APPENDIX 4.9

Noise Memorandum

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Memo

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From: Casey T. Zaglin
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Subject: **UC Santa Cruz Student Housing West, Santa Cruz, CA – Noise and Vibration Levels associated with Construction Activities**
I&R Job: 17-070

The proposed UC Santa Cruz Student Housing West (SHW) project is an approximately 3,000-student bed project, which is planned for completion by UC Santa Cruz by 2022. The SHW project is split into two sites: the Hagar Site where the project would construct approximately 148 units of housing for student families northeast of the intersection of Glen Coolidge Drive and Hagar Drive, and the Heller Site where the project would demolish existing buildings and construct approximately 2,852 student beds west of Heller Drive. The project would also construct utility corridors to provide water and wastewater service to the new sites.

This memo presents the results of the noise and vibration assessment of project construction activities. Appendix A presents the fundamentals of environmental noise and vibration for those who may not be familiar with acoustical terminology and/or concepts.

Construction Noise Assessment

Construction noise impacts evaluated in the 2005 Long Range Development Plan (LRDP) EIR[1] were assessed with regard to exceedance of the following significance thresholds:

- 80 dBA L_{eq} (8-hour) during daytime (7:00 a.m. to 7:00 p.m.) and evening (7:00 p.m. to 10:00 p.m.); and
- 70 dBA L_{eq} (8-hour) during nighttime (10:00 p.m. to 7:00 a.m.).

The LRDP EIR determined that construction of campus facilities could expose nearby sensitive receptors to excessive airborne noise but not to excessive groundborne vibration or groundborne

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[1] University of California Santa Cruz 2005 Long Range Development Plan Final Environmental Impact Report, University of California Santa Cruz, Office of Physical Planning & Construction, September 2006.

noise. LRDP Mitigation NOIS-1, which is applicable to and included in all projects proposed under the LRDP, requires that the following measures are implemented to minimize construction noise impacts:

LRDP Mitigation NOIS-1: Prior to initiation of construction of a specific development project, the Campus shall approve a construction noise mitigation program that shall be implemented for each construction project. This shall include but not be limited to the following:

- Construction equipment used on campus is properly maintained and has been outfitted with feasible noise-reduction devices to minimize construction-generated noise.
- Stationary noise sources such as generators or pumps are located at least 100 feet away from noise-sensitive land uses as feasible.
- Laydown and construction vehicle staging areas are located at least 100 feet away from noise-sensitive land uses as feasible.
- Whenever possible, academic, administrative, and residential areas that will be subject to construction noise will be informed in writing at least a week before the start of each construction project.
- Loud construction activity (i.e., construction activity such as jackhammering, concrete sawing, asphalt removal, and large-scale grading operations) within 100 feet of a residential or academic building shall not be scheduled during finals week.
- Loud construction activity as described above within 100 feet of an academic or residential use shall, to the extent feasible, be scheduled during holidays, Thanksgiving break, Christmas break, Spring break, or Summer breaks.
- Loud construction activity within 100 feet of a residential building shall be restricted to the hours between 7:30 AM and 7:30 PM, Monday through Saturday.
- Loud construction activity within 100 feet of an academic building shall be scheduled to the extent feasible on weekends.

Noise generated by project-related construction activities would be a function of the noise levels generated by individual pieces of construction equipment, the type and amount of equipment operating at any given time, the timing and duration of construction activities, the proximity of nearby sensitive land uses, and the presence or lack of shielding at these sensitive land uses. Construction-generated noise levels drop off at a rate of about 6 dBA per doubling of the distance between the source and receptor. Construction noise levels would vary on a day-to-day basis during each phase of construction depending on the specific task being completed. Each construction phase would require a different combination of construction equipment necessary to complete the task and differing usage factors for such equipment. Construction noise would primarily result from the operation of heavy construction equipment and the arrival and departure of heavy-duty trucks.

The Federal Highway Administration's (FHWA) Roadway Construction Noise Model (RCNM) was used to calculate the average noise levels anticipated during the worst-case phases of construction that would occur across the site. This construction noise model includes representative sound levels for the most common types of construction equipment and the approximate usage factors of such equipment that were developed based on an extensive database of information gathered during the construction of the Central Artery/Tunnel Project in Boston, Massachusetts (CA/T Project or "Big Dig"). The usage factors represent the percentage of time that the equipment would be operating at full power. Project-specific data was provided by the developer. Project-specific vehicles and equipment anticipated during each phase of construction were input into RCNM to calculate noise levels at the distance of the nearest sensitive receptors to the center of the construction sites (the proposed utility corridor or the building area). Calculations were also made to predict construction noise levels when construction occurs at its closest point to sensitive receptors. These would represent the worst-case condition.

Hagar Site

Construction activities planned at the Hagar site are anticipated to begin in Fall 2018 and end in Fall 2019, lasting approximately 12 months. Project construction phases would include site preparation, grading, building construction, paving, and architectural coating. Off-site construction activities would include trenching, placement of utility lines, backfilling, and restoring the disturbed area. Figure 1 shows the Hagar site and associated utility corridor and the locations of the nearest sensitive receptors. Anticipated construction noise levels, by construction activity and phase, for the typical conditions are summarized in Table 1.

Figure 1 Hagar Site

TABLE 1 Calculated Construction Noise Levels at Nearest Receptors from Center of Construction Sites

Construction Phase	Average Equivalent Noise Level (dBA, L_{eq})		
	Utility Corridor	Hagar Development	
	Southern Residence (Hagar Meadow) (350 feet)	Southeast Residence (Rockridge Lane) (650 feet)	Southwest Residence (Hagar Meadow) (700 feet)
Site Preparation	NA	65	64
Grading	74	69	68
Building Construction	NA	60	59
Paving	NA	62	61
Architectural Coatings	NA	46	45
Overall Range of Construction Noise Levels	74	46-69	45-68

TABLE 2 Calculated Construction Noise Levels at Nearest Receptors from Perimeter of Construction Sites

Construction Phase	Average Equivalent Noise Level (dBA, L_{eq})		
	Utility Corridor	Hagar Development	
	Southern Residence (Hagar Meadow) (200 feet)	Southeast Residence (Rockridge Lane) (220 feet)	Southwest Residence (Hagar Meadow) (320 feet)
Site Preparation	NA	74	71
Grading	79	78	75
Building Construction	NA	69	66
Paving	NA	71	68
Architectural Coatings	NA	55	52
Overall Range of Construction Noise Levels	79	55-78	52-75

The typical levels in Table 1 are used to compare to the noise thresholds established above. The predicted typical construction noise levels resulting from construction activities at distances ranging from 350 feet to 700 feet from the nearest sensitive receptors (i.e., residences to the south) would not exceed the significance thresholds of 80 dBA L_{eq} (8-hour) during daytime and evening periods. The worst-case construction noise levels at the perimeter of the sites are shown in Table 2. During the brief periods when utility construction would occur at the closest point to the nearby southern residences (approximately 200 feet), construction noise levels would be up to 79 dBA L_{eq}. Construction noise levels could potentially exceed 70 dBA L_{eq} (8-hour) during nighttime; however, the implementation of LRDP Mitigation Measure NOIS-1 would reduce the impact to a less-than-significant level by restricting construction to the hours between 7:30 AM and 7:30 PM, Monday through Saturday. No additional mitigation would be required.

Heller Site

Construction activities planned at the Heller site are anticipated to begin in Fall 2019 and end in Fall 2022, lasting approximately 3 years. Project construction phases would include demolition and site preparation, grading, building construction, paving, and architectural coating. Figure 2 shows the project site, utility corridor and the nearest sensitive receptors. Anticipated construction noise levels, by construction activity and phase, for the typical conditions are summarized in Table 3.

Figure 2 Heller Site

TABLE 3 Calculated Construction Noise Levels at Nearest Receptors from Center of Construction Sites

Construction Phase	Average Equivalent Noise Level (dBA, L_{eq})	
	Utility Corridor	Heller Development
	Porter/Kresge College Residences (400 feet)	Rachel Carson College Residences (650 feet)
Demolition and Site Preparation	NA	67
Grading	74	70
Building Construction	NA	69
Paving	NA	64
Architectural Coatings	NA	65
Overall Range of Construction Noise Levels	74	64 to 70

TABLE 4 Calculated Construction Noise Levels at Nearest Receptors from Perimeter of Construction Sites

Construction Phase	Average Equivalent Noise Level (dBA, L_{eq})	
	Utility Corridor	Heller Development
	Porter/Kresge College Residences (200 feet)	Rachel Carson College Residences (350 feet)
Demolition and Site Preparation	NA	72
Grading	80	75
Building Construction	NA	74
Paving	NA	69
Architectural Coatings	NA	70
Overall Range of Construction Noise Levels	80	69 to 75

The typical levels in Table 3 are used to compare to the noise thresholds. The predicted typical construction noise levels resulting from construction activities at distances ranging from 400 feet to 650 feet from the nearest sensitive receptors (i.e., residences at Porter, Kresge, and Rachel Carson Colleges) would not exceed the significance thresholds of 80 dBA L_{eq} (8-hour) during daytime and evening periods. The worst-case construction noise levels at the perimeter of the sites are shown in Table 4. During the brief periods when construction would occur at the closest point to the nearby Porter/Kresge College residences (approximately 200 feet), construction noise levels would be up to 80 dBA L_{eq}. Construction noise levels could potentially exceed 70 dBA L_{eq} (8-hour) during nighttime; however, the implementation of LRDP Mitigation Measure NOIS-1 would reduce the impact to a less-than-significant level by restricting construction to the hours between 7:30 AM and 7:30 PM, Monday through Saturday. No additional mitigation would be required.

Construction Vibration Assessment

The LRDP EIR determined that construction of future projects on the campus would not expose sensitive receptors to excessive groundborne vibration or groundborne noise because construction techniques having the potential of yielding relatively high vibration levels, such as pile driving or blasting, were not anticipated. Nonetheless, an evaluation was conducted to confirm that the construction activities associated with the proposed project would not result in excessive groundborne vibrations.

For structural damage, the California Department of Transportation recommends a vibration limit of 0.5 inches/second, peak particle velocity (in/sec PPV) for buildings structurally sound and designed to modern engineering standards, 0.3 in/sec PPV for older residential buildings, and 0.25 for historic and some old buildings. All buildings in the project vicinity are assumed to be structurally sound, but these buildings may or may not have been designed to modern engineering standards.

Table 5, below, presents typical vibration levels that could be expected from construction equipment at 25 feet. Vibration levels produced by a vibratory roller (0.210 in/sec PPV at 25 feet) would represent a credible worst-case scenario for proposed construction activities.

TABLE 5 Vibration Levels for Construction Equipment

Equipment		Vibration Levels at Representative Distances			
		PPV at 25 ft. (in/sec)	PPV at 200 ft. (in/sec)	PPV at 220 ft. (in/sec)	PPV at 350 ft. (in/sec)
Clam shovel drop		0.202	0.021	0.018	0.011
Hydromill (slurry wall)	in soil	0.008	0.001	0.001	0.000
	in rock	0.017	0.002	0.002	0.001
Vibratory Roller		0.210	0.021	0.019	0.012
Hoe Ram		0.089	0.009	0.008	0.005
Large bulldozer		0.089	0.009	0.008	0.005
Caisson drilling		0.089	0.009	0.008	0.005
Loaded trucks		0.076	0.008	0.007	0.004
Jackhammer		0.035	0.004	0.003	0.002
Small bulldozer		0.003	0.000	0.000	0.000

Source: Transit Noise and Vibration Impact Assessment, United States Department of Transportation, Office of Planning and Environment, Federal Transit Administration, May 2006.

Of the equipment listed in Table 5 above, a vibratory roller would produce the highest vibrations and was used to estimate potential off-site vibrations. Vibration levels are highest close to the source, and then attenuate with increasing distance at the rate $(D_{ref}/D)^{1.1}$, where D is the distance from the source in feet and D_{ref} is the reference distance of 25 feet. [2] Using the attenuation rate above, a vibratory roller would produce vibration levels of 0.021 in/sec PPV when construction occurs at its closest point to receptors. The receptors represented by this worst-case scenario

[2] These levels are based on calculations assuming normal propagation conditions, using a standard equation of $PPV_{eqmt}=PPV_{ref} *(25/D)^{1.1}$.

include the residences 200 feet south of the utility corridor at the Hagar site and Porter/Kresge College residences 200 feet east of the utility corridor at the Heller site. Vibration levels at the 220 foot distance are calculated to occur at the residences south of the Hagar site. Vibration levels at the 350 foot distance are calculated to occur at the Rachel Carson College residences east of the Heller site. At these distances, vibration levels would not approach or exceed the 0.25 or the 0.3 in/sec PPV threshold used to assess the potential for cosmetic damage (e.g., minor cracks in plastered walls or the loosening of paint) at older residential buildings. There would be no impact to buildings in the vicinity of the project site because of the distance separating the buildings from proposed construction activities. Groundborne vibration levels resulting from proposed construction equipment could be perceptible at times. A vibration limit of 0.1 in/sec PPV, produced by continuous/frequent intermittent sources of construction vibration would be strongly perceptible and would cause human annoyance. As shown in Table 3, vibration levels would be below this threshold and represented nearby receptors. No mitigation would be required.

APPENDIX A: FUNDAMENTALS OF NOISE AND VIBRATION

Fundamentals of Environmental Noise

Noise may be defined as unwanted sound. Noise is usually objectionable because it is disturbing or annoying. The objectionable nature of sound could be caused by its *pitch* or its *loudness*. *Pitch* is the height or depth of a tone or sound, depending on the relative rapidity (frequency) of the vibrations by which it is produced. Higher pitched signals sound louder to humans than sounds with a lower pitch. *Loudness* is intensity of sound waves combined with the reception characteristics of the ear. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave.

In addition to the concepts of pitch and loudness, there are several noise measurement scales which are used to describe noise in a particular location. A *decibel (dB)* is a unit of measurement which indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc. There is a relationship between the subjective noisiness or loudness of a sound and its intensity. Each 10 decibel increase in sound level is perceived as approximately a doubling of loudness over a fairly wide range of intensities. Technical terms are defined in Table A-1.

There are several methods of characterizing sound. The most common in California is the *A-weighted sound level (dBA).* This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table A-2. Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This *energy-equivalent sound/noise descriptor* is called L_{eq}. The most common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration.

The scientific instrument used to measure noise is the sound level meter. Sound level meters can accurately measure environmental noise levels to within about plus or minus 1 dBA. Various computer models are used to predict environmental noise levels from sources, such as roadways and airports. The accuracy of the predicted models depends upon the distance the receptor is from the noise source. Close to the noise source, the models are accurate to within about plus or minus 1 to 2 dBA.

Fundamentals of Groundborne Vibration

Ground vibration consists of rapidly fluctuating motions or waves with an average motion of zero. Several different methods are typically used to quantify vibration amplitude. One method is the Peak Particle Velocity (PPV). The PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. In this report, a PPV descriptor with units of mm/sec or in/sec is used to evaluate construction generated vibration for building damage and human complaints. Table A-3 displays the reactions of people and the effects on buildings that continuous vibration levels produce.

The annoyance levels shown in Table A-3 should be interpreted with care since vibration may be found to be annoying at much lower levels than those shown, depending on the level of activity or the sensitivity of the individual. To sensitive individuals, vibrations approaching the threshold of perception can be annoying. Low-level vibrations frequently cause irritating secondary vibration, such as a slight rattling of windows, doors, or stacked dishes. The rattling sound can give rise to exaggerated vibration complaints, even though there is very little risk of actual structural damage.

Construction activities can cause vibration that varies in intensity depending on several factors. The use of pile driving and vibratory compaction equipment typically generates the highest construction related ground-borne vibration levels. Because of the impulsive nature of such activities, the use of the PPV descriptor has been routinely used to measure and assess ground-borne vibration and almost exclusively to assess the potential of vibration to induce structural damage and the degree of annoyance for humans.

The two primary concerns with construction-induced vibration, the potential to damage a structure and the potential to interfere with the enjoyment of life, are evaluated against different vibration limits. Studies have shown that the threshold of perception for average persons is in the range of 0.008 to 0.012 in/sec PPV. Human perception to vibration varies with the individual and is a function of physical setting and the type of vibration. Persons exposed to elevated ambient vibration levels, such as people in an urban environment, may tolerate a higher vibration level.

Damage caused by vibration can be classified as cosmetic or structural. Cosmetic damage includes minor cracking of building elements (exterior pavement, room surfaces, etc.). Structural damage includes threatening the integrity of the building. Damage resulting from construction related vibration is typically classified as cosmetic damage. Safe vibration limits that can be applied to assess the potential for damaging a structure vary by researcher and there is no general consensus as to what amount of vibration may pose a threat for structural damage to the building. Construction-induced vibration that can be detrimental to the building is very rare and has only been observed in instances where the structure is at a high state of disrepair and the construction activity occurs immediately adjacent to the structure.

TABLE A-1 Definition of Acoustical Terms Used in this Report

Term	Definition
Decibel, dB	A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micro Pascals.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro Pascals (or 20 micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e. g., 20 micro Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sound are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, L_{eq}	The average A-weighted noise level during the measurement period.
L_{max}, L_{min}	The maximum and minimum A-weighted noise level during the measurement period.
L_{01}, L_{10}, L_{50}, L_{90}	The A-weighted noise levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period.
Day/Night Noise Level, L_{dn} or DNL	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 pm and 7:00 am.
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 pm to 10:00 pm and after addition of 10 decibels to sound levels measured in the night between 10:00 pm and 7:00 am.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

Source: Handbook of Acoustical Measurements and Noise Control, Harris, 1998.

TABLE A-2 Typical Noise Levels in the Environment

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	110 dBA	Rock band
Jet fly-over at 1,000 feet		
	100 dBA	
Gas lawn mower at 3 feet		
	90 dBA	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	80 dBA	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	70 dBA	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	60 dBA	
		Large business office
Quiet urban daytime	50 dBA	Dishwasher in next room
Quiet urban nighttime	40 dBA	Theater, large conference room
Quiet suburban nighttime		
	30 dBA	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	20 dBA	
		Broadcast/recording studio
	10 dBA	
	0 dBA	

Source: Technical Noise Supplement (TeNS), California Department of Transportation, September 2013.

TABLE A-3 Reaction of People and Damage to Buildings from Continuous or Frequent Intermittent Vibration Levels

Velocity Level, PPV (in/sec)	Human Reaction	Effect on Buildings
0.01	Barely perceptible	No effect
0.04	Distinctly perceptible	Vibration unlikely to cause damage of any type to any structure
0.08	Distinctly perceptible to strongly perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
0.1	Strongly perceptible	Virtually no risk of damage to normal buildings
0.3	Strongly perceptible to severe	Threshold at which there is a risk of damage to older residential dwellings such as plastered walls or ceilings
0.5	Severe - Vibrations considered unpleasant	Threshold at which there is a risk of damage to newer residential structures

Source: Transportation and Construction Vibration Guidance Manual, California Department of Transportation, September 2013.