Resilience of Water Distribution Networks After an Earthquake

May 26, 2016

Dylan Moriarty
Sandia National Laboratories

Kate Klise
Sandia National Laboratories

Michael Bynum
Purdue University

Regan Murray
U.S. Environmental Protection Agency

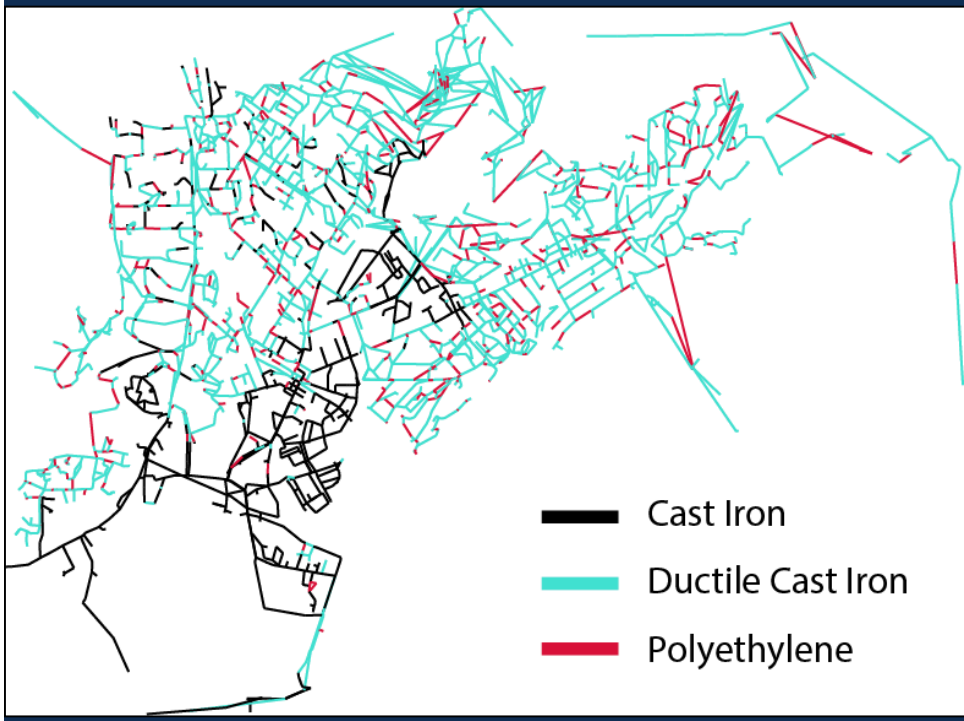
The U.S. Environmental Protection Agency through its Office of Research and Development funded and collaborated in the research described here. The research has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011–XXXXP.

SAND2016-5155C

Exceptional service in the national interest

Sandia National Laboratories



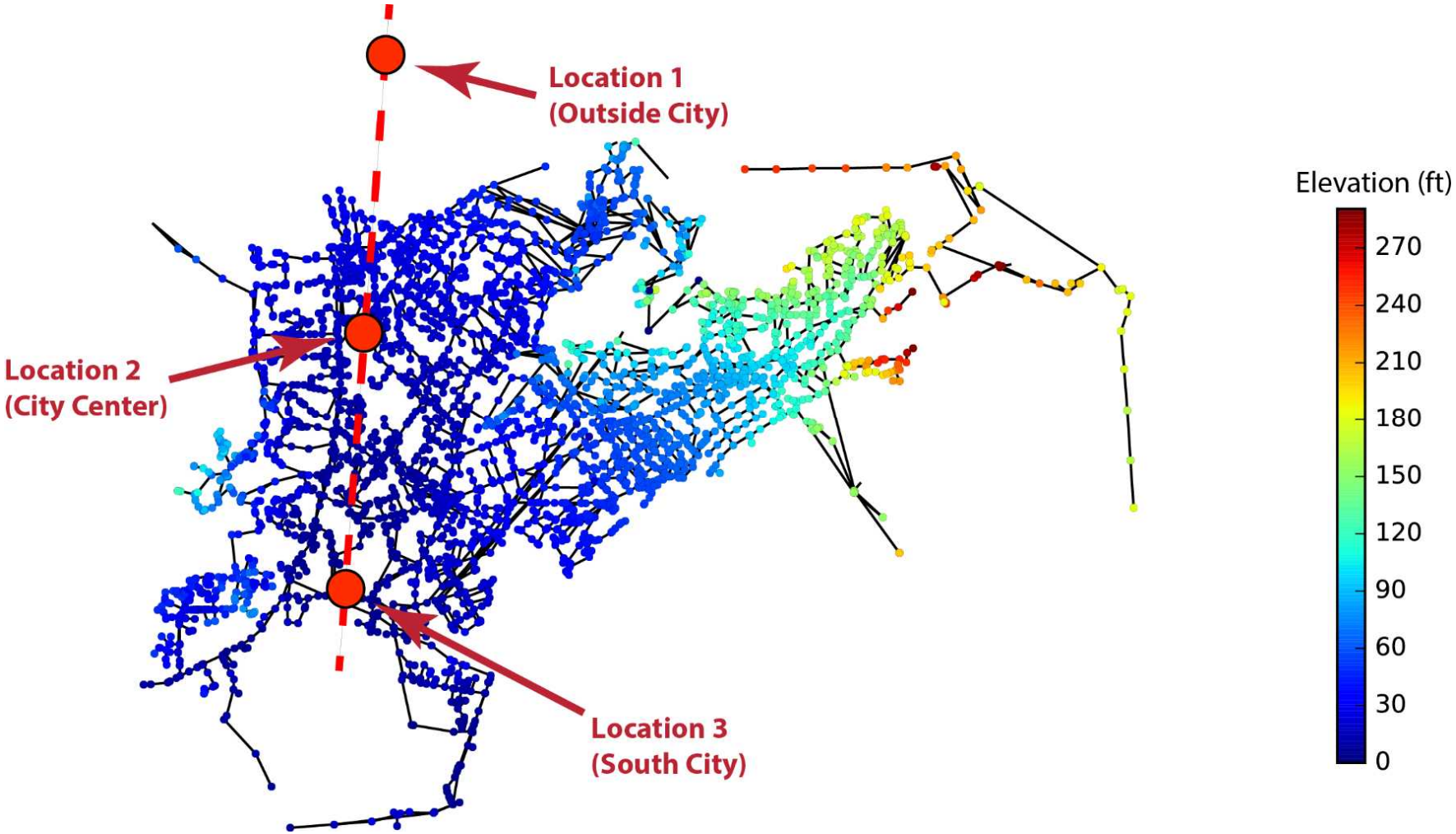
Overview

Sandia National Laboratories

- **Objective:** Analyze the resilience of a water distribution network after an earthquake
- Scenario
  - Medium sized network (3000+ nodes & 3000+ links)
  - Varied parameters (magnitude, location, response strategies)
- Develop the pressure driven demand simulator in WNTR to simulate before, during, and after earthquake
  - Realistic node demands & tank/pump controls
  - Stop/start simulations to fix broken pipes/tanks/pumps
- Resilience is quantified by population impacted over time

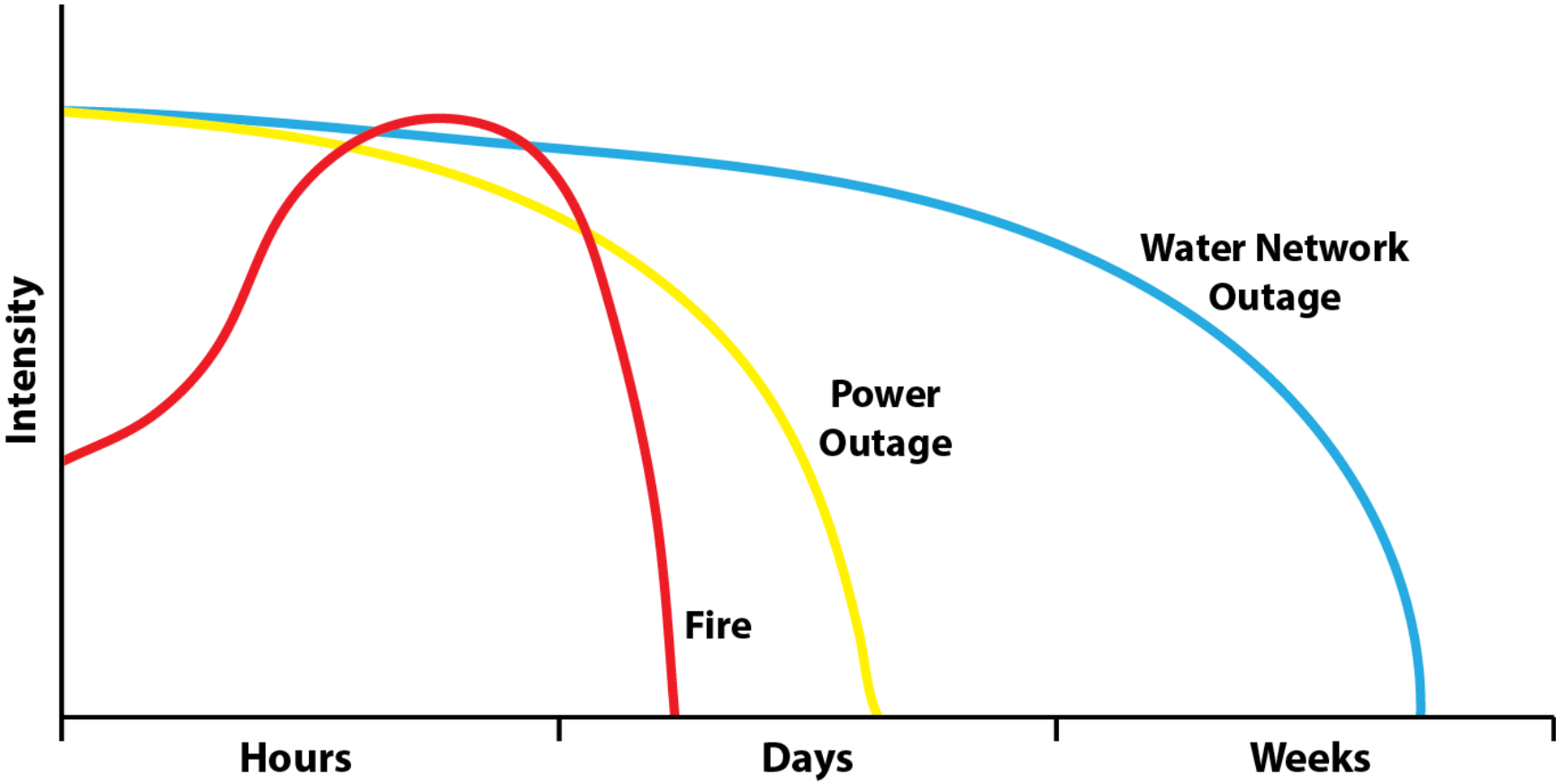
Earthquake Scenario

Sandia National Laboratories

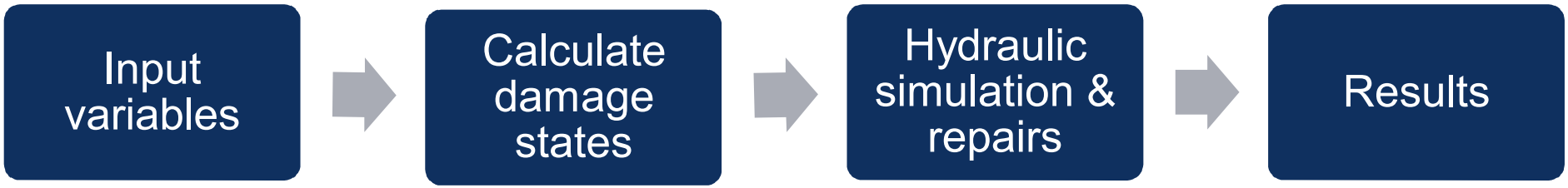


Earthquake Scenario

Sandia National Laboratories



Workflow


Input variables
Calculate damage states
Hydraulic simulation & repairs
Results

Input Variables

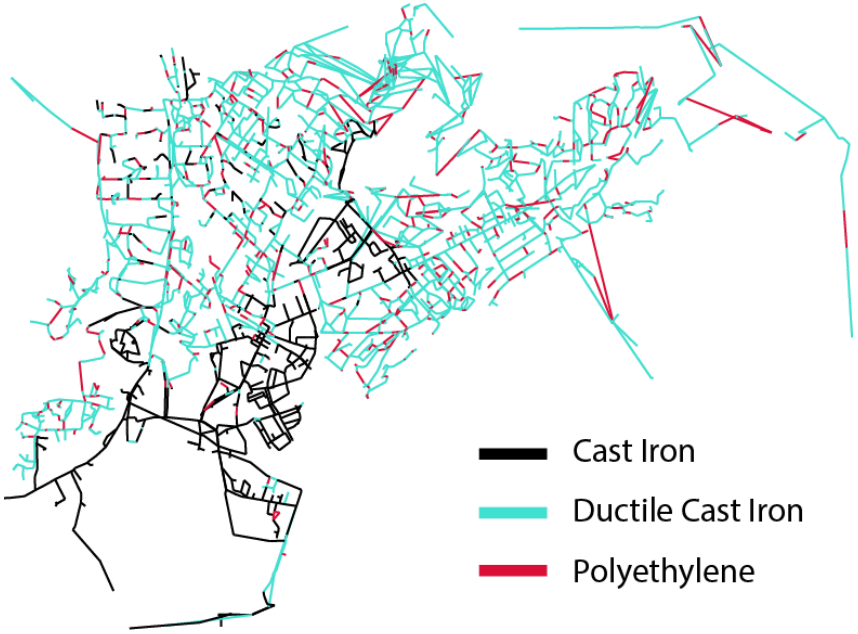
Sandia National Laboratories

- Network Characteristics
  - Pipe material
  - Liquefaction potential
  - Topography
  - Pipe diameter
- Repairs
  - Number of crews
  - Repair duration
- Controls
  - Pump / Tank
  - Valves
- Demands
  - Fire demands
  - Water conservation

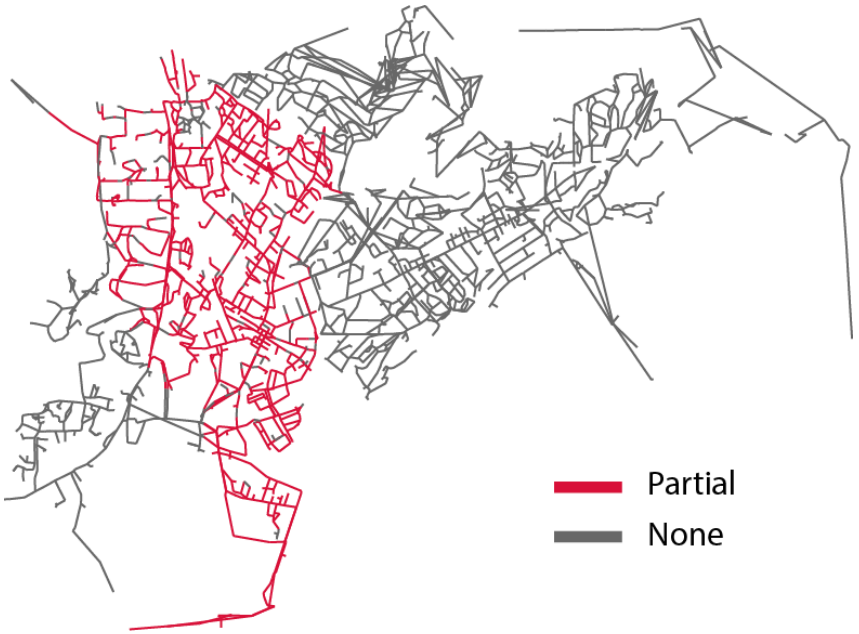
Network Characteristics

Sandia National Laboratories

Pipe Material

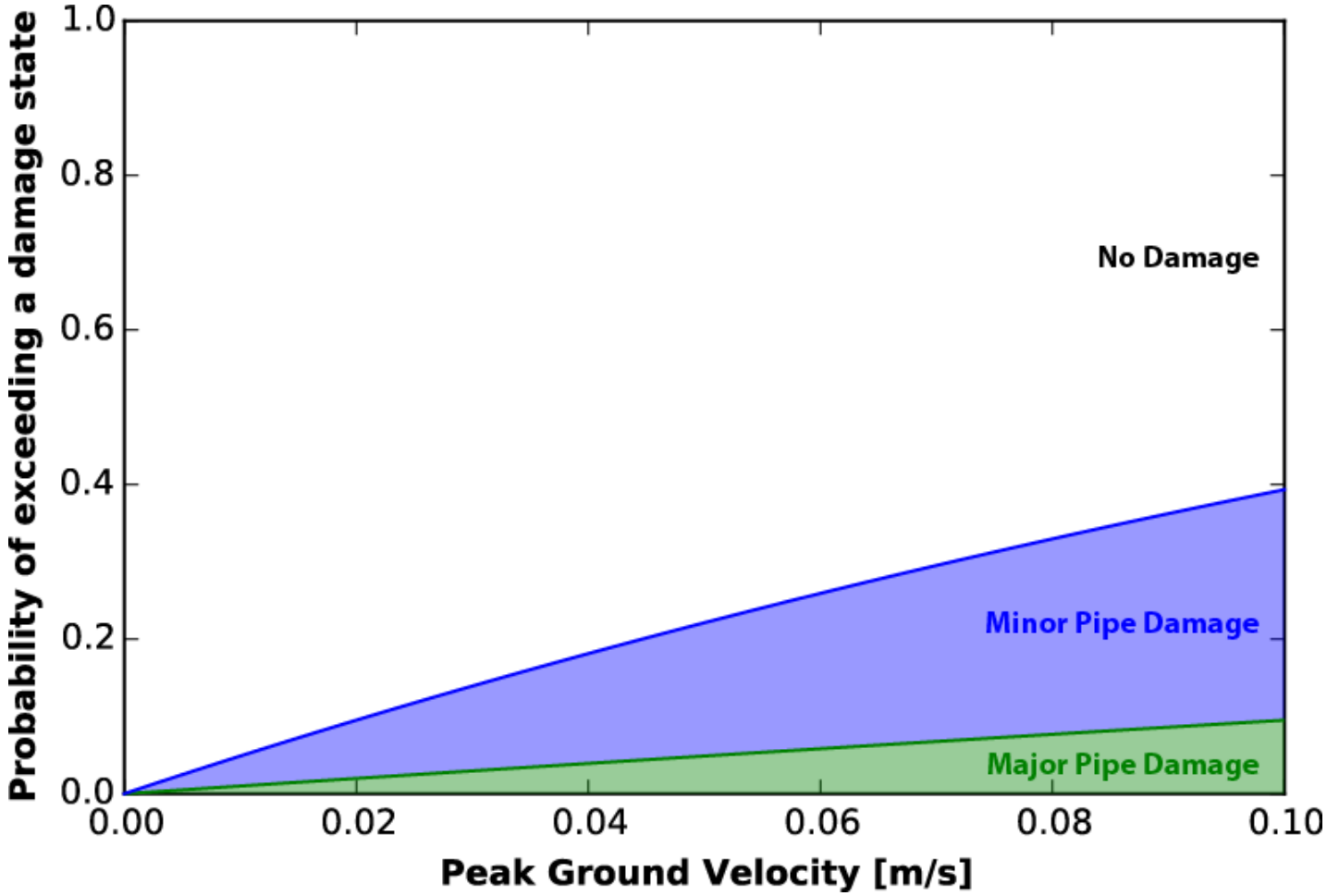


Liquefaction Potential



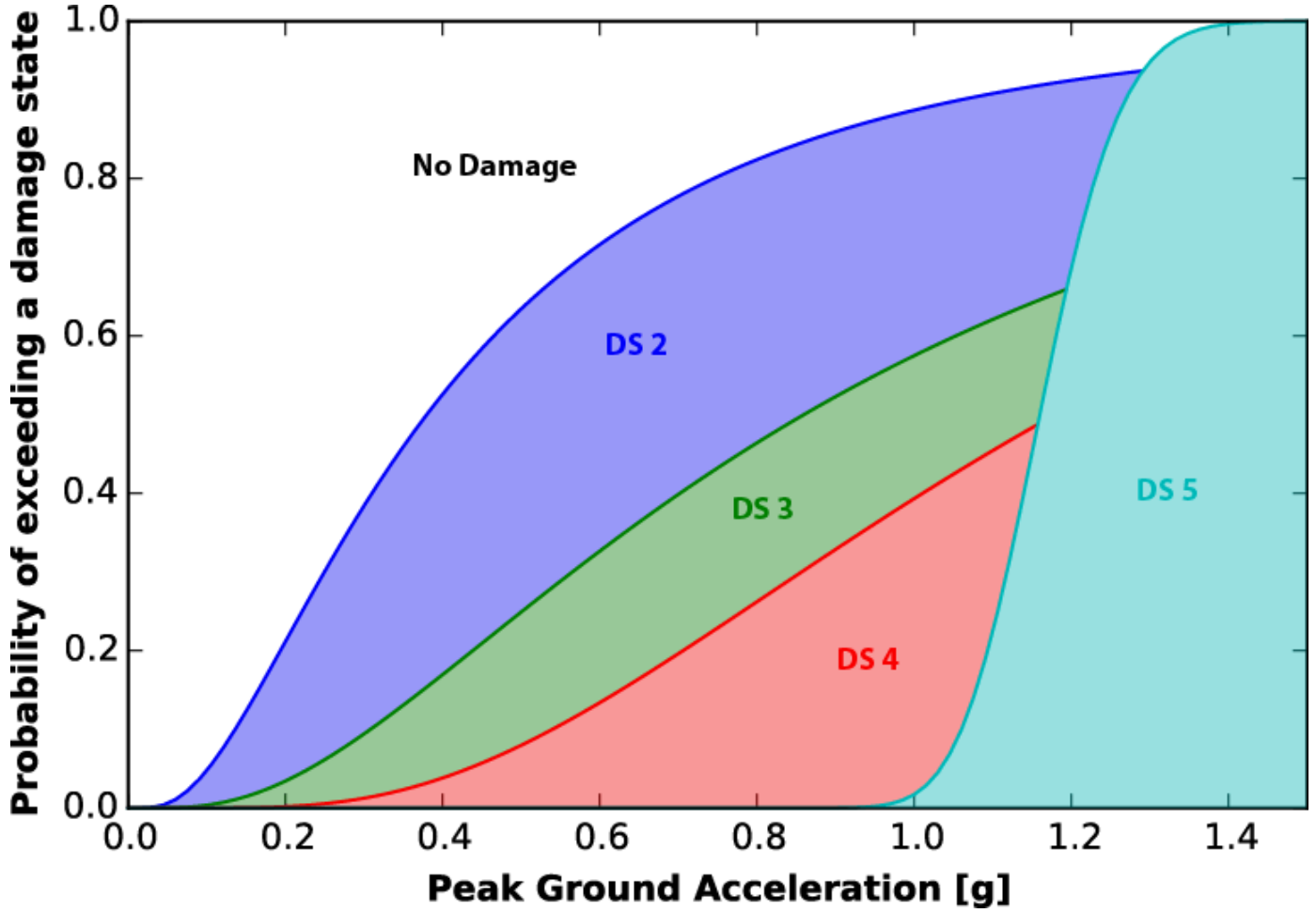
Input variables → Calculate damage states → Hydraulic simulation & repairs → Results

Damage State – Pipes



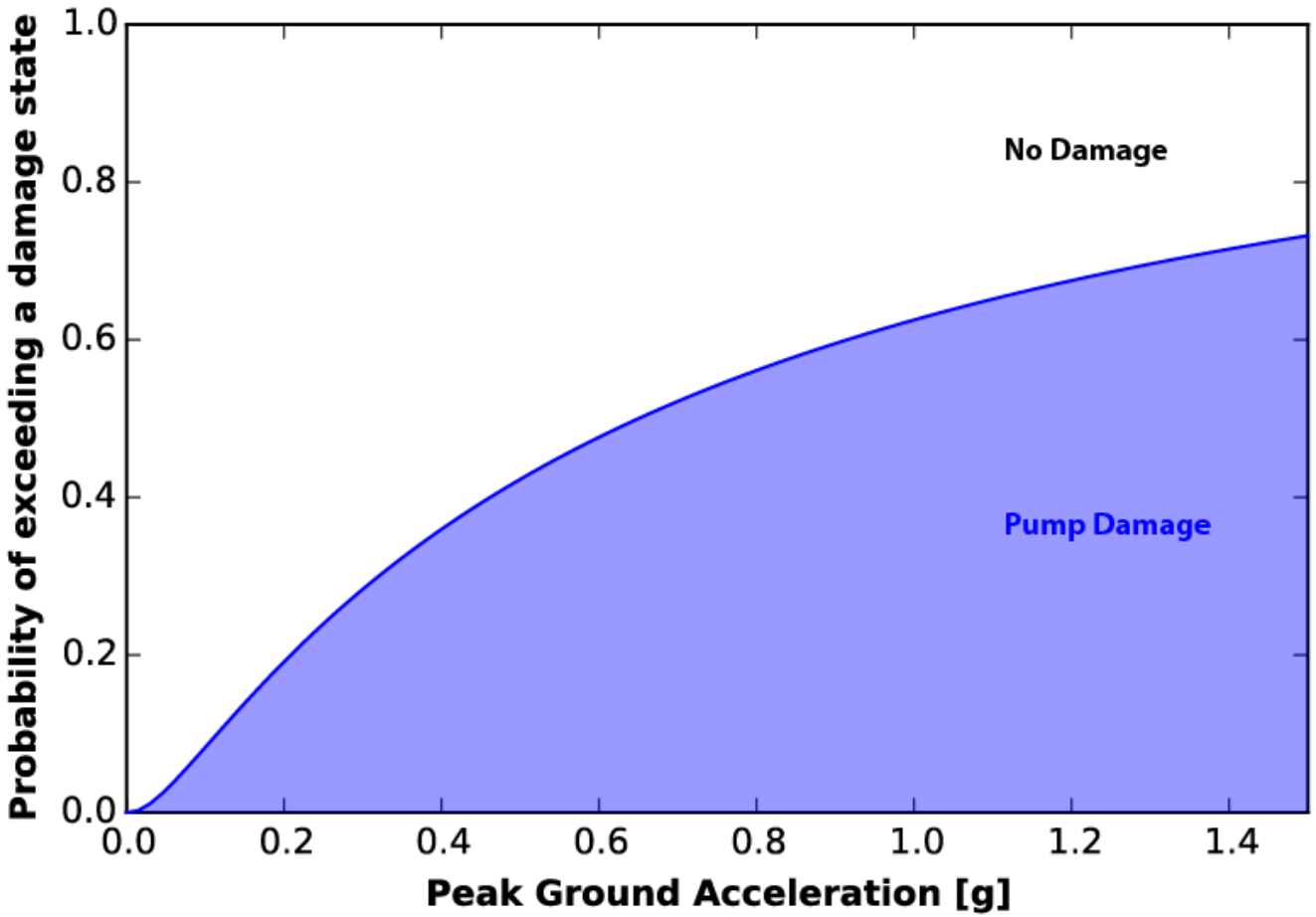
Input variables → Calculate damage states → Hydraulic simulation & repairs → Output results

Damage State – Tanks



Input variables → Calculate damage states → Hydraulic simulation & repairs → Results

Damage State – Pumps



Input variables → Calculate damage states → Hydraulic simulation & repairs → Results

WNTR

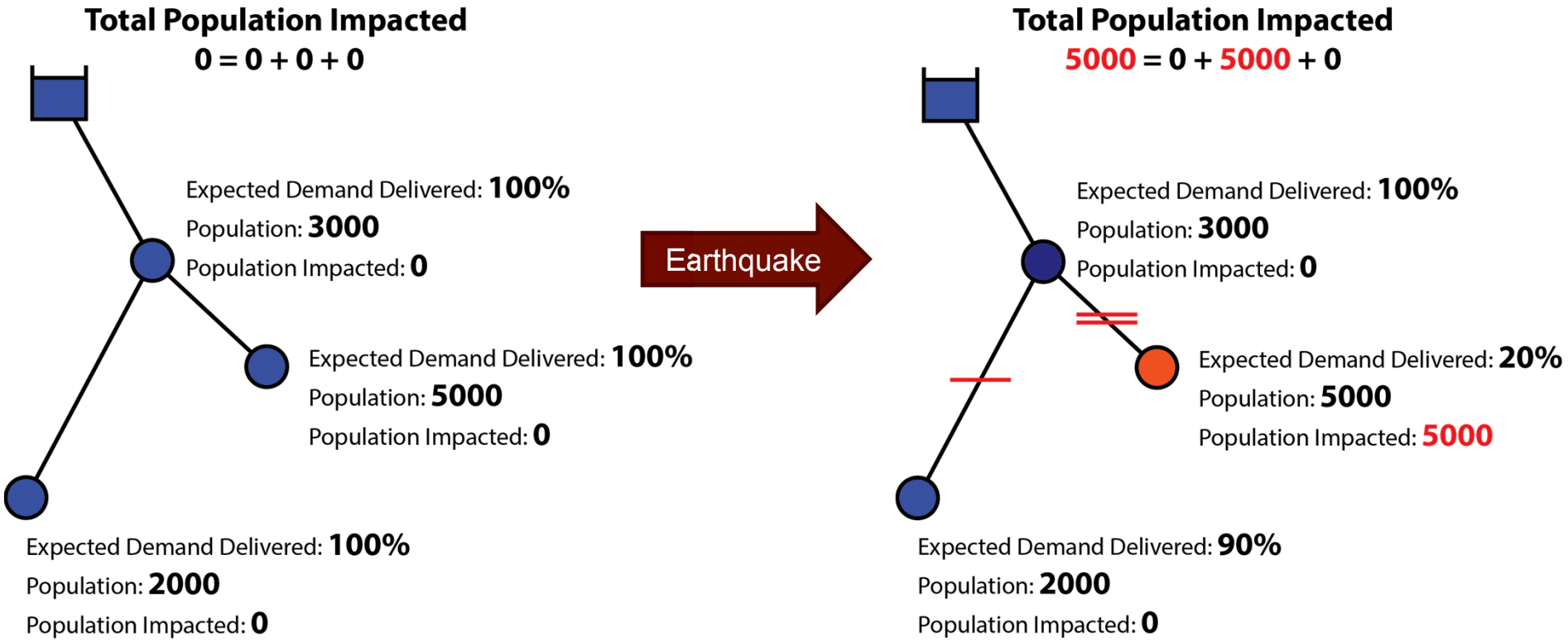
Sandia National Laboratories

- Water Network Tool for Resilience (WNTR)
  - Pressure driven demand simulator
- Can add and repair leaks on the fly

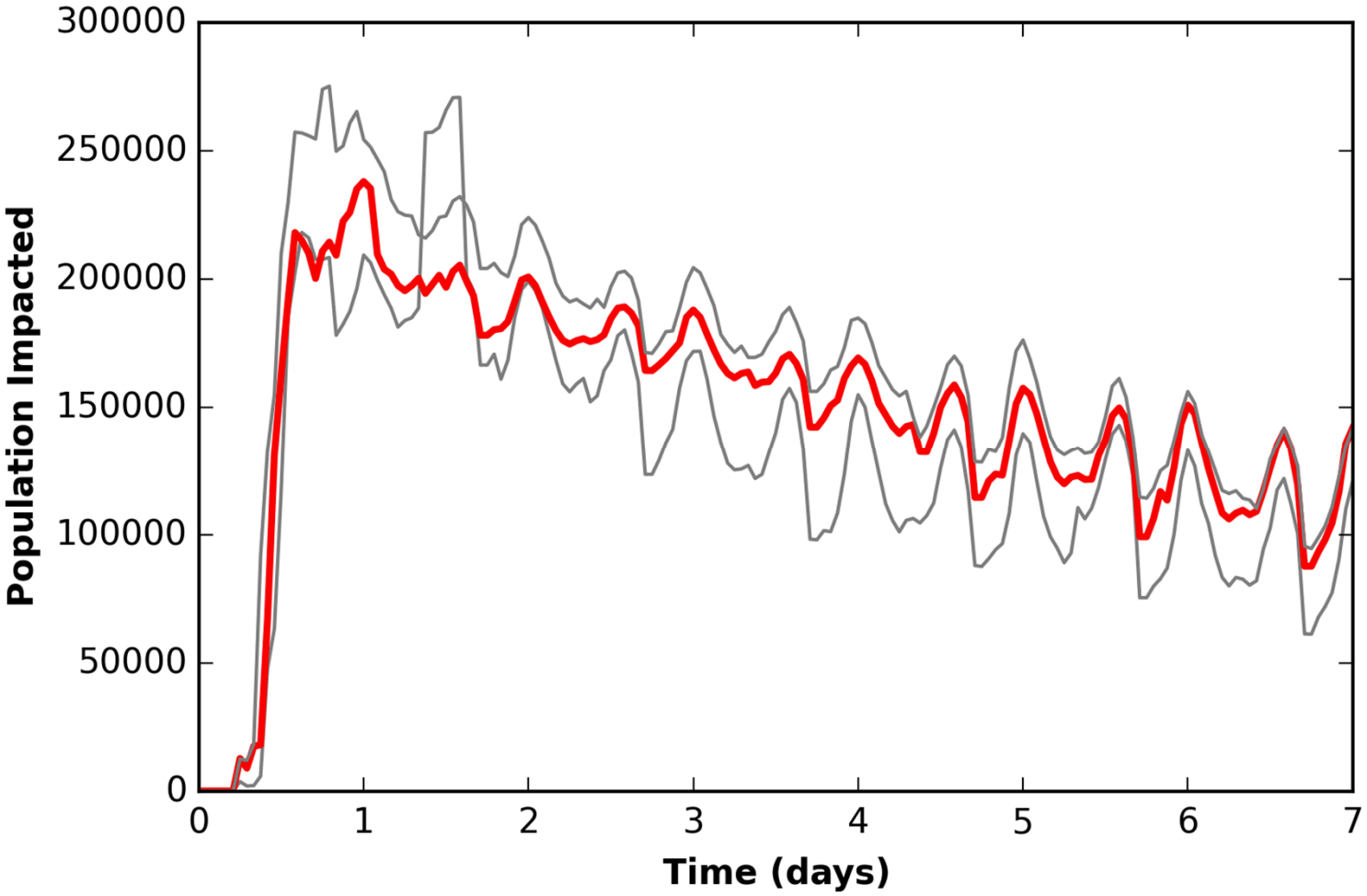
	Pipes	Tanks	Pumps
Adding Leaks / Damage	Single pipe change to two pipes with leak node in middle	Leak demand is added to tank node	Pump is turned off
Repair Leaks / Damage	Two adjacent pipes are isolated, leak node is removed	Leak demand is removed from tank node	Pump is turned on
Repair Prioritization	Greatest amount leaked	Greatest amount leaked	Nearest to reservoir

Results – Metrics

- Population Impacted
  - If a node does not receive 80% of expected demand the population at that node is considered impacted

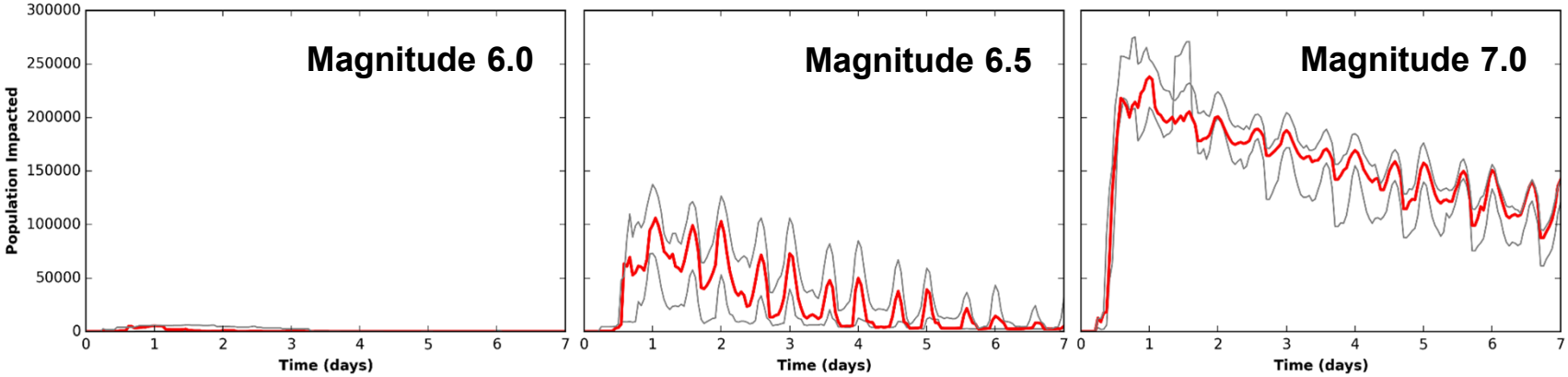


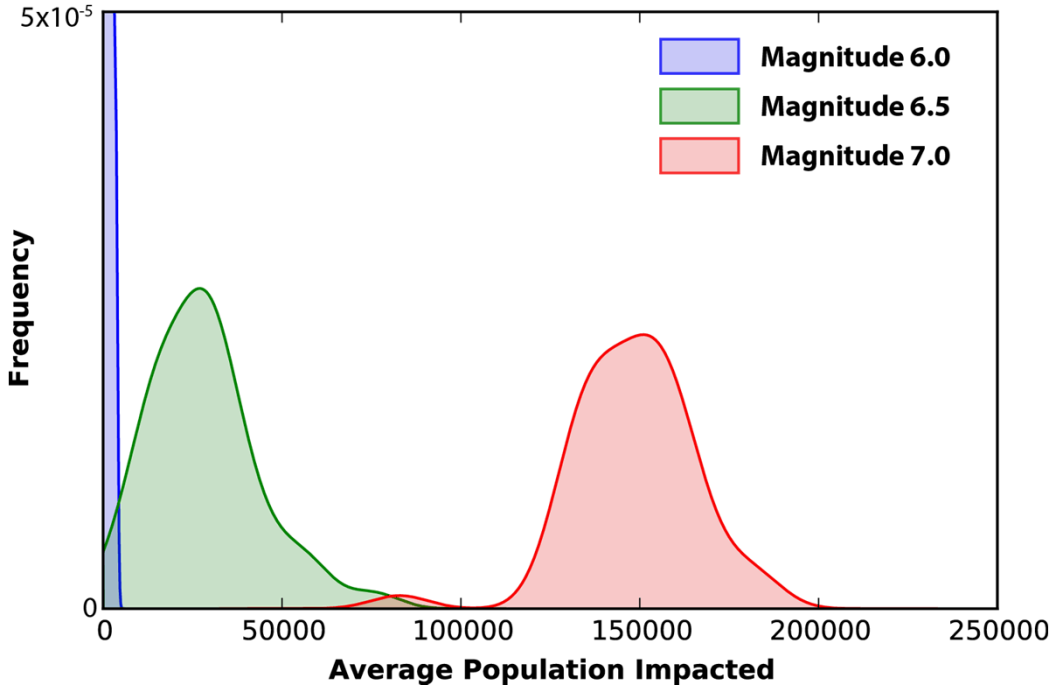
Results – Example



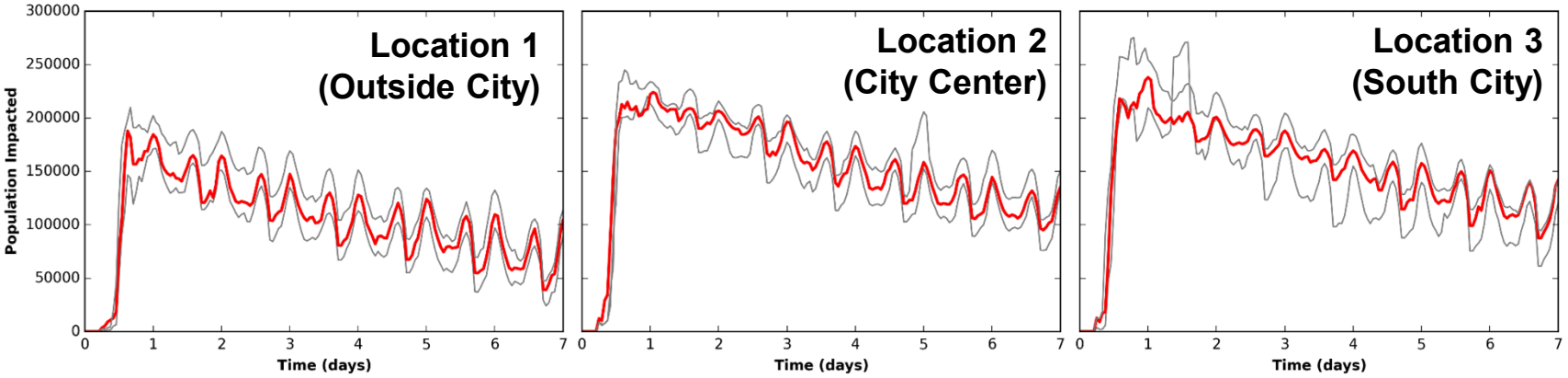
Magnitude 7.0 earthquake at Location 3 (South City)

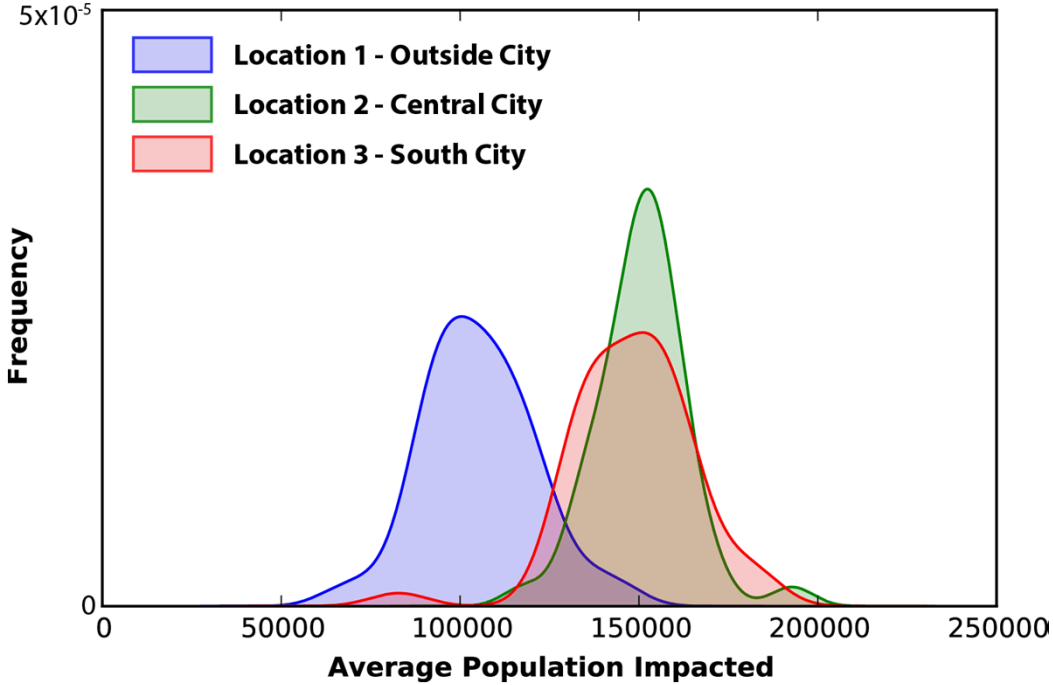
Results – Effect of Magnitude



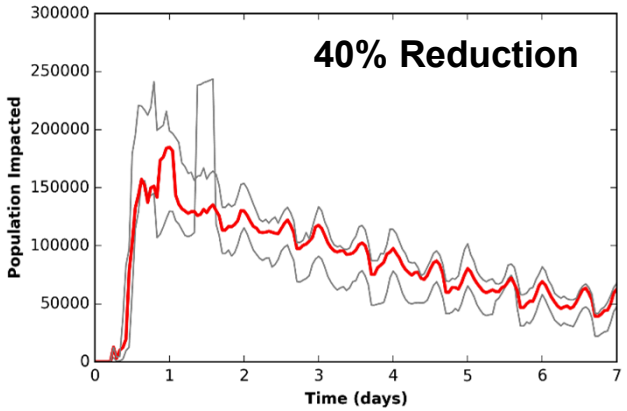


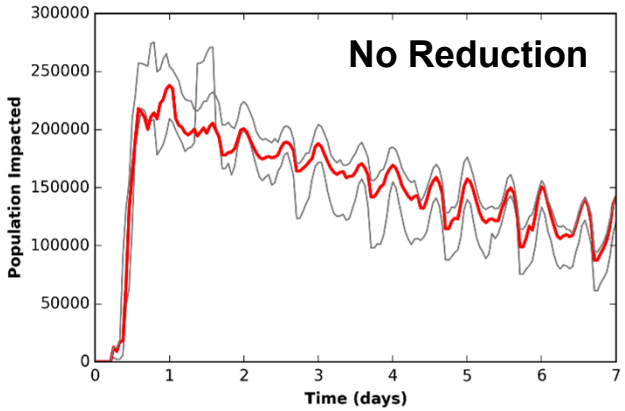
Results – Effect of Location

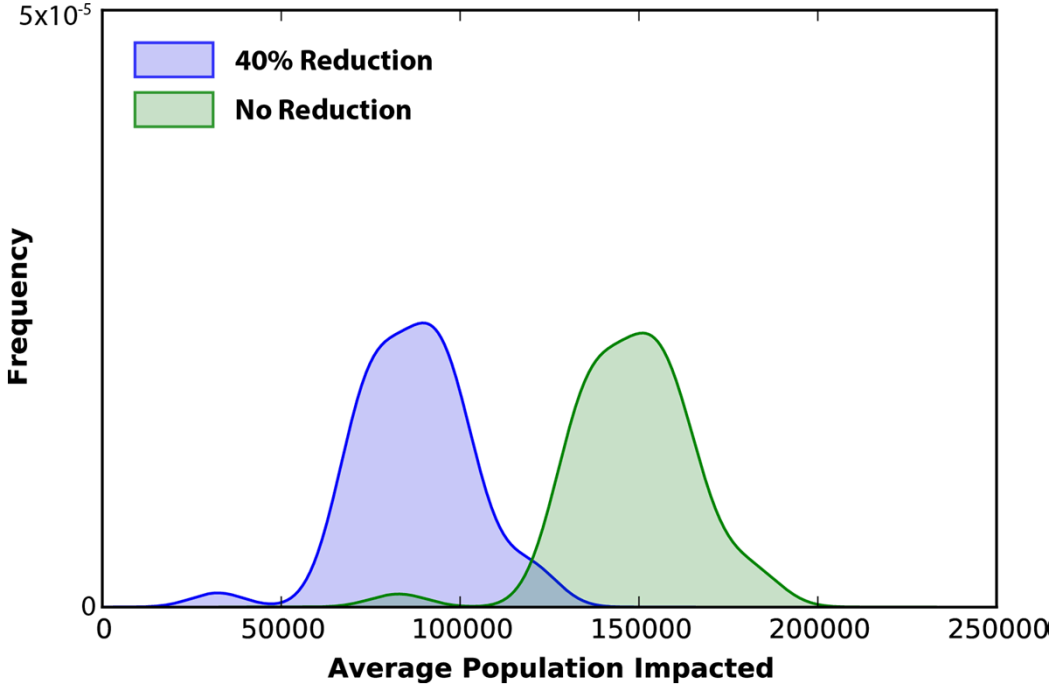




Results – Effect of Conservation







Next Steps

Sandia National Laboratories

- Continue development of robust pressure driven demand simulator
- Determining impact of each variable
  - Rank importance of each factor
  - Identify critical infrastructure
- Optimizing response based on available resources
  - Bringing in extra crews
  - Retrofitting/replacing certain pipes
- Pilot study with partner utility

Sandia National Laboratories

Dylan Moriarty
dmmoria@sandia.gov

QUESTIONS?