles Subdivision, the trains (freight) may run on shoofly in various configurations. There are three construction/shoofly alternatives currently being considered for the UPRR Niles Subdivision:

Alternative 1:

a. Construct shoofly 30 feet south of existing UPRR

b. Construct north portion of underpass structure (Project Roadway)

c. Reconstruct UPRR track in original location

d. Construct south portion of underpass structure (Project Roadway)

Alternative 2:

a. Construct shoofly #1 10 feet north (towards Klondike) of existing UPRR track

b. Construct south portion of underpass structure (Project Roadway)

c. Construct shoofly #2 40 feet south of existing UPRR (on top of just completed southern underpass

d. Construct north portion of underpass structure (Project Roadway)

e. Reconstruct UPRR track in original location

Alternative 3:

a. Construct shoofly #1 15 feet from north right of way (control and switch house to be relocated)

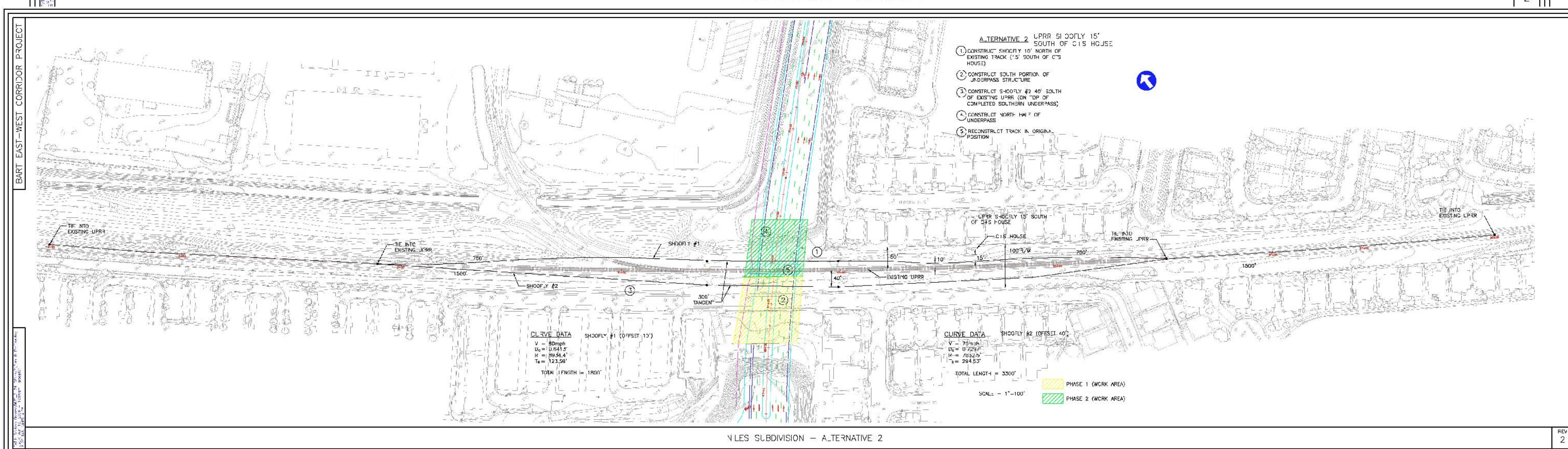
b. Construct south portion of underpass structure (Project Roadway)

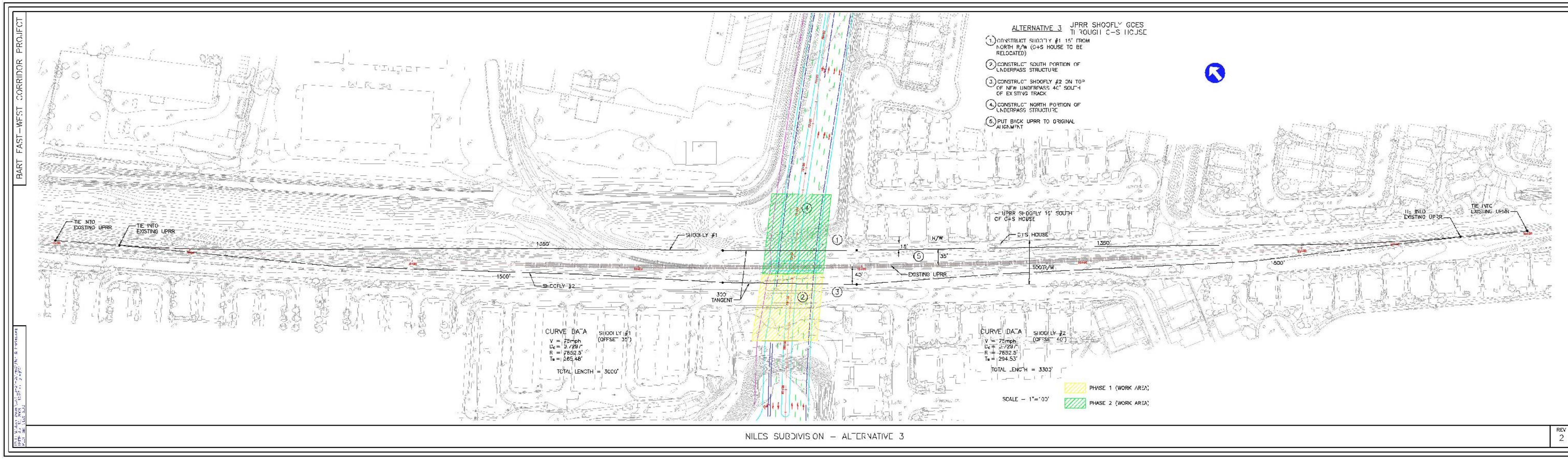
c. Construct shoofly #2 40 feet south of existing UPRR (on top of just completed southern underpass

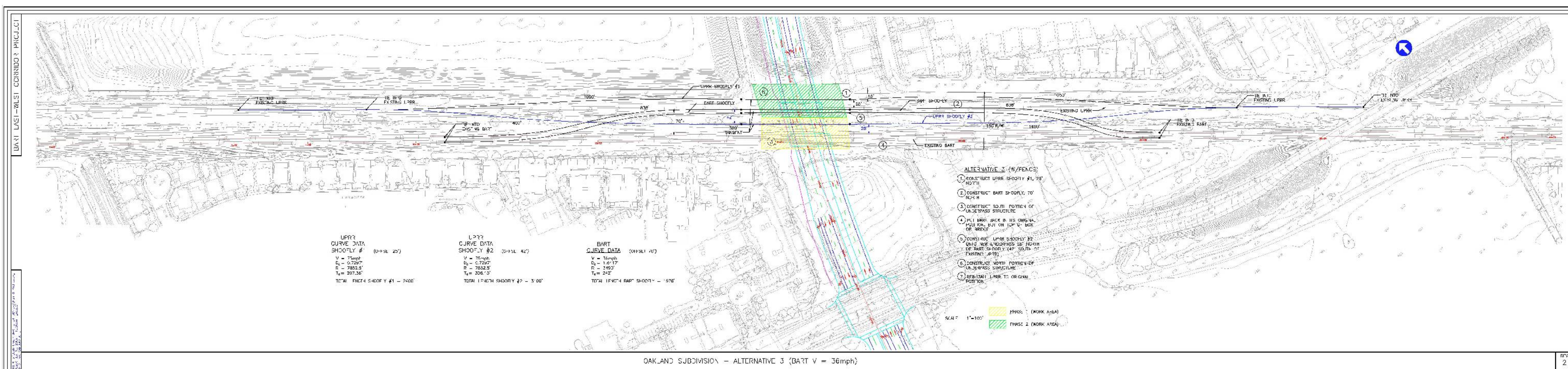
d. Construct north portion of underpass structure (Project Roadway)

e. Reconstruct UPRR track in original location


BART EAST-WEST CORRIDOR PROJECT
ALTERNATIVE 1 UPRR SHOOFLY 30' SOUTH OF EXISTING TRACK
1. SHIFT UPRR TO SOUTH 30'
2. CONSTRUCT NORTH PORTION OF UNDERPASS STRUCTURE
3. PUT BACK UPRR TO ORIGINAL ALIGNMENT
4. CONSTRUCT SOUTH PORTION OF UNDERPASS STRUCTURE
TIE INTO EXISTING UPRR
C+S HOUSE
100' R/W
EXISTING UPRR
1200'
30'
300' TANGENT
UPRR SHOOFLY
CURVE DATA (OFFSET 30')
V = 80mph
Dc = 0.6413°
R = 8934.4'
Ts = 246.78'
TOTAL SHOOFLY LENGTH = 2700'
SCALE – 1"=100'
PHASE 1 (WORK AREA)
PHASE 2 (WORK AREA)
NILES SUBDIVISION – ALTERNATIVE 1
REV 2


BART EAST-WEST CORRIDOR PROJECT
ALTERNATIVE 2 UPRR SHOOFLY 15' SOUTH OF C+S HOUSE
1. CONSTRUCT SHOOFLY 10' NORTH OF EXISTING TRACK (15' SOUTH OF C+S HOUSE)
2. CONSTRUCT SOUTH PORTION OF UNDERPASS STRUCTURE
3. CONSTRUCT SHOOFLY #2 40' SOUTH OF EXISTING UPRR (ON TOP OF COMPLETED SOUTHERN UNDERPASS)
4. CONSTRUCT NORTH HALF OF UNDERPASS
5. RECONSTRUCT TRACK IN ORIGINAL POSITION
TIE INTO EXISTING UPRR
SHOOFLY #1
SHOOFLY #2
UPRR SHOOFLY 15' SOUTH OF C+S HOUSE
C+S HOUSE
100' R/W
EXISTING UPRR
750'
1500'
300' TANGENT
CURVE DATA SHOOFLY #1 (OFFSET 15')
V = 80mph
Dc = 0.6413°
R = 8934.4'
Ts = 123.56'
TOTAL LENGTH = 1800'
CURVE DATA SHOOFLY #2 (OFFSET 40')
TOTAL LENGTH = 3300'
SCALE – 1"=100'
PHASE 1 (WORK AREA)
PHASE 2 (WORK AREA)
NILES SUBDIVISION – ALTERNATIVE 2
REV 2


BART EAST-WEST CORRIDOR PROJECT
ALTERNATIVE 3 UPRR SHOOFLY GOES THROUGH C-S HOUSE
1. CONSTRUCT SHOOFLY #1 15' FROM NORTH R/W (C+S HOUSE TO BE RELOCATED)
2. CONSTRUCT SOUTH PORTION OF UNDERPASS STRUCTURE
3. CONSTRUCT SHOOFLY #2 ON TOP OF NEW UNDERPASS 40' SOUTH OF EXISTING TRACK
4. CONSTRUCT NORTH PORTION OF UNDERPASS STRUCTURE
5. PUT BACK UPRR TO ORIGINAL ALIGNMENT
TIE INTO EXISTING UPRR
SHOOFLY #1
SHOOFLY #2
EXISTING UPRR
CURVE DATA SHOOFLY #1 (OFFSET 35')
TOTAL LENGTH = 3000'
CURVE DATA SHOOFLY #2 (OFFSET 40')
TOTAL LENGTH = 3300'
PHASE 1 (WORK AREA)
PHASE 2 (WORK AREA)
SCALE – 1"=100'
NILES SUBDIVISION – ALTERNATIVE 3
REV 2


BART EAST-WEST CORRIDOR PROJECT
UPRR SHOOFLY #1
BART SHOOFLY
UPRR SHOOFLY #2
EXISTING UPRR
EXISTING BART
ALTERNATIVE 3 (W/FENCE)
1. CONSTRUCT UPRR SHOOFLY #1, 25' NORTH
2. CONSTRUCT BART SHOOFLY, 70' NORTH
3. CONSTRUCT SOUTH PORTION OF UNDERPASS STRUCTURE
4. PUT BART BACK IN ITS ORIGINAL POSITION, BUT ON TOP OF BOX OR BRIDGE
5. CONSTRUCT UPRR SHOOFLY #2 ONTO NEW UNDERPASS 28' NORTH OF BART SHOOFLY (42' SOUTH OF EXISTING UPRR)
6. CONSTRUCT NORTH PORTION OF UNDERPASS STRUCTURE
7. REINSTALL UPRR TO ORIGINAL POSITION
PHASE 1 (WORK AREA)
PHASE 2 (WORK AREA)
SCALE 1"=100'
OAKLAND SUBDIVISION – ALTERNATIVE 3 (BART V = 36mph)
REV 2

11 APPENDIX D VIBRATION COMMUNITY NOTICE

As noted above, there are several conditions where vibration from Project-related activities would potentially be easily perceptible. In some cases (as with pile driving), the vibration could approach or exceed the criteria for cosmetic damage to residential structures (wood frame) of 0.2 in/sec PPV. In others, the vibration would remain well below the building damage criterion, but would nevertheless be felt by nearby residents, possibly creating undue alarm and claims.

Appropriate outreach to reduce the public's worries about vibration would include the following:

- Initial Information packets should include information regarding typical vibration and responses (Figure 3-1).
- Highlight the large difference in magnitude between the amplitude at which vibration is perceivable by humans (0.003 in/sec PPV) vs. that which could potentially cause cosmetic damage (0.2 in/sec PPV).
- Secondary effects may be caused by the vibration, including rattling of windows and items on walls or shelves. Encourage nearby residents (as discussed above) to move precious or fragile items off of shelves or walls.
- Regular communications should be conducted with nearby residents (via phone, mail, email or web information page) as to the construction schedule for vibration-generating activities (pile driving, vibratory compacting, shoofly, etc.)
- Provide a project liaison who will be available to respond to community concerns regarding vibration