

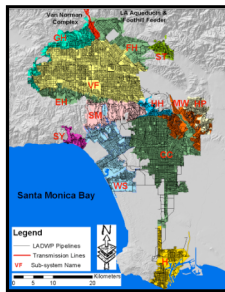
# Post-Earthquake Restoration Modeling for Water Supply Systems

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## PROJECT OBJECTIVES

- Create a discrete-event simulation model for the post-earthquake restoration process of the Los Angeles Department of Water and Power (LADWP)
- Run model for a suite of earthquakes that represent the region's seismicity
- Use model to produce:
  - quantitative restoration curves with uncertainty bounds
  - dynamic maps showing the spatial distribution of outages changing over time
  - information on how personnel and repair materials are used throughout the process
  - rapidity risk surface
- Conduct a sensitivity analysis and explore effectiveness of different restoration strategies



Map of the LADWP water supply system (Shi 2006).

Water pump in San Francisco pumping station.



A dresser coupling (Çağnan 2005).

## DISCRETE EVENT SIMULATION MODELING APPROACH

An artificial history of the system being modeled is generated and observations are collected to estimate system performance measures. Advantages of discrete event simulation include:

- **Models the real-life restoration process explicitly.** Requires less simplification of process.
- **Enables representation of the uncertainty** in the restoration curve.
- **Includes utility company's decision variables explicitly** (e.g., number of restoration crews, prioritization rules), allowing investigation of their effects on the speed of the restoration.
- **Requires only available data.**
- **Is flexible** so that it can be applied to other lifelines and hazards, adapted to changes in the restoration process or data, or extended to accommodate multi-lifeline interactions. It has already been used by Çağnan and Davidson (2006) and Çağnan et al. (2006) for the LADWP electric power system.

## LADWP's RESTORATION PROCESS

- **Damage assessment:** Occurs immediately following earthquake, conducted by on-duty and reporting personnel who report status of facilities to headquarters
- **Rerouting:** Shutdown and/or adjustments made to critical facilities and valves, like pump stations, in order to minimize number of customers without water; occurs in hours following earthquake once system damage is determined
- **Repair and construction:** Crews of different sizes dispatched based on damage assessments

## MODEL OUTLINE

- **Entities:** pipes, regulator stations, pump stations, reservoirs, and dams
- **Attributes (can include):** inspection, damage, and repair indicators, distance to earthquake epicenter, material type, water level, pipe diameter
- **Resources:** damage assessment teams, repair teams (pipelines), reservoir and dam inspection teams, etc.
- **Events:** damage assessment, rerouting, repair and construction

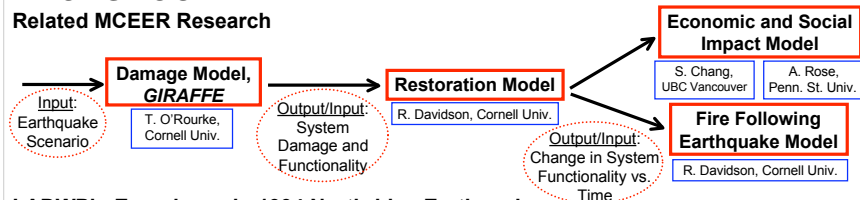
## WORK PLAN

This project is ongoing and the next steps are:

- Finalize gathering of information on the current restoration process for LADWP
- Program model based on information from Northridge experience and current emergency response plans
- Validate and verify model
- Run model for suite of 59 earthquake scenarios that represent region's seismicity
- Conduct sensitivity analyses and explore different restoration strategies

## BACKGROUND

### Related MCEER Research



## LADWP's Experience in 1994 Northridge Earthquake

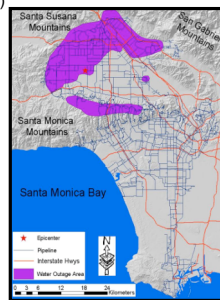
- Most recent earthquake to cause major damage
- LADWP sustained almost \$44 million in economic loss due to damage; 74 trunk line and 1,013 distribution line repairs
- Approximately 500,000 customers experienced water outages (Eguchi and Chung 1995)

## REFERENCES

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## ACKNOWLEDGEMENTS

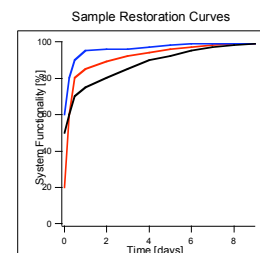
Principal investigator and faculty advisor: Rachel A. Davidson  
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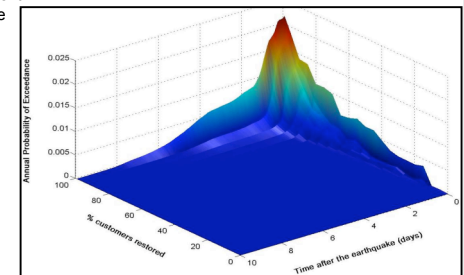
Water outage areas following the 1994 Northridge Earthquake. (Wang 2006; Shi 2006)

## ANTICIPATED RESULTS

Output from the restoration model will take several different forms. System functionality as it evolves over time will be recorded and can be shown in restoration curves:



The different restoration curves above could represent the restoration of the system for 3 different earthquake scenarios.



Example of the *water rapidity risk* that can be found by running the model for the 59 scenario earthquakes that represent the region's seismicity. The graph above presents results from the LADWP electric power restoration model (Çağnan 2005).