SCOPE OF WORK 3
Master Sponsored Research Agreement
Sewer Backup Risk Score

This Scope of Work 3 is made and entered into effective the 20th day of September, 2018 (the "SOW Effective Date") by The Travelers Indemnity Company ("Travelers") and the University of Connecticut ("University") pursuant to the terms of the MASTER SPONSORED RESEARCH AGREEMENT between the parties dated August 31, 2018 (the "Master Agreement").

Title: Sewer Backup Risk Score

Principal Investigators: Professors Xinyi Shen, Emmaouil Anagnostou and Efthymios Nikolopoulos

Total Project Cost: $42,554

Period of Performance: October 1, 2018 – October 31, 2019

Technical Plan:
Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain not only storm water but also untreated human and industrial waste, toxic materials, and debris.

They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems. Wastewater flows (combined hydrograph) for analysis and design of sanitary sewers can be divided into three categories: (1) base wastewater flow (BWF) associated with the sanitary flow contribution; (2) groundwater infiltration (GWI) associated with flows infiltrated during dry weather periods; and, (3) extraneous flow associated with flows from wet weather events. BWF are usually expressed as percentages (or "return ratio") of per capita water consumptions. These ratios can be determined from analysis of long-term (year) monitored sewer flow data and water consumption data.

The rate of GWI depends on the number and size of defects within a sewer and the hydraulic head available, and hence is greater in a wet spring when a high groundwater table would prevail. Local monitoring flow data are needed for determination of GWI rates that meaningfully reflect the gross site-specific conditions. Rainfall-derived infiltration and inflow (RDII) can be estimated by synthetic streamflow regression method, which simulates stream flow records and then correlates hydrologic responses to sewer flow responses by multi regression techniques using sewershed characteristics or synthetic unit hydrograph method, which calculates the RDII

hydrograph from a specified "unit" hydrograph shape that relates RDII to unit precipitation volume and specified duration, and sewershed characteristics. Finally, the combined hydrograph will be combined with customer data and input into a Machine Learning software to develop a predictive model for Sewer Backup Risk Score. Development of this model requires data on peak sewer flows, or indirect data through sewer backup customer claims.

In this study we propose using customer claims along with hydrological and geographic data to develop a risk scoring system for sewer backup flows.

Specifically, the goal of the work under this SOW is to develop a modeling framework to:

(i) develop and demonstrate the efficiency of a machine learning software to relate combined hydrograph from urban precipitation to peak sewer flow or sewer backup customer claims and other social and economic factors (customer data), and

(ii) develop based on the machine learning model a multi-criterion scoring system that scores the likelihood of sewer backup for different return period storm events (2 years to 500 years).

The work will use data from Hartford, and University will be responsible for sourcing the relevant data for the Project (the "Data"). Sewer backup customer claims and customer data will be provided by Travelers.

University will provide scientific and technical review, management, testing, design, development, validation and documentation of algorithms and software for the work under this SOW. The parties acknowledge that the data for the work will be limited to the combined sewer system in Hartford, CT, but the Deliverables are intended to have general applicability to any city with a combined sewer system.

All software and algorithms will be developed and provided to Travelers in a mutually agreeable, generally available programming language.

University will provide Travelers with a monthly progress report on the work, or more frequently as mutually agreed. The progress report will be written or oral, and will detail significant events, accomplishments, and issues, and additional information that will assist Travelers is evaluating progress under this SOW.

Deliverables:

Deliverable	Description	Due Date
Data files	Raw data files of combined overflow time series. Travelers provides claim and customer data from Hartford. Data will be provided in a mutually agreeable format.	January 31, 2019
Machine learning	Present a methodology to relate storm-runoff with	May 30, 2019

software	customer data and sewer backup customer claims. Evaluate results	
Scoring system	Present a multi-criterion scoring system to score sewer backup risk based on a stochastic storm-runoff extreme events simulator and the developed machine learning software.	September 30, 2019
Final Report	Submit a PDF document with executive summary and detailed analysis of the work.	October 30, 2019

University will provide Travelers with a draft version of the Final Report for Travelers review and comment. University will meeting with Travelers at a mutually agreeable date and time to review the finding in the Final Report.

Please list any PI's or co-PI's Background Intellectual Property related to the Project:
None

Please list of Third Party Rights or Open Source tools required for the Project:
None

Signatures on following page.

IN WITNESS WHEREOF, the parties hereto have reviewed and approved this Scope of Work to be executed by their duly authorized officers as of the SOW Effective Date and shall be incorporated into the Master Agreement.

UNIVERSITY OF CONNECTICUT		**THE TRAVELERS INDEMNITY COMPANY**
DocuSigned by: Laura Kozma 392FC7A6438449B...	Signature	DocuSigned by: Deborah C Strong 6DF8728C92384C7...
Laura Kozma	Typed Name	Deborah C Strong
Executive Director	Title	CFO, Technology
12/3/2018	Date	11/30/2018

Co-PI		**Co-PI**
DocuSigned by: Xinyi Shen 05686795F5614B0...	Signature	
Xinyi Shen	Typed Name	
Assistant Research Professor	Title	
12/10/2018	Date	

Co-PI		
	Signature	
	Typed Name	
	Title	
	Date	