Proposal

Date: July 18, 2017

To: Paul Miller, City of Minneapolis

From: Lee Petersen, Ryan Peterson

Re: Calhoun Isles Condominium Association Vibration Study

Ref: 3-5952-01

1.0 INTRODUCTION

The Calhoun Isles Condominium Association (CICA) comprises high-rise buildings, townhomes, and a parking ramp located at the intersection of the Kenilworth and Greenway trails. The proposed Southwest Light Rail Transit (SWLRT) alignment runs along the northwest side of the property, within a few feet of the high-rise and parking ramp.

Construction of the 3118 Lake Street Apartments (Trammel Crow) in 2015 produced damage to units both in the high-rise and the townhomes. The Trammel Crow project is located to the southeast of CICA buildings, a minimum of 160 ft from the high rise, and up to 350 ft from the damaged townhomes. Damage to the high rise occurred up to the eighth floor. Seismographs placed on the ground adjacent to the high-rise measured peak particle velocities (PPV) up to 0.185 inches per second (ips). Residents also reported that the vibrations were unbearable.

Three aspects of this experience are noteworthy and well outside common experience:

1. damages from pile driving at these distances;
2. damages up to the eight floor of an engineered building; and
3. damages at vibration levels of 0.185 ips.

Thus, the CICA property and buildings appear to be especially susceptible to vibration impacts and vibration damage.

2.0 WORK PLAN

2.1 Purpose

This work plan describes planning, data collection, data analysis, and reporting of the vibration-related behavior of the CICA site and structures. The results include:

1. documented ground and structure response to vibrations;
2. an understanding of the response of the site and structures to ground-borne vibrations;
3. an understanding of the uncommon responses to the Trammel Crow construction; and
4. prediction of how construction and operation of the SWLRT project will affect CICA (i.e., the susceptibility of the CICA property to SWLRT construction and operation vibrations).

2.2 Work Tasks

The proposed work plan has the following tasks:

1. Task 1: Develop Detailed Monitoring Plan—This first task will flesh out the details of the monitoring plan, including the seismograph locations, mounting methods (where necessary), source locations, sequence of data collection, etc.
2. Task 2: Select, Rent, and Install Equipment—The study requires several seismographs to collect vibration data and a vibratory compactor as a vibration source. The seismographs will be installed in several locations at once and in several groups of locations during the data collection. Significant time will be required to coordinate these locations, string the necessary cabling, and confirm operations. In this task, Itasca will select, arrange for, rent, and install these items.
3. Task 3: Collect Vibration Data—Data collection will be done using both existing vibration sources, and a vibratory compactor rented specifically for this study.
    a. Data collection using existing vibration sources—Existing vibration sources include the rail traffic on the Kenilworth corridor and traffic on nearby roads. Data collection from these existing sources will be interspersed with data collection from new sources. The procedure for collecting vibrations from rail traffic has been developed jointly with TC&W Railroad. These procedures include:
        i. take time-stamped vibration measurements;
        ii. contact TC&W Railroad at an agreed-upon interval; and
        iii. TC&W will use their records, including an automated reader north of Cedar Lake Parkway that can match up actual train specifics (i.e., total number of cars, total tonnage, speed, etc.).
    b. Data collection using new sources—The new vibration source will be exercised during gaps in the existing vibration sources. The new source will be a small vibratory compactor.

   c. Duration—The data collection duration will be three to four days, including installation, depending upon the frequency of rail traffic. Itasca staff will be on site roughly during business hours, downloading data, observing rail and road traffic, and operating the new data sources. Equipment installation will also occur during this three- to four-day time frame.
   d. Number of seismographs—Five seismographs will be used to collect data. The seismographs will likely be relocated several times during the data collection phase, including locations near vibration sources, on the ground adjacent to the high-rise, in the below-ground spaces of the high rise, in higher floors of the high rise, various places in the garage structure, on the ground adjacent to the townhouses, and in townhouses.
4. Task 4: Analyze Data—Data analysis will be focused on the following two objectives.
   a. Determine attenuation characteristics and transfer functions—The data collected in Task 3 will be analyzed to determine the attenuation characteristics of the ground and CICA structures. Ground attenuation is commonly represented by empirical functions that account for both geometrical spreading and material damping. Geometrical spreading is a decrease in wave amplitude, or energy, due to spreading of the wave as it propagates farther from the source. Geomaterials are not perfectly elastic and each wave cycle involves the movement of particles, which requires energy to overcome friction and other forces. This lost energy during each cycle is characterized as material damping. Transfer functions are commonly used to characterize the coupling loss between the ground and structures. More massive structures typically experience a greater coupling loss.
   b. Determine structural vibration frequencies and velocities—These data analyses are aimed at understanding the behavior of the CICA high-rise. Attenuation through structures is often expressed in terms of both floor to floor vibration intensity loss and amplification due to resonances of floors, walls, and ceilings. Structure attenuation can be very difficult to characterize and is influenced by dispersion and attenuation or amplification of the vibration energy as it propagates through a building.
5. Task 5: Prediction of SWLRT Vibration Impacts—This task describes two approaches to using the data collected in earlier tasks to predict the vibration impacts of the SWLRT project. Task 5a is the simpler approach and is not optional. Task 5b is more complex and is aimed at addressing the transmission of vibrations from operating trains to the CICA structures, specifically the differences in attenuation distances between SPO's consultant and Itasca. Task 5b is optional.
   a. Task 5a: Prediction Using Attenuation Relations
      i. The data collected in Task 3 will be used to estimate the parameters of attenuation relations for the site soils, and for the attenuation from soil to

structure and from floor to floor (and location to location) in the structures.

  ii. Estimates of construction vibrations will be expressed in terms of peak particle velocity. This is a more appropriate measure for structural response to vibrations.
  iii. Estimates of operational vibrations will be expressed in terms of root mean square velocity. This is a more appropriate measure for human response to vibrations.

b. Task 5b: Prediction Using Modeling—A two-dimensional, dynamic, numerical model will be developed for two purposes. Itasca's commercial continuum software *FLAC* will be used.
  i. First, the model will be used to back analyze the collected data from the study. Model parameters will be calibrated to obtain the responses measured during the field phase. The dynamic input will be obtained from the seismographs placed near the vibration sources.
  ii. Second, the calibrated model will be used to predict the vibrations the CICA structures will be subject to during SWLRT construction and operation.
  iii. Estimates of construction vibrations will be expressed in terms of peak particle velocity. This is a more appropriate measure for structural response to vibrations.
  iv. Estimates of operational vibrations will be expressed in terms of root mean square velocity. This is a more appropriate measure for human response to vibrations.

6. Task 6: Report Preparation—Itasca will prepare a written report documenting data collection, data analysis, modeling, and findings. The budget also includes a meeting to present findings to project stakeholders.

3.0 SCHEDULE, DELIVERABLES, AND ESTIMATED COST

3.1 Schedule

Table 1 lists the proposed tasks, durations and deliverables. Approximately 15 weeks are required from a notice to proceed to the delivery of the final report. The schedule depends somewhat on the weather, and the TC&W train schedule. The Task 1 and Task 4 deliverables will be informal. The monitoring plan submitted under Task 1 is intended to facilitate coordination with the Calhoun Isles Condominium Association. The Task 4 data summary will be submitted as the raw data for the review and use by others, and will ultimately be included as an appendix of the final report.

Table 1 Summary of Task Durations and Deliverables

Task	Duration	Deliverable
Task 1: Develop Detailed Monitoring Plan	2 weeks	Monitoring Plan
Task 2: Select, Rent, and Install Equipment	2 weeks	None
Task 3: Collect Vibration Data	1 week	None
Task 4: Analyze Data	4 weeks	Data Summary
Task 5: Prediction of SWLRT Vibration Impacts	4 weeks	None
Task 6: Report Preparation	2 weeks	Report
Task 7: Present Findings	T.B.D.	Presentation

3.2 Estimated Cost

The preceding work plan contains a basic proposal, and an optional subtask. The basic proposal includes all tasks except Tasks 5b and 6b. As noted above, Task 5b work predicts vibrations during SWLRT operation, and requires computer modeling of the vibration propagation. The work is more complex and expensive than the other tasks. These tasks have been separated from the basic proposal for these reasons. Task 6b is the reporting and presentations associated with Task 5b.

The proposed costs are presented in Figure 1, and summarized below:

1. Basic proposal—Total labor $59,400, Expenses $5,415, Total $64,855
2. Optional Task 5b—Total $29,250

Note that the seismograph rental costs are most the expenses, and may vary depending upon schedule as driven the rail traffic and weather.

Calhoun Isles Vibration Susceptibility Study Itasca Consulting Group												
Activity	Principal Engineer		Senior Engineer		Project Engineer		Field Engineer		Support Staff		Total	
	$225		$195		$185		$162		$120			
Tasks	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost
Task 1 Task 1 Develop Detailed Monitoring Plan	**2**	**$ 450**	**0**	**$ -**	**12**	**$ 2,220**	**12**	**$ 1,946**	**0**	**$ -**	**26**	**$ 4,616**
Task 2 Task 2 Select, Rent, and Install Equipment	**2**	**$ 450**	**0**	**$ -**	**16**	**$ 2,960**	**40**	**$ 6,486**	**0**	**$ -**	**58**	**$ 9,896**
Task 3 Task 3 Collect Vibration Data	**4**	**$ 900**	**0**	**$ -**	**24**	**$ 4,440**	**40**	**$ 6,486**	**0**	**$ -**	**68**	**$ 11,826**
Task 4 Task 4 Analyze Data	**4**	**$ 900**	**0**	**$ -**	**32**	**$ 5,920**	**32**	**$ 5,189**	**0**	**$ -**	**68**	**$ 12,009**
Task 5 Task 5 Prediction of SWLRT Vibration Impacts	**36**	**$ 8,100**	**0**	**$ -**	**112**	**$ 20,720**	**32**	**$ 5,189**	**0**	**$ -**	**180**	**$ 34,009**
Task 5.1 Task 5a Prediction Using Attenuation Relationships	4	$ 900	0	$ -	32	$ 5,920	32	$ 5,189	0	$ -	68	$ 12,009
Task 5.2 Task 5b Prediction Using Modeling	32	$ 7,200	0	$ -	80	$ 14,800	0	$ -	0	$ -	112	$ 22,000
Task 6 Task 6 Reporting	**20**	**$ 4,500**	**0**	**$ -**	**36**	**$ 6,660**	**26**	**$ 4,216**	**8**	**$ 960**	**90**	**$ 16,336**
Task 6.1 Task 6a1 Report Preparation	4	$ 900	0	$ -	8	$ 1,480	20	$ 3,243	4	$ 480	36	$ 6,103
Task 6.2 Task 6a2 Present Findings	4	$ 900	0	$ -	6	$ 1,110	6	$ 973	0	$ -	16	$ 2,983
Task 6.3 Task 6b1 Report Preparation	6	$ 1,350	0	$ -	16	$ 2,960	0	$ -	4	$ 480	26	$ 4,790
Task 6.4 Task 6b2 Present Findings	6	$ 1,350	0	$ -	6	$ 1,110	0	$ -	0	$ -	12	$ 2,460
Labor Total	68	$15,300	0	$0	232	$42,920	182	$29,510	8	$960	490	$88,690
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Total Labor	$88,690
Total Expenses	$5,415
Total (excl. Taxes)	$94,105

Figure 1 Estimated project costs.