

## **Section 12 – Preconstruction Assessment and Damage Mitigation Procedures**

- A. Introduction - In past years, HRSD received complaints from private property owners, the public and locality staff regarding the condition of roads, sidewalks, drainage ditches, private property, damage to buildings, etc. within and along pipeline construction corridors and in close proximity to pumping station construction projects. For many of these construction projects, the captured preconstruction photography and/or video coverage were inadequate to resolve claims or complaints. This section provides evaluation processes and expectations for varying levels of preconstruction surveys and active construction impact monitoring during construction related to the potential of construction noise, vibration, ground settlement, building damage, water ponding, and restoration complaints. Numerous publications have been authored on the matter of construction related noise and vibration and on impacts to individuals and structures. Included in this section are excerpts from some of these publications to assist FIRM in determining the appropriate level of preconstruction survey / assessment and active construction impacts monitoring to be performed for a planned construction project for the purpose of protecting all parties. Also included in this document are template forms and documentation that are to be used by FIRM for encounters with property owners and businesses in the determined impact zone from a HRSD construction project. FIRM must obtain a waiver, in writing, from the responsible Chief of Design and Construction as well as HRSD’s Real Estate Manager for any variances from the required use of this or any parts of this section of the standards.
- B. Organization and outline of this Section – This section is divided into Stages that correspond with evaluations and decision points related to the various identified types of possible construction related impacts for typical HRSD projects. Figure B-1 is a decision flow chart that is included to assist in navigating this section. Every project to go through a Stage 1 discovery and review resulting in a project team discussion to determine the process forward. FIRM shall provide a detailed summary report and file it in the project’s folder utilizing HRSD’s UNIFIER Software. Workshops shall be facilitated by the FIRM related to Preconstruction Assessment and Damage Mitigation during the design phase of each project. The timing of these workshops is described in the following section.

For a more detailed understanding of each stage and its requirements, see the corresponding and following sections beginning with item “C” of this section of the Standards.

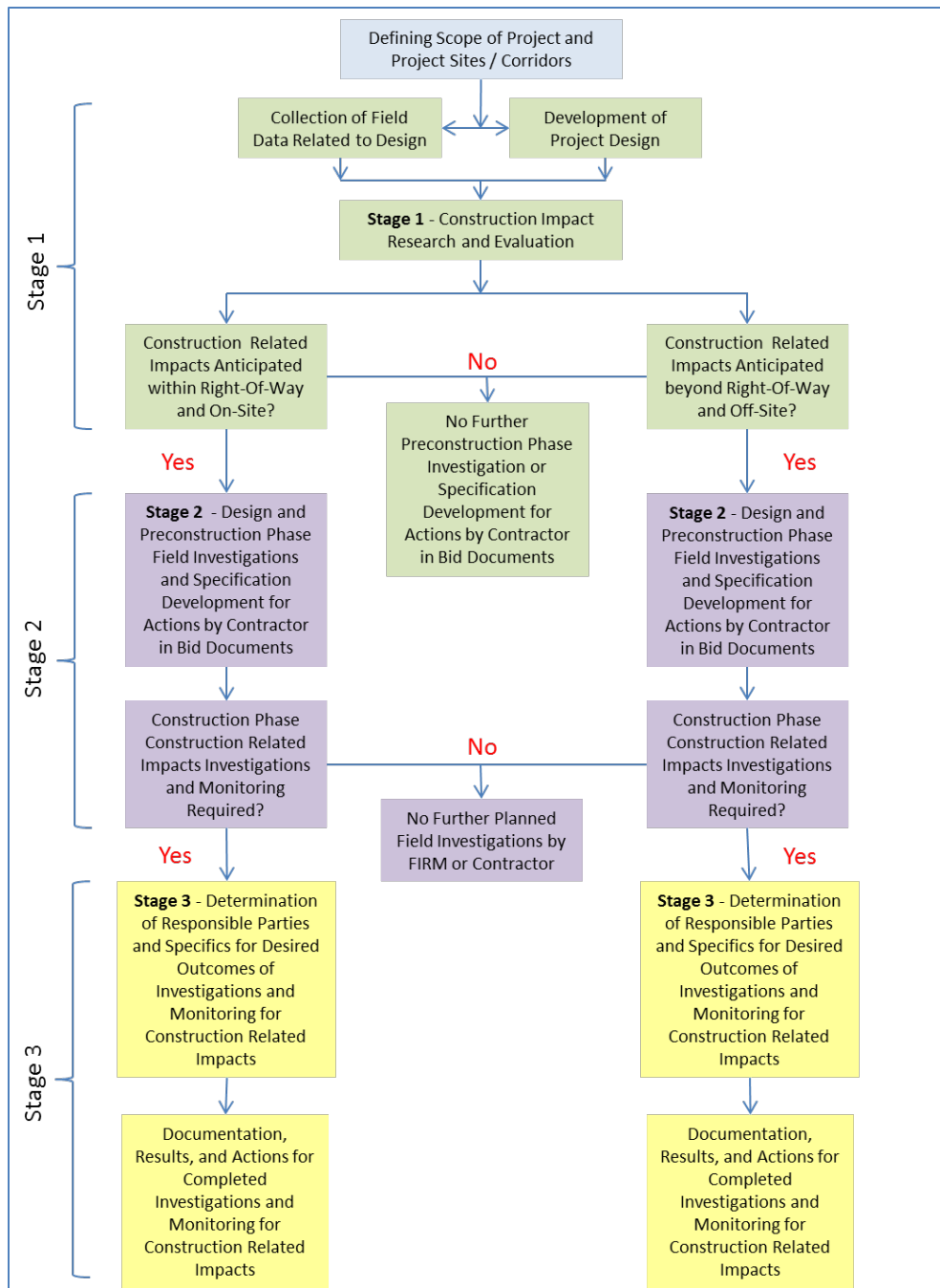
Following HRSD review and acceptance of 50% design development plans and prior to the 90% design development stage, the FIRM will conduct a workshop to discuss the Stage 1 (Construction Impact Research and Evaluation) report and any recommendations for further actions in the preconstruction or construction phases that are detailed in the Stage 2 and Stage 3. Attendees at this workshop will include the HRSD Project Manager, Real Estate Manager, and other key stakeholders within HRSD.

1. Stage 1 – Construction Impact Research and Evaluation
  - a. Research and Investigations
    - i. Soil conditions
    - ii. Previous projects in the area and issues

- iii. What types of sensitive structures may exist in the area (schools, churches, historical buildings, or monuments)
- b. Likely Construction Means and Methods Determinations
- c. Potential of Construction Related Impacts
  - i. Noise Generation and Impacts
  - ii. Vibrations Impacts
  - iii. Dewatering Impacts on Ground and Structures Settlement (remember to consider pools and other subsurface structures)
  - iv. Construction Impacts on Existing Topography, Hydrology, and Construction Travel Routes
  - v. Dust, Odor, and Other Emissions beyond Construction Zone
  - vi. Locality Limitations, Requirements or Ordinances (for the items above)
- d. Determination of the construction zone of influence for each potential construction related impacts both perceived and actual (Provide written report clearly detailing impact distances from project site and visual diagram detailing the same).
  - i. Sample – Vibration Generation and Impacts (diagram and impact table)
  - ii. Sample – Noise Generation and Impacts (diagram and impact table)
  - iii. Sample – Noise and Vibration Impacts (combined map)
  - iv. Sample – Dewatering Impacts

Following HRSD review and acceptance of 90% design development plans and prior to the 100% design development stage, the FIRM will conduct a workshop to discuss Stage 2 (Risk Mitigation Analysis and Bid Document Development for Contractor Actions) and Stage 3 (Specific Pre-Construction Field Surveys and Construction Activity Monitoring Programs) if recommended actions are to be incorporated into the Bid Documents for the Contractor to perform, recommended actions are to be performed and/or coordinated by the FIRM during the construction phase, and any other recommended actions to be undertaken by HRSD or a third party to monitor and/or mitigate potential construction related damages to adjacent properties. Attendees at this workshop will include the HRSD Project Manager, Real Estate Manager, and other key stakeholders within HRSD.

- 2. Stage 2 – Risk Mitigation Analysis and Bid Document Development for Contractor Actions
  - a. Noise Impacts, Restrictions, and Abatement
  - b. Vibration Impacts, Abatement, and Monitoring
  - c. Groundwater Dewatering Requirements
  - d. Pre-Construction Surveys and Assessments within Construction Corridors and Impact Areas
  - e. Fugitive Emissions Controls and Restrictions
- 3. Stage 3 – Specific Pre-Construction Field Surveys and Construction Activity Monitoring Programs
  - a. Responsibilities of the FIRM
  - b. Responsibilities of the Contractor
  - c. Identification of Other Party Responsibilities



**Figure B-1: Flow Chart for Preconstruction Assessment Decisions and Actions**

**C. Stage 1 – Construction Impact Research and Evaluation**

1. The FIRM shall perform the following research and investigations during the Design phase of a project at a minimum to provide needed information for determination of possible construction related impacts to surrounding areas:
  - a. Determination of the zone of influence throughout the entire project impact area.
  - b. Presence of historically significant buildings, structures, and/or sites.

- c. Determination of the types of buildings (residential, business, religious, education, etc.).
  - d. Determination of age, materials of construction, presence of basements for buildings.
  - e. Distance from closest point of construction to each building, structure and/or site.
  - f. Soil types and strata from soil borings (at recommended locations).
  - g. Groundwater levels and seasonal variations within the construction site or corridor.
  - h. Topography and hydrology and known or likely stormwater drainage issues.
  - i. Dust, odor, and other emissions.
2. The FIRM shall determine the following during the Design phase of a project to provide information for possible construction related impacts to surrounding areas:
- a. Ranges of depth of construction (bottom of pipe trench, pump station wet well, vault, etc.)
  - b. Anticipated heavy construction equipment for specific areas (noise and vibration impacts).
  - c. Construction methods and materials for trench or excavation pit stabilization and foundation support (driven temporary or permanent sheet piling, auger foundation piles, driven foundation piles).
  - d. Dewatering methods and likely impacts on ground or structure settling because of dewatering in the cone of depression zone.
  - e. Pavement type and thickness where construction equipment will travel upon, or equipment /materials staged upon.
  - f. Determination of day verses night construction noise requirements.
  - g. Determination of prevailing winds in areas of construction and fugitive emissions from the construction zone.
3. The FIRM shall evaluate the potential of construction related impacts to adjacent properties and structures based upon collected information as mentioned in the preceding paragraphs of this Section. Referenced publications and excerpts from noted publications are included in this Section to assist the FIRM in determining the potential of construction related impacts and a course of action for preconstruction assessments that suite the risks. This referenced information and these procedures are not all inclusive, and therefore the FIRM shall apply their own experience and evaluations to supplement the information in this Section to minimize risks related to construction impacts. At the conclusion of this process, the FIRM shall produce a single detailed report of the findings and FIRM's determination of construction related impacts and submit to the HRSD Project Manager (PM) and Real Estate Manager (REM).
- a. **Noise Generation and Impacts.** Noise influences from construction activities may vary depending on the duration, equipment used, sound frequencies, environmental conditions, among other factors that need to be evaluated and possibly abated depending upon the anticipated impact of noise.

The following tables and information from the *Federal Transit Administration Office of Planning and Environment Transit Noise and Vibration Impact Assessment May 2006* publication should be reviewed by the FIRM to assess noise influences and

action plans.

### **12.1.1 Quantitative Noise Assessment Methods**

A quantitative construction noise assessment is performed by comparing the predicted noise levels with impact criteria appropriate for the construction stage. The approach requires an appropriate descriptor, a standardized prediction method and a set of recognized criteria for assessing the impact.

The *descriptor* used for construction noise is the  $L_{eq}$ . This unit is appropriate for the following reasons:

- It can be used to describe the noise level from operation of each piece of equipment separately and is easy to combine to represent the noise level from all equipment operating during a given period.
- It can be used to describe the noise level during an entire phase.
- It can be used to describe the average noise over all phases of the construction.

The recommended *method* for predicting construction noise impact for major transit projects requires:

- An emission model to determine the noise generated by the equipment at a reference distance.
- A propagation model that shows how the noise level will vary with distance.
- A way of summing the noise of each piece of equipment at locations of

noise sensitivity. The first two components of the method are related by the following equation:

$$L_{eq}(equip) = E.L. + 10 \log(U.F.) - 20 \log(D/50) - 10G \log(D/50)$$

where:  $L_{eq}$  (*equip*) is the  $L_{eq}$  at a receiver resulting from the operation of a single piece of equipment over a specified time period

*E.L.* is the noise emission level of the particular piece of equipment at the reference distance of 50 feet, taken from Table 12-1

*G* is a constant that accounts for topography and ground effects, taken from Figure 6-5 (Chapter 6)

*D* is the distance from the receiver to the piece of equipment, and

*U.F.* is a usage factor that accounts for the fraction of time that the equipment is in use over the specified time period.

The combination of noise from several pieces of equipment operating during the same time period is obtained from decibel addition of the  $L_{eq}$  of each single piece of equipment found from the above equation.

### **General Assessment**

The approach can be as detailed as necessary to characterize the construction noise by specifying the various quantities in the equation. For projects in an early assessment stage when the equipment roster and schedule are undefined, only a rough estimate of construction noise levels is practical.

The following assumptions are adequate for a general assessment of each phase of construction:

- Full power operation for a time period of one hour is assumed because most construction equipment operates continuously for periods of one hour or more at some point in the construction period. Therefore,  $U.F. = 1$ , and  $10 \log(U.F.) = 0$ .
- Free-field conditions are assumed and ground effects are ignored. Consequently,  $G = 0$ .
- Emission level at 50 feet, E.L., is taken from Table 12-1.
- All pieces of equipment are assumed to operate at the center of the project, or centerline, in the case of a guideway or highway construction project.
- The predictions include only the two noisiest pieces of equipment expected to be used in each construction phase.

### **Detailed Assessment**

A more detailed approach can be used if warranted, such as when a large number of noise-sensitive sites are adjacent to a construction project or where contractors are faced with stringent local ordinances or heightened public concerns expressed in early outreach efforts. Additional details include:

- **Duration.** Long-term construction project noise impact is based on a 30-day average  $L_{dn}$ , the times of day of construction activity (nighttime noise is penalized by 10 dB in residential areas), and the percentage of time the equipment is to be used during a period of time which will affect U.F. For example, an 8-hour  $L_{eq}$  is determined by making U.F. the percentage of time each individual piece of equipment operates under full power in that period. Similarly, the 30-day average  $L_{dn}$  is determined from the U.F. expressed by the percentage of time the equipment is used during the daytime hours (7 a.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m.), separately over a 30-day period. However, to account for increased sensitivity to nighttime noise, the nighttime percentage is multiplied by 10 before performing the computation.

- Site Characteristics. Taking into account the site topography, natural and man-made barriers and ground effects will involve the factor  $G$ . Use Figure 6-5 (Chapter 6) to calculate  $G$ .
- Noise Sources. Measuring or certifying the emission level of each piece of equipment will refine  $E.L.$
- Site Layout. Determining the location of each piece of equipment while it is working will specify the distance factor  $D$  more accurately.
- Combined Sources. Including all pieces of equipment in the computation of the 8-hour  $L_{eq}$  and the 30- day average  $L_{dn}$  will determine the total noise levels using Table 6-11 (Chapter 6).

### **12.1.2 Noise from Typical Construction Equipment and Operations**

The noise levels generated by construction equipment will vary greatly depending on factors such as the type of equipment, the specific model, the operation being performed, and the condition of the equipment. The equivalent sound level ( $L_{eq}$ ) of the construction activity also depends on the fraction of time that the equipment is operated over the time period of construction. The dominant source of noise from most construction equipment is the engine, usually a diesel, often without sufficient muffling. In a few cases, such as impact pile-driving or pavement-breaking, noise generated by the process dominates.

For considerations of noise assessment, construction equipment can be considered to operate in two modes, stationary and mobile. Stationary equipment operates in one location for one or more days at a time, with either a fixed power operation (pumps, generators, compressors) or a variable noise operation (pile drivers, pavement breakers). Mobile equipment moves around the construction site with power applied in cyclic fashion (bulldozers, loaders), or to and from the site (trucks). The movement around the site is handled in the construction noise prediction procedure discussed earlier in this chapter. Variation in power imposes additional complexity in characterizing the noise source level from a piece of equipment. This is handled by describing the noise at a reference distance from the equipment operating at full power and adjusting it based on the duty cycle of the activity to determine the  $L_{eq}$  of the operation. Standardized procedures for measuring the exterior noise levels for the certification of mobile and stationary construction equipment have been developed by the Society of Automotive Engineers.<sup>(1,2)</sup> Typical noise levels from representative pieces of equipment are listed in Table 12-1. These source levels can be used in FHWA's Windows-based screening tool, "Roadway Construction Noise Model" (RCNM), for the prediction of construction noise.<sup>(3)</sup>

Construction activities are characterized by variations in the power expended by equipment, with resulting variation in noise levels with time. Variation in the power is expressed in terms of the previously mentioned "usage factor" of the equipment, which is the percentage of time during the workday that the equipment is operating

at full power. Time-varying noise levels are converted to a single number ( $L_{eq}$ ) for each piece of equipment during the operation. Besides having daily variations in activities, major construction projects are accomplished in several different phases. Each phase has a specific equipment mix depending on the work to be accomplished during that phase.

As a result of the equipment mix, each phase has its own noise characteristics; some have higher continuous noise levels than others, some have high impact noise levels. The purpose of the quantitative assessment is to determine not only the levels, but also the duration of the noise. The  $L_{eq}$  of each phase is determined by combining the  $L_{eq}$  contributions from each piece of equipment used in that phase. The impact and the consequent noise mitigation approaches depend on the criteria to be used in assessing impact, as discussed in the next section.

<b>Equipment</b>	<b>Typical Noise Level (dBA) 50 ft from Source</b>
Air Compressor	81
Backhoe	80
Ballast Equalizer	82
Ballast Tamper	83
Compactor	82
Concrete Mixer	85
Concrete Pump	82
Concrete Vibrator	76
Crane, Derrick	88
Crane, Mobile	83
Dozer	85
Generator	81
Grader	85
Impact Wrench	85
Jack Hammer	88
Loader	85
Paver	89
Pile-driver (Impact)	101
Pile-driver (Sonic)	96
Saw	76
Pneumatic Tool	85
Pump	76
Rail Saw	90
Rock Drill	98
Roller	74
Saw	76
Scarifier	83



<b>Equipment</b>	<b>Typical Noise Level (dBA) 50 ft from Source</b>
Scraper	89
Shovel	82
Spike Driver	77
Tie Cutter	84
Tie Handler	80
Tie Inserter	85
Truck	88

*Table based on an EPA Report,<sup>(4)</sup> measured data from railroad construction equipment taken during the Northeast Corridor Improvement Project, and other measured data.*

### **12.1.3 Construction Noise Criteria**

No standardized criteria have been developed for assessing construction noise impact. Consequently, criteria must be developed on a project-specific basis unless local ordinances can be found to apply. Generally, local noise ordinances are not very useful in evaluating construction noise. They usually relate to nuisance and hours of allowed activity and sometimes specify limits in terms of maximum levels, but are generally not practical for assessing the impact of a construction project. Project construction noise criteria should take into account the existing noise environment, the absolute noise levels during construction activities, the duration of the construction, and the adjacent land use. While it is not the purpose of this manual to specify standardized criteria for construction noise impact, the following guidelines can be considered reasonable criteria for assessment. If these criteria are exceeded, there may be adverse community reaction.

#### **General Assessment**

Estimate the combined noise level in one hour from the two noisiest pieces of equipment, assuming they both operate at the same time. Then identify locations where the level exceeds the following:

<u>Land Use</u>	<u>One-hour L<sub>eq</sub> (dBA)</u>	
	<u>Day</u>	<u>Night</u>
Residential	90	80
Commercial	100	100
Industrial	100	100

#### **Detailed Assessment**

Where a more refined analysis is needed, predict the noise level in terms of 8-hour L<sub>eq</sub> and 30-day averaged L<sub>dn</sub> and compare to criteria in the following table:

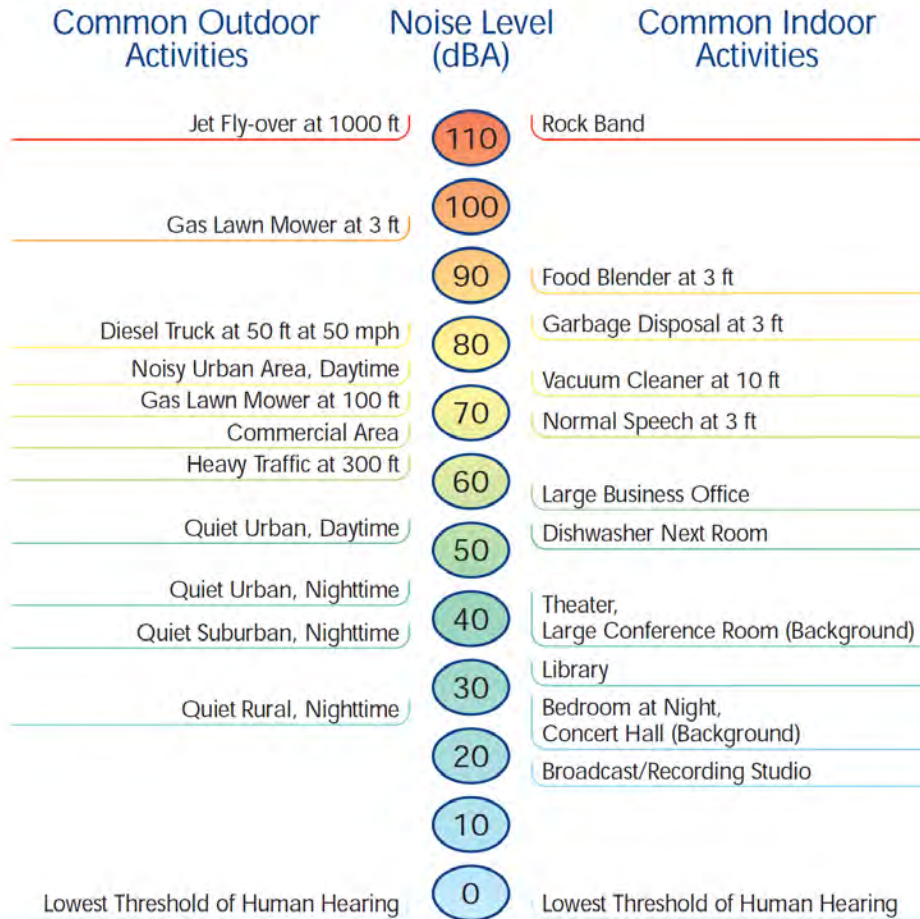
<u>Land Use</u>	8-hour $L_{eq}$ (dBA)		$L_{dn}$ (dBA)
	<u>Day</u>	<u>Night</u>	<u>30-day Average</u>
Residential	80	70	75 <sup>(a)</sup>
Commercial	85	85	80 <sup>(b)</sup>
Industrial	90	90	85 <sup>(b)</sup>

<sup>(a)</sup> In urban areas with very high ambient noise levels ( $L_{dn} > 65$  dB),  $L_{dn}$  from construction operations should not exceed existing ambient + 10 dB.

<sup>(b)</sup> Twenty-four-hour  $L_{eq}$ , not  $L_{dn}$ .

The following diagram provides a visual relationship between common indoor and outdoor sound generators and their accompanying decibel levels. This type of graphic can be used to compare expected construction related noise levels to more commonly experienced sounds.

## LOUDNESS COMPARISON CHART (dBA)



An increase of 3 dBA is barely perceptible to the human ear.

Figure C-1: Decibel Levels for Common Sound Sources

- b. **Vibration Impacts.** Ground vibration impacts from construction activities may vary depending on the duration, equipment used, soil types, groundwater level, vibration frequencies, construction methods among other factors that need to be evaluated and monitored depending on the anticipated impact of vibration.

The following tables and information from the *Federal Transit Administration Office of Planning and Environment Transit Noise and Vibration Impact Assessment May 2006* publication should be reviewed by the FIRM to assess vibration impacts, create action plans, and identify the zone of influence specific to each project.

## **12.2 CONSTRUCTION VIBRATION ASSESSMENT**

Construction activity can result in varying degrees of ground vibration, depending on the equipment and methods employed. Operation of construction equipment causes ground vibrations that spread through the ground and diminish in strength with distance. Buildings founded on the soil in the vicinity of the construction site respond to these vibrations, with varying results ranging from no perceptible effects at the lowest levels, low rumbling sounds and perceptible vibrations at moderate levels, and slight damage at the highest levels. As expressed previously in this chapter with respect to construction noise, the type of assessment – qualitative or quantitative – and the level of construction vibration analysis will be determined by factors related to the scale of the project and the sensitivity of the surrounding land use. A quantitative analysis should be conducted in cases where construction vibration may result in prolonged annoyance or building damage.

Ground vibrations from construction activities do not often reach the levels that can damage structures, but they can achieve the audible and feelable ranges in buildings very close to the site. A possible exception is the case of fragile buildings, many of them old, where special care must be taken to avoid damage. The construction vibration criteria include special consideration for such buildings. The construction activities that typically generate the most severe vibrations are blasting and impact pile driving.

In cases where prolonged annoyance or damage from construction vibrations are not expected, a qualitative assessment is appropriate. Such an assessment should include a description of the duration and the type of equipment to be used during the construction, with an explanation of how the ground-borne vibration will be maintained at an acceptable level. For example, if the equipment is of the type that generates little or no ground vibration – air compressors, light trucks, hydraulic loaders, etc. – a simple explanation is sufficient and no quantitative analysis is necessary.

### **12.2.1 Quantitative Construction Vibration Assessment Methods**

Construction vibration should be assessed quantitatively in cases where there is significant potential for impact from construction activities. Such activities include blasting, pile-driving, vibratory compaction, demolition, and drilling or excavation in close proximity to sensitive structures. The recommended procedure for estimating vibration impact from construction activities is as follows:

#### **Damage Assessment**

- Select the equipment and associated vibration source levels at a reference distance of 25 feet from Table 12-2.
- Make the propagation adjustment according to the following formula (this formula is based on point sources with normal propagation conditions):

$$PPV_{equip} = PPV_{ref} \times (25/D)^{1.5}$$

where: PPV (equip) is the peak particle velocity in in/sec of the equipment adjusted for distance

PPV (ref) is the reference vibration level in in/sec at 25 feet from Table 12-2.

D is the distance from the equipment to the receiver.

- Apply the vibration damage criteria from Table 12-3.

### **Annoyance Assessment**

- If desired for consideration of annoyance or interference with vibration-sensitive activities, estimate the vibration level  $L_v$  at any distance D from the following equation and apply the vibration impact criteria for General Assessment in Chapter 8 for vibration-sensitive sites:

$$L_v(D) = L_v(25 \text{ ft}) - 30\log(D/25)$$

#### **12.2.2 Vibration Source Levels from Construction Equipment**

Ground-borne vibration related to human annoyance is generally related to root mean square (rms) velocity levels expressed in VdB. However, a major concern with regard to construction vibration is building damage. Consequently, construction vibration is generally assessed in terms of peak particle velocity (PPV), as defined in Chapter 7.1.2. The relationship of PPV to rms velocity is expressed in terms of the “crest factor,” defined as the ratio of the PPV amplitude to the rms amplitude. Peak particle velocity is typically a factor of 1.7 to 6 times greater than rms vibration velocity.

Various types of construction equipment have been measured under a wide variety of construction activities with an average of source levels reported in terms of velocity as shown in Table 12-2. In this table, a crest factor of 4 (representing a PPV-rms difference of 12 VdB) has been used to calculate the approximate rms vibration velocity levels from the PPV values. Although the table gives one level for each piece of equipment, it should be noted that there is a considerable variation in reported ground vibration levels from construction activities. The data provide a reasonable estimate for a wide range of soil conditions.

<b>Table 12-2. Vibration Source Levels for Construction Equipment</b> (From measured data. <sup>(7,8,9,10)</sup> )			
<b>Equipment</b>		<b>PPV at 25 ft (in/sec)</b>	<b>Approximate L<sub>v</sub><sup>†</sup> at 25 ft</b>
Pile Driver (impact)	upper range	1.518	112
	Typical	0.644	104
Pile Driver (sonic)	upper range	0.734	105
	Typical	0.170	93
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	in soil	0.008	66
	in rock	0.017	75
Vibratory Roller		0.210	94
Hoe Ram		0.089	87
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58
† RMS velocity in decibels (VdB) re 1 micro-inch/second			

The following diagram provides a relationship between vibration sources and likely impacts from the vibrations they generate.

### Typical Vibration Sources and Sensitivities

Peak Ground Velocity (in/sec)	TYPICAL VIBRATION SOURCES			EFFECTS OF VIBRATION			
	Transportation Sources	Construction Sources	Natural Sources	Structural Damages	Human Perception	People and Equipment Tolerance	
100							
10			<ul style="list-style-type: none"> <li>San Francisco, CA Earthquake 4/18/06</li> <li>Santa Cruz, CA Earthquake 10/17/89</li> </ul>		Intolerable		
1.0		Blasting at 50 ft.	<ul style="list-style-type: none"> <li>Coalinga, CA Earthquake 5/2/83</li> </ul>	<ul style="list-style-type: none"> <li>Structural Damage</li> <li>Minor Damage</li> </ul>	<ul style="list-style-type: none"> <li>Extremely Unpleasant</li> <li>Very Unpleasant</li> <li>Unpleasant</li> </ul>	<ul style="list-style-type: none"> <li>Human Exposure</li> <li>1 Minute</li> <li>1 Hours</li> </ul>	
0.1		Pile Driving at 50 ft.	Typical Moonquake	Low Probability of Damage		8 Hours	ISO 2631 Limits
0.01				Very Safe to Buildings		24 Hours	
0.001	Subway Train (Measure above tunnel)	Truck or Dozer at 50 ft.			Strongly Noticeable	Computers	
0.01	Motor Vehicle Traffic at 50 ft. on Rough Roadway and Elevated Highway	Jackhammer at 50 ft.			Easily Noticeable	Office	
0.001	Motor Vehicle Traffic at 50 ft. on Smooth Roadway and At-grade Highway	Blasting at 500 ft.	Micro-Meteorite Impacts at 50 ft.		Barely Perceptible	Residences	
0.0001	Truck at 200 ft. on Rough Roadway	Pile Driving at 500 ft.			Imperceptible	Optical Microscopes	
						Electron Microscopes	

Source: Nugent & Amick, 1992, Environmental Monitor Vibration Considerations in Land Use Planning, Summer 1992.  
 Ogden, 1995, Typical Vibration Sources and Sensitivities.

Figure C-2: Typical Vibration Sources and Sensitivities

- c. **Dewatering Impacts on Ground and Structures Settlement.** Dewatering of deep construction trenches and excavation pits is a common practice for HRSD construction projects. The cone of depression for ground water removal with well point dewatering systems needs to be evaluated for possible settling impacts on ground movement, paved surfaces, buried utilities, buildings, and other structures near the construction zone. Common occurrences with groundwater dewatering are compaction of soils as water is removed resulting in soil movement and removal of fine soil particles along with the groundwater resulting in voids in the soil. The FIRM is to evaluate settlement abatement methods and materials, create action plans and

identify the zone of influence specific to each project.

This following figure shows the results of groundwater modeling for a calculated withdrawal rate.

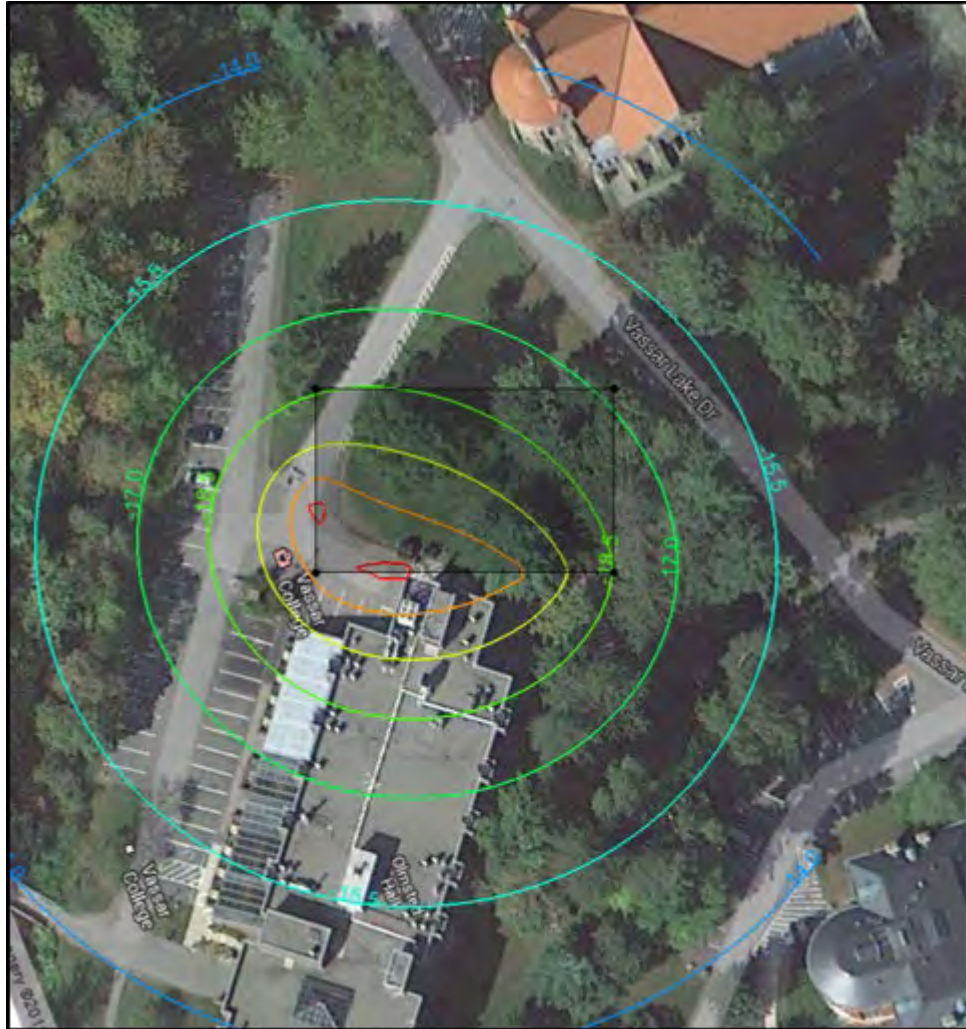


Figure C-3: Example of Impact Zone and Groundwater Elevations during Withdrawal

- d. **Construction Impacts on Existing Topography, Hard Surfaces, Hydrology, and Construction Travel Routes.** The FIRM to document existing conditions and evaluate likely impacts on stormwater drainage, unpaved surfaces, paved surface, concrete driveways / sidewalks, vegetation / plantings from construction equipment and material storage within the construction zones. Consideration to be given to preventative and protective measures as practical to be incorporated into the construction Bid Documents. The FIRM to consider how the Contractor(s) will deliver materials to the construction area and storage sites and movement of construction equipment across paved and unpaved surfaces. The FIRM shall create



action plans and identify the zone of influence specific to each project.

- e. **Dust, Odor, and Other Emissions beyond Construction Zone.** Construction projects have the potential to generate numerous type and quantities of fugitive emissions. Some examples of emission generating activities include site clearing; excavation and earthwork; stockpiles and storage mounds; demolition activities; spray painting; power washing; operating equipment exhausts, and site vehicular entrances and exits. The FIRM is to consider the types of construction equipment and activities within the construction zone and the potential of fugitive emissions from these sources and nuisance of these emissions. Determination of prevailing wind direction and proximity of buildings and/or sensitive receptors are to be made by the FIRM as part of this evaluation. Upon completion of these evaluations, if nuisance emissions are considered likely beyond the construction zone, then further investigations and abatement efforts are warranted. The FIRM shall create action plans and identify the zone of influence specific to each project.

D. Stage 2 – Risk Mitigation Analysis and Bid Document Development for Contractor Actions.

1. Based upon the risk assessment of noise impacts emanating beyond the limits of the construction zone, the FIRM needs to take appropriate steps to mitigate these potential impacts. The following information from the *Federal Transit Administration Office of Planning and Environment Transit Noise and Vibration Impact Assessment May 2006* publication should be reviewed by the FIRM to mitigate noise influences and other action plans as recommended.

**12.1.4 Mitigation of Construction Noise**

After using the above approaches to locate potential impacts from construction noise, the next step is to identify appropriate control measures. Three categories of noise control approaches, with examples, are given below:

1. *Design considerations and project layout:*
  - Construct noise barriers, such as temporary walls or piles of excavated material, between noisy activities and noise-sensitive receivers.
  - Re-route truck traffic away from residential streets, if possible. Select streets with fewest homes if no alternatives are available.
  - Site equipment on the construction lot as far away from noise-sensitive sites as possible.
  - Construct walled enclosures around especially noisy activities or clusters of noisy equipment. For example, shields can be used around pavement breakers and loaded vinyl curtains can be draped under elevated structures.
2. *Sequence of operations:*

- Combine noisy operations to occur in the same time period. The total noise level produced will not be significantly greater than the level produced if the operations were performed separately.
- Avoid nighttime activities. Sensitivity to noise increases during the nighttime hours in residential neighborhoods.

3. *Alternative construction methods:*

- Avoid use of an impact pile driver where possible in noise-sensitive areas. Drilled piles or the use of a sonic or vibratory pile driver are quieter alternatives where the geological conditions permit their use.
- Use specially-quieted equipment, such as quieted and enclosed air compressors and properly- working mufflers on all engines.
- Select quieter demolition methods, where possible. For example, sawing bridge decks into sections that can be loaded onto trucks results in lower cumulative noise levels than impact demolition by pavement breakers.

If possible, the environmental impact assessment should include descriptions of how each impacted location will be treated with one or more mitigation measures. However, with a large, complex project, the information available during the preliminary engineering phase may not allow final decisions to be made on all specific mitigation measures. In such cases, it is appropriate to describe and commit to a mitigation plan that will be developed during final design. The objective of the plan should be to minimize construction noise using all reasonable (i.e., cost vs. benefit) and feasible (i.e., physically achievable) means available. Components of the plan may include some or all of the following provisions which would be specified in construction contracts:

- *Equipment noise emission limits.* These are absolute noise limits applied to generic classes of equipment at a reference distance (typically 50 feet). The limits should be set no higher than what is reasonably achievable for well-maintained equipment with effective mufflers. Lower limits that require source noise control may be appropriate for certain equipment when needed to minimize community noise impact, if reasonable and feasible. Provisions could also be included to require equipment noise certification testing prior to use on site.
- *Lot-line construction noise limits.* These are noise limits that apply at the lot line of specific noise- sensitive properties. The limits are typically specified in terms of both noise exposure (usually Leq over a 20-30 minute period) and maximum noise level. They should be based on local noise ordinances, if applicable, as well as pre-construction baseline noise levels; limits that are 3-5 decibels above the baseline are often used.
- *Operational and/or equipment restrictions.* It may be necessary to prohibit or restrict certain construction equipment and activities near residential areas during nighttime

hours. This is particularly true for activities that generate tonal, impulsive or repetitive sounds, such as back-up alarms, hoe ram demolition and pile driving.

- *Noise abatement requirements.* In some cases specifications may be provided for particular noise control treatments, based on the results of the design analysis and/or prior commitments made to the public by civic authorities. An example would be the requirement for a temporary noise barrier to shield a particular community area from noisy construction activities.
- *Noise monitoring plan requirements.* Plans can be developed for pre-project noise monitoring to establish baseline noise levels at sensitive locations, as well as for periodic equipment and lot-line noise monitoring during the construction period. The plan should outline the measurement and reporting methods that will be used to demonstrate compliance with the project noise limits.
- *Noise control plan requirements.* For major construction projects, specifications have required the preparation and submission of noise control plans on a periodic basis (e.g., every six months). These plans should predict the construction noise at noise-sensitive receptor locations based on the proposed construction equipment and methods. If the analysis predicts that the specified noise limits will be exceeded, the plan should specify the mitigation measures that will be applied and should demonstrate the expected noise reductions these measures will achieve. The objective of this proactive approach is to minimize the likelihood of community noise complaints by ensuring that any necessary mitigation measures are included in the construction plans.
- *Compliance enforcement program.* If construction noise is a significant issue in the community, it is important that a program be put in place to monitor contractor compliance with the noise control specifications and mitigation plan. It is best that this function be performed by a construction management team on behalf of the public agency.
- *Public information and complaint response procedures.* To maintain positive community relations, the public should be kept informed about the construction plans and efforts to minimize noise, and procedures should be established for prompt response and corrective action with regard to noise complaints during construction.

Most of these provisions are appropriate for very large projects where construction activity will continue for many months, if not years. References 4 and 5 contain details on dealing with construction noise on major transportation projects.<sup>(5,6)</sup>

2. Based upon the risk assessment of vibration impacts emanating beyond the limits of the construction zone, the FIRM needs to take appropriate steps to mitigate these potential impacts. The following information from the *Federal Transit Administration Office of Planning and Environment Transit Noise and Vibration Impact Assessment May 2006* publication should be reviewed by the FIRM to mitigate vibration influences and other action plans as recommended. The FIRM is to collaborate with HRSD to identify and determine the level of preconstruction surveys of properties, buildings, and structures

with the potential to be impacted by construction vibrations.

### **12.2.3 Construction Vibration Mitigation**

After using the above methods to locate potential human impacts or building damage from construction vibrations, the next step is to identify control measures. Similar to the approach for construction noise, mitigation of construction vibration requires consideration of equipment location and processes, as follows:

1. *Design considerations and project layout:*
  - Route heavily-loaded trucks away from residential streets, if possible. Select streets with fewest homes if no alternatives are available.
  - Operate earth-moving equipment on the construction lot as far away from vibration-sensitive sites as possible.
2. *Sequence of operations:*
  - Phase demolition, earth-moving and ground-impacting operations so as not to occur in the same time period. Unlike noise, the total vibration level produced could be significantly less when each vibration source operates separately.
  - Avoid nighttime activities. People are more aware of vibration in their homes during the nighttime hours.
3. *Alternative construction methods:*
  - Avoid impact pile driving where possible in vibration-sensitive areas. Drilled piles or the use of a sonic or vibratory pile driver causes lower vibration levels where the geological conditions permit their use (however, see cautionary note below).
  - Select demolition methods not involving impact, where possible. For example, sawing bridge decks into sections that can be loaded onto trucks results in lower vibration levels than impact demolition by pavement breakers, and milling generates lower vibration levels than excavation using clam shell or chisel drops.
  - Avoid vibratory rollers and packers near sensitive areas.

Pile-driving is one of the greatest sources of vibration associated with equipment used during construction of a project. The source levels in Table 12-2 indicate that sonic pile drivers may provide substantial reduction of vibration levels. However, there are some additional vibration effects of sonic pile drivers that may limit their use in sensitive locations. A sonic pile driver operates by continuously shaking the pile at a fixed frequency, literally vibrating it into the ground. Vibratory pile drivers operate on the same principle, but at a different frequency. However, continuous operation at a fixed frequency may be more noticeable to nearby residents, even at lower vibration levels. Furthermore, the steady-state excitation of the ground may induce a growth in the resonant response of building components. Resonant response may be unacceptable in cases of fragile buildings or

vibration-sensitive manufacturing processes. Impact pile drivers, on the other hand, produce a high vibration level for a short time (0.2 seconds) with sufficient time between impacts to allow any resonant response to decay.

As with construction noise, in many cases the information available during the preliminary engineering phase will not be sufficient to define specific construction vibration mitigation measures. In such cases, it is appropriate to describe and commit to a mitigation plan that will be developed and implemented during the final design and construction phases of the project. The objective of the plan should be to minimize construction vibration damage using all reasonable and feasible means available. The plan should provide a procedure for establishing threshold and limiting vibration values for potentially affected structures based on an assessment of each structure's ability to withstand the loads and displacements due to construction vibrations. The plan should also include the development of a vibration monitoring plan during final design and the implementation of a compliance monitoring program during construction.

3. Based upon the risk assessment of dewatering impacts emanating beyond the limits of the construction zone, the FIRM to take appropriate steps to mitigate these potential impacts. The FIRM to collaborate with HRSD to identify and determine the level of preconstruction surveys of properties, buildings, and structures with the potential to be impacted by construction dewatering.
4. Based upon the risk assessment of construction impacts to existing drainage, loss of trees / vegetation, damage to locality and/or private roads, the FIRM to take appropriate steps to mitigate these potential impacts and incorporate appropriate requirements for the Contractor within the Bid Documents. The FIRM to collaborate with HRSD to identify and determine the level of preconstruction surveys within and outside of the construction zone.
5. Based upon the risk assessment of dust, odor and other fugitive emissions emanating beyond the limits of the construction zone, the FIRM to take appropriate steps to mitigate these potential impacts and incorporate appropriate requirements for the Contractor within the Bid Documents.

E. Stage 3 – Specific Pre-Construction Field Surveys and Construction Activity Monitoring Programs

1. General Discussion – The following paragraphs detail communication, documentation, responsible parties, and action plans for site specific pre-construction condition assessments for public and private property and facilities, and construction activity monitoring in areas where a level of damage or nuisance is possible. These efforts are intended to follow best practices for protecting all parties from damage and nuisance related claims and occurrences. HRSD has developed templates and examples of various forms and recording logs that are included in this publication of *HRSD Design and*

Construction Standards.

2. The FIRM shall perform the following services during the Pre-Construction Phase for all pipelines, pump stations, storage tanks, and similar projects. This effort is divided into two parts with the first part held in coordination with the Contractor and the second part conducted independently from the Contractor.
  - a. Part 1 - Conduct a pre-construction condition assessment, with the Contractor's staff in attendance, after award of the construction contract and prior to any work beginning, to document the existing conditions of areas to be impacted by the work and adjacent areas which could be potentially impacted by the work. The purpose of this assessment is to provide a baseline condition on all properties documenting existing conditions prior to any construction services taking place. This effort should document the existing conditions of but not limited to: right of ways, utilities, storm drains and inlets, manholes, fire hydrants, telephone, power and light poles, medians, signage, pavement, curb and gutter, sidewalks, drainage, driveways and aprons, mailboxes, landscaping, adjacent structures, residences, commercial and industrial property and other areas to be used by the Contractor along the project alignment or in close proximity to the construction activities, within the zone of influence and any structure identified to be of significant importance (such as historical registry). Document the exterior and interior (if possible) of residences, commercial and industrial properties after obtaining the signed approval of the owner or owner's authorized agent for the property. Documentation should include detailed and identifiable video of all areas and structures within the areas identified above. Digital images of both areas in which existing deficiencies are observed and areas in fair condition shall be documented. The documentation shall also provide detailed comments to describe the location / area documented (i.e. 1<sup>st</sup> floor, living room, right wall) and any observations (i.e. step crack 4mm width and 36-inch length). Review of past surveys will be coordinated with HRSD's REM for format information upon request (a small sample is included in the attachment portion of this section. Review the limits of the proposed pre-construction survey with HRSD's PM and REM prior to beginning these assessments. The FIRM shall coordinate the assessments with all parties ensuring they are completed 30 days prior to the Contractor entering the site. The FIRM shall provide a copy of this documentation to HRSD's PM and REM within one week of completing the field assessments for review and approval. Once approved, the FIRM will forward a copy to the Contractor for their use.
  - b. Part 2 – Conduct a post rain event field reconnaissance as soon after the event as practically feasible. At a minimum, take photographs at each roadway intersection, all driveways, and a minimum of two pictures at the front of each property. Photograph all standing water areas within the construction limits. Digital photographs are to be labeled with the time and date taken. Photographs are also to be referenced to the construction plans to highlight the location and angle taken. Furnish digital images to the HRSD PM for review and approval. Capture video recordings along the construction limits including roadway intersections, all driveways and each property. Recorded audio on the video tracks shall call out highlighted observances either by

property number of construction stationing. Furnish a DVD to the HRSD PM for review and approval.

3. The following are specific procedures associated with pre-construction condition assessment of private property buildings and facilities if warranted based upon the risk assessment.
  - a. The FIRM to incorporate into the Contract Documents the requirements and specifics of the pre-construction existing conditions assessment program for designated structures and locations.
  - b. Maintain the HRSD Approved Pre-Construction Conditions Assessment Communications and Contact Tracking Log, using HRSD's template to include each verified property owner and address contacted, method of contact, and number of contact attempts with dates to gain access permission. Three (3) certified return receipt attempts for each property are the minimum standard.
  - c. Use HRSD's Approved Assessment of Pre-Existing Conditions Request Letters to gain permission to enter the property for this assessment.
    - i. Letter to Business - Template
      - i. To include Right to Access Property Form - Template
    - ii. Letter to Private Property (residential) – Template
      - i. To include Right to Access Property Form - Template
  - d. Use HRSD's Right to Access Property form, have this document signed by the property owner or verifiable authorized agent, and provide a copy to property owner for their records prior to entering private property.
  - e. Provide video, still photographs and describe the particulars of each noted crack or defect. Included in the description should be the length and width of each crack.
    - i. Photographs and videos should be taken with a high pixel camera with "Exchange Image File Format" (EXIF) the date stamp should be present on all files.
    - ii. A ruler or other measurement device should be included in the photograph and video next to the observed crack or defect.
    - iii. Log the conditions using the HRSD approved Pre-Existing Condition Assessment – Report On-Site Form and gaining a signature from the property owner after completion.
  - f. Document via a sketch of each room of the building interior and/or exterior where a crack or defect is observed.
  - g. FIRM shall prepare an overall summary report of each property visited and provide to HRSD's REM for review. This process shall be completed and reviewed prior to the contractor entering the work site.

\*Note – all documentation sent out to the public shall be approved by HRSD Communications Department prior to distribution or use. Coordinate this effort with both the Public Information Specialist and the REM.
4. The following are specific procedures associated with a vibration monitoring program if warranted based upon risk assessment.

- a. The FIRM to incorporate into the Contract Documents the technical requirements and specifics of a vibration monitoring program at designated locations.
  - b. Specify peak particle velocity (PPV) thresholds for the individual structures to be monitored.
  - c. Specify the calibration requirements for vibration monitors.
  - d. Specify experience and qualification requirements for technician and firm performing the vibration monitoring program.
  - e. Evaluate the use vibration monitors in tandem, placed a designated distance apart, for properties to be monitored.
  - f. Verify vibration monitors are properly installed at the correct locations.
  - g. Evaluate and specify amount of memory needed for each vibration monitor to capture data in the monitoring log for the date ranges required.
  - h. Specify locations throughout the project extents for a vibration monitoring program.
  - i. Based upon observations of cracks in buildings where pre-construction surveys were performed, evaluate, and recommend a monitoring program for changes to these benchmark cracks during the construction period.
  - j. Produce a document intended for educational use with the public, detailing the zone of influence, distance attenuation of ground vibrations and how it was determined, the levels of vibration (maximum peak velocity) recorded during the project and examples of what those levels equate to for the public. This document could be used throughout the life of the project when discussing claims and concerns with property owners.
5. The following example of “Special Provision Language for Vibration Control and Monitoring” was found through Internet search (no accompanying Ownership reference available) and included in this section to provide insight for establishing various responsibilities and accountabilities for a construction related vibration program. The FIRM is to collaborate with HRSD to establish a vibration control and monitoring program specific to the construction project need.

Sample Program  
***Special Provision Language for  
Vibration Control and Monitoring***

Vibration producing activities (such as blasting, pile driving, vibratory compaction, pavement breaking or operation of heavy construction equipment) are common in construction projects. Four levels of vibration control can be provided on a project, depending on things such as structure susceptibility to damage, proximity to vibration producing activities, local concerns, or district policy. The "levels" are defined as follows:

- Level 1 -** No specific mention in contract of possible problems or controls. This is most common for minor or small quantities of pavement breaking or pile driving, when they are not in proximity to occupied structures or sensitive receptors.
- Level 2 -** Alert contractor to possible problems by brief description in the special provisions.



Vibration levels and monitoring are at the discretion of the contractor, and the contractor is responsible for all damage caused by his activities.

**Level 3 -** Detail concerns and require the contractor to do a prescribed condition survey and to employ a qualified vibration specialist to establish a safe vibration level and monitor the vibrations. As an alternative, a vibration level may be set by the Owner. It may also be appropriate to use experienced based vibration criteria. The contractor is still responsible for any problems.

**Level 4 -** Owner takes lead role and has consultant(s) do a damage susceptibility study to establish vibration control limits, and a preconstruction condition survey for each structure. The Owner also takes responsibility for vibration monitoring during construction to ensure compliance with vibration control limits. At this level, the Owner assumes some responsibility for damage to structures if the established vibration limits are not exceeded by the contractor. The degree of responsibility depends on the vibration specification - most vibration specifications are aimed at avoiding structural damage, leaving the contractor responsible for any cosmetic damage (e.g. plaster cracks, broken windows, etc.) and keeping residents/occupants informed and "happy".

Examples of Level 2 through Level 4 specifications are given below. Each of these was produced for a specific project and need to be personalized or fine-tuned for other projects. There may be levels between those shown, but care must be taken to keep the specifications consistent, for example, it would be inconsistent to expect the contractor to take total responsibility for vibrations and then put a vibration specification in the contract.

### **Level 2**

#### S- CONSTRUCTION VIBRATIONS

Vibration producing activities (such as blasting, pile driving, vibratory compaction, pavement breaking or operation of heavy construction equipment) may be required for construction of this project. The Contractor is advised that structures are located close to the proposed work and that construction activities shall be conducted so as to preclude damage to these structures and undue annoyance to occupants. The Contractor shall be responsible for all damage caused by his activities.

### **Level 3**

#### S- CONSTRUCTION CONTROLS AND MONITORING

Vibration producing activities (such as blasting, pile driving, vibratory compaction, pavement breaking, or operation of heavy construction equipment) may be required for construction of this project. The Contractor is advised that structures are located close to the proposed work and that construction activities shall be conducted to preclude damage to same. The Contractor shall be responsible for any damage caused by his activities.

At least 30 days prior to start of such work, the Contractor shall provide a \_\_\_\_\_ plan (blasting, pile driving, etc.) plan to the Engineer, which shall include, but not be limited to the

following: proposed construction method(s), vibration monitoring plans (including the format for reporting the vibration readings), anticipated vibration levels at the closest building(s), condition survey format, and public relations activities. A copy of all reports shall be provided to the Engineer.

#### S- .1 Condition Survey

A preconstruction building Condition Survey shall be conducted by the Contractor on the \_\_\_ building(s), prior to the commencement of any vibration producing activity. (In lieu of naming the buildings, a radius of \_\_\_ ft from the vibration producing activity can be used – this distance can be adjusted based on the type of activity and the sensitivity of the receptors.)

The survey will include documentation of interior sub-grade and above grade accessible walls, ceilings, floors, roof, and visible exterior as viewed from the grade level. It will detail (by engineering sketches, video tape, photographs, and/or notes) any existing structural, cosmetic, plumbing, or electrical damage. The survey will be conducted by a Professional Engineer, registered in the State of Virginia.

A report shall be issued that will summarize the pre-construction condition of the building(s) and will identify areas of concern, including potential personnel hazards (falling debris) and structural elements that may require support or repair.

Crack displacement monitoring gages will be installed as appropriate across any significant existing cracks to help verify any additional building distress if it should develop. The appropriate location, number, and type of gages will be established by the Contractor and/or the Project Engineer. The gages will be read prior to vibration producing activities, as well as during these activities. Data shall be obtained on a weekly basis for as long as vibration-producing activities are being conducted. A report shall be submitted which summarizes the data. The Engineer shall be alerted if any significant movement is detected by the monitoring gages.

#### S- .2 Vibration Controls

(Sound level limits should also be included for blasting projects)

The Contractor shall employ a qualified vibration specialist to establish a safe vibration level for the building(s). This specialist shall also supervise the Contractor's vibration-monitoring program. During all vibration producing activities, the Contractor shall monitor vibration levels at \_\_\_ building(s) and shall not exceed the safe level established to preclude damage to this structure(s).

The vibration monitoring equipment shall be capable of continuously recording the peak particle velocity and providing a permanent record of the entire vibration event. Copies of all vibration records and associated construction activity (blasting, pile driving, pavement breaking, etc.) data shall be provided to the Engineer in a format approved by the Engineer.

#### S- .3 Public Relations

The Contractor shall maintain a complaint log and make this available to the Engineer on request. Occupants/owners of adjacent buildings shall be notified by the Contractor at least 2 weeks prior to commencement of any vibration producing activity that might affect the

structure or inhabitants.

#### **Level 4**

##### **S- VIBRATION MONITORING AND CONTROL**

The following provisions do not relieve the Contractor of any responsibility for damage caused by his operations, nor do they relieve the Contractor from compliance with all applicable federal, state, county, and city codes relative to the use and storage of explosives. If a conflict occurs between this specification and other codes, it shall be resolved by the Engineer.

##### **S- .1 Susceptibility Study**

A detailed document titled \_\_\_\_\_, has been prepared for Owner by (Name of consulting firm), and a copy of this report is available for inspection at \_\_\_\_\_ (address & contact). This report includes an evaluation of buildings and structures in proximity to the project and an evaluation of their susceptibility to construction vibration damage. The vibration criteria for this project is based on this study.

##### **S- .2 Condition Survey**

A condition survey will be (or has been) performed for buildings in proximity to the project. This survey will document the existing exterior and interior conditions of these buildings.

The survey will include documentation of interior sub-grade and above grade accessible walls, ceilings, floors, roof, and visible exterior as viewed from the grade level. It will detail (by engineering sketches, video tape, photographs, and/or notes) the existing structural, cosmetic, plumbing, and electrical damage, but will not necessarily be limited to areas in buildings showing existing damage.

Crack displacement monitoring gages will be installed as appropriate across any significant existing cracks to help verify any additional building distress, should it develop. The gages will be read prior to commencement of vibration producing activities, as well as during these activities. Results of this monitoring will be made available to the Contractor.

##### **S- .3 Ground Vibration Controls**

The following vibration control limits are applicable for all construction work, including but not limited to blasting, pile driving, compaction, ripping, and hauling activities.

The Contractor is advised that the ground vibration control limits defined herein may restrict his construction practices, and that he should consider these limitations in preparing his bid.

If the Contractor exceeds 80% of the ground vibration limit as given below, for any construction activity, he shall cease that activity and submit a report. The report shall give the construction parameter data and include a proposal for corrective action necessary to ensure that the specified limit is not exceeded for future activities. This report shall be submitted to the Engineer, and his permission must be obtained prior to the continuation, or beginning of any future vibration producing construction activities.

If the Contractor exceeds the ground vibration limit for any construction activity, the Engineer will

direct that all activities related to those causing the vibration to be stopped. The Contractor shall submit to the Engineer a report giving the construction parameter data and include the proposed corrective action for future construction events. To proceed with any further vibration producing activities, written permission must be obtained from the Engineer.

#### A. Definitions

The following definitions shall apply to the vibration controls:

Peak particle displacement - the peak particle displacement is the maximum movement induced by the vibration. The displacement amplitudes are in units of mils (0.001 inch) zero to peak amplitude.

Peak particle velocity - The peak particle velocity is the maximum rate of change with respect to time of the particle displacement. The velocity amplitudes are in units of inches per second (ips), zero to peak amplitude.

Frequency - The frequency of the vibration is the number of oscillations which occur in one second. The frequency units are given in Hertz (Hz) where one Hz equals one cycle per second.

#### B. Ground vibration control limit

(Sound level limits should also be included for blasting projects)

The ground vibration controls are applicable to external locations adjacent to affected buildings or structures. The maximum single component peak particle velocity resulting from construction activity shall not exceed\_\_.

#### S- .4 Instrumentation

The Contractor shall furnish, maintain, and operate three vibration monitors (amplitude and frequency sensitive) during any vibration producing activities that could, in the judgment of the Engineer, produce measurable ground vibrations. If the Contractor chooses to have concurrent vibration producing activities at more than one location on the construction site, he shall notify the Engineer in writing at least two weeks prior to the commencement of such activities. The Engineer may require additional vibration monitoring instruments at each location depending on site parameters.

No vibration producing activities may be started until the appropriate instrumentation is provided by the Contractor and approved by the Engineer.

All vibration instruments shall be powered with rechargeable batteries, and the Contractor shall supply extension geophone and microphone cables so that the instruments can be placed within structures if outside temperatures drop below 32 degrees Fahrenheit.

All vibration instruments shall be supplied with current calibration documents and shall be recalibrated on approximately a six-month use interval. At a minimum, instrument specific calibration curves of peak particle velocity input to peak particle velocity output shall be provided over the specified frequency ranges at both 0.5 and 1.0 ips for each instrument.

The Contractor shall be responsible for instrument maintenance. If the Contractor does not maintain a sufficient number of instruments to monitor the buildings/structures adjacent to the vibration producing activity, the Engineer may direct that all vibration activities cease until a sufficient number are working. Recording tape shall be supplied by the Contractor and at least a two-week supply maintained.

The Contractor shall designate an individual in his organization or under contract to him, who will be responsible for instrument coordination. The Contractor will be responsible for placing the instruments at measuring locations designated by the Engineer and reading and recording the pertinent vibration event data. The Contractor will report the data to the Engineer at the completion of each vibration event.

The amplitude/frequency vibration monitor shall be an InstanTel Blastemate II, or equivalent. This instrument shall be capable of measuring, recording and producing a hard copy of the frequency and peak particle velocity in three mutually perpendicular axes. ("Vector sum" instruments are not acceptable). This instrument shall be capable of measuring Linear Scale (dB-L) sound levels.

#### S- .5 Public Relations

The Contractor is required to have both letter and personal contact with residents and owners or operators of the buildings that are adjacent to the construction area or near enough to it for ground vibrations from construction operations to affect the personal property, displays or merchandise of these buildings. This contact will be made prior to the beginning of any vibration producing activity. The Contractor will furnish a list of those contacted to the Engineer.

As described elsewhere in these provisions, the ground vibration resulting from construction work will be monitored by the Contractor. The Contractor will measure the magnitude of each vibration event with at least two vibration instruments, generally located adjacent to the closest or most critical structures.

#### S- .6 Record Keeping

The Contractor shall maintain a log of all vibration-producing activities at which ground vibrations were measured. The log shall include the maximum peak particle velocity and its associated frequency, type and location of the vibration producing event, location of the geophones and closest distance from the vibration-producing event to the geophone(s). When vibration-producing activities are in progress, the Contractor shall submit daily reports to the Engineer which include all the vibration log data from that day. These reports shall be submitted at the end of each day, and no further vibration producing activity will be allowed until such reports are received by the Engineer.

The Contractor shall be responsible for removing all vibration records produced by the vibration instruments and attaching them to the corresponding Blast Log for submittal to the Engineer as part of the daily report.

The Contractor shall maintain a complaint log of all vibration related complaints, contacts, and actions, and shall furnish copies to the Engineer on request.

## **Researched Publications**

- *Federal Transit Administration Office of Planning and Environment Transit Noise and Vibration Impact Assessment May 2006*
- *New Hampshire DOT Research Record Ground Vibrations Emanating from Construction Equipment*
- *Construction Vibration and Historic Buildings*, prepared for Bureau of Environment Division of Transportation Infrastructure Development, prepared by CTC & Associates LLC, WisDOT RD&T Program (July 8, 2003)
- *Construction Vibration Damage Guide (CVDG) Professional Edition*, John M. Zeigler

## **Attachments**

1. Attachment A: Sample – Vibration Generation and Impacts (diagram and impact table) / Noise and Vibration Impacts (combined map)
2. Attachment B: Sample – Noise Generation and Impacts (diagram and impact table)
3. Attachment C: Sample – Dewatering Impacts
4. Attachment D: Pre-Construction Conditions Assessment Communications and Contact Tracking Log
5. Attachment E: Assessment of Pre-Existing Conditions - Right to Access Property Form
6. Attachment F: Letter to Property Owner Template for Pre-Existing Conditions Assessment
7. Attachment G: Pre-Existing Condition Assessment – Reporting Form – Template
8. Attachment H: Sample – Precondition Assessment and Damage Mitigation Report
9. Attachment I: Sample – Precondition Assessment Field Survey Report (excerpts)

**End of Section**