EXHIBIT A
SCOPE OF SERVICES

DISPLACEMENT MONITORING OF I-35W BRIDGE WITH CURRENT VIBRATION-BASED SYSTEM

BACKGROUND
Vertical displacements, while informative for monitoring the long-term serviceability and short-term behavior of bridge structures, are traditionally challenging to measure without on-site surveying. This project would develop an advanced sensor system to estimate the long-term and the dynamic vertical displacements without a reference or on-site surveying. The long-term vertical displacements would reflect the serviceability of the bridge; while, the dynamic displacements would be used to augment the monitoring of the I-35W bridge as a more robust indicator of stiffness, connection, and foundation degradation. Additionally, vertical deflection may offer a more direct comparison with design calculations and maintenance guidelines.

Minnesota offers the unique opportunity of using the acceleration data from the I-35W Saint Anthony Falls Bridge alongside the Global Positioning System (GPS) correction service offered by MnDOT to implement a vertical deflection monitoring system. Based on the long-term fidelity of the acceleration data, the accelerometer data (accounting for temperature and time-dependent effects) would be used in conjunction with a low-cost GPS sensor to estimate the vertical displacement of the bridge. Thus, no GPS base-station or fixed reference would be required. If the technique is successful and inexpensive, the monitoring approach could be widely implemented to help MnDOT prioritize maintenance needs among bridges and could limit routine surveying requirements.

OBJECTIVE
If successful and inexpensive, the technique could be implemented on a wide variety of bridge types to help MnDOT identify which bridges are maintenance priorities. Additionally, the project benefits from sensors already installed and the MnDOT GPS correction service; the monitoring program for the I-35W Bridge is mandated by legislation.

SCOPE
This project will focus on three main components: analytical study of approach to estimate deflections given the fidelity of the data, small-scale laboratory test to verify technique, and proof of principle on the I-35W bridge.

An analytical study of the approach will be required as the quality of the acceleration data and number of GPS receivers will be essential for success of the project. The acceleration measurements, characterized in a previous study, and GPS displacement data will be used within a Kalman Filter to estimate the non-zero mean vertical displacements. If the signal-to-noise ratio of the current system is too low, given the stiffness of the structure, higher-sensitivity accelerometers might be required.

A small-scale laboratory test would be used to verify the sensor selection and signal processing technique developed in the analytical study. The small-scale tests allows for evaluation of the technique in a more controlled environment such that hardware limitations and implementation challenges can be identified prior to field deployment.

Finally, given successful development, the vertical deflection system would be implemented on the southbound river span of the bridge. If the current accelerometer system is not adequate, the monitoring system would be augmented with higher-sensitivity wireless accelerometers. Additionally, low-cost GPS sensors would be deployed. Verification of the technique would require the implementation to coincide with routine surveying of the bridge.

ASSISTANCE
Data collected from the I-35W Saint Anthony Falls Bridge is owned by MnDOT. The research team will need remote access to the server to download data. MnDOT maintains the server, along with the data acquisition sensors and equipment. The researcher team will need access into the river span box of the I-35W Bridge and monitoring system for implementation of the vertical deflection system and maintenance of the current system. The research team will also require access to survey data for the I-35W Bridge since completion. If possible, routine surveying should be scheduled during deployment of the system in Task 3.

WORK PLAN

Task Descriptions

Task 1: Analytical Study of Technique to Estimate Vertical Deflections
Under this task, the University will evaluate the Kalman Filtering technique by using the Finite Element Method (FEM) model to generate acceleration time histories, point-wise displacement data, and corresponding vertical deflections. Given the fidelity of the acceleration data, which was assessed in MnDOT Project "Feasibility of vibration-based long-term bridge monitoring using I-35W Bridge", the University will determine adequacy of the acceleration measurements for the application. Based on selected measurement fidelity, the University will conduct a parametric study to determine the number of low-cost GPS sensors to be used in conjunction with the accelerometers required to offer quality vertical deflection measurements across the bridge.

Task 2: Small-Scale Laboratory Implementation
Under this task, the University will use the sensing system and signal processing technique identified in Task 1 to implement a small-scale test in the Structures Laboratory at University. The small-scale test would use a single-bay steel frame fitted with a dynamic actuator. The beam of the frame will be subjected to dynamic motion in the elastic range and the subsequent response will be captured with the monitoring system. A non-contact camera-based instrument will measure the displacements for comparison with the monitoring system. The test allows for evaluation of the technique in a more controlled environment such that hardware limitations and implementation challenges can be identified prior to field deployment.

Task 3: Vertical Deflection Monitoring System Implemented on I-35W Bridge
Under this task, the University will install the low-cost GPS sensors and accelerometers, if necessary, that are selected in Task 1 and 2 in the southbound river span of the I-35W Bridge and tied to the existing monitoring system. The University will implement the signal processing software in the base-station computer. The University will compare the vertical deflection results with routine surveying measurements taken by MnDOT. (The project budget does not cover the cost of the surveying.)

Task 4: Maintain Operation of Current Monitoring System – Part I
Under this task, the University will facilitate the operation and maintenance of the I-35W Bridge monitoring system. The project team will aid in the upkeep of the data acquisition system and identify possible repair solutions, if necessary. (The project budget does not cover the cost of any repair solutions.)

Task 5: Maintain Operation of Current Monitoring System – Part II
Under this task, the University will facilitate the operation and maintenance of the I-35W Bridge monitoring system. The project team will aid in the upkeep of the data acquisition system and identify possible repair solutions, if necessary. (The project budget does not cover the cost of any repair solutions.)

Task 6: Compile Report, Technical Advisory Panel Review and Revisions
Under this task, the University will prepare a draft report, following MnDOT's publication guidelines, to document project activities, findings and recommendations. This report will need to be reviewed by the Technical Advisory Panel (TAP), updated by the University's Principal Investigator to incorporate technical comments, and then approved by Technical Liaison before this task is considered complete. Holding a TAP meeting to discuss the draft report and review comments is strongly encouraged. TAP members may be consulted for clarification or discussion of comments.

Task 7: Editorial Review and Publication of Final Report
During this task the Approved Report will be processed by MnDOT's Contract Editors. The editors will review the document to ensure it meets the publication standard. This task must be completed within the contract time because the editors will provide editorial comments and request information from the University's Principal Investigator.

Task Deliverables

Task:	Deliverable(s):
1:	A 2-3 page report summarizing the findings and recommendation for the acceleration monitoring system
2:	A 2-3 page report summarizing the findings
3:	A 3-5 page report summarizing the findings and detailing the implemented system
4:	A report that summarizes any modifications and repair to the monitoring system during the task period

5:	A report that summarizes any modifications and repair to the monitoring system during the task period
6:	A Draft Report and Final Report Approved for Publication; an operational vertical displacement monitoring system
7:	Final Published Report

PROJECT SCHEDULE

Task Durations

	2016						2017											
Months:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Task 1	X	X	X	X	X	X	X	X	X									
Task 2								X	X	X	X	X	X	X	X	X		
Task 3																X	X	X
Task 4	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Task 5													X	X	X	X	X	X
Task 6																		
Task 7																		

	2018											
Months:	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Task 1												
Task 2												
Task 3	X	X	X	X	X							
Task 4												
Task 5	X	X	X	X	X	X	X					
Task 6							X	X	X	X		
Task 7										X	X	X

Deliverable Due Dates

Task:	Draft Deliverable Due Date:	Final Task Approval Date:
1:	January 31, 2017	March 31, 2017
2:	August 31, 2017	October 31, 2017
3:	March 31, 2018	May 31, 2018
4:	June 30, 2017	August 31, 2017
5:	May 31, 2018	July 31, 2018
6:	August 31, 2018	October 31, 2018
7:		December 31, 2018

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