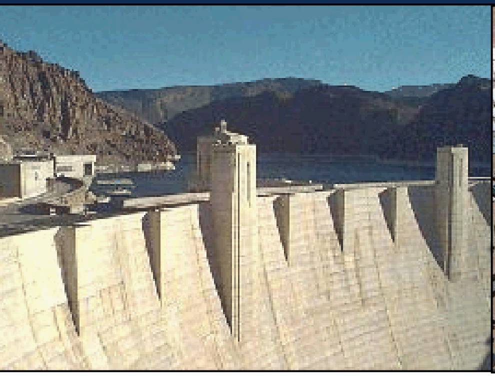
SAND2016-4660PE

Exceptional service in the national interest

Sandia National Laboratories




Infrastructure Risk Assessment

Sandia National Laboratories
Albuquerque, NM

May 5, 2016

U.S. DEPARTMENT OF ENERGY

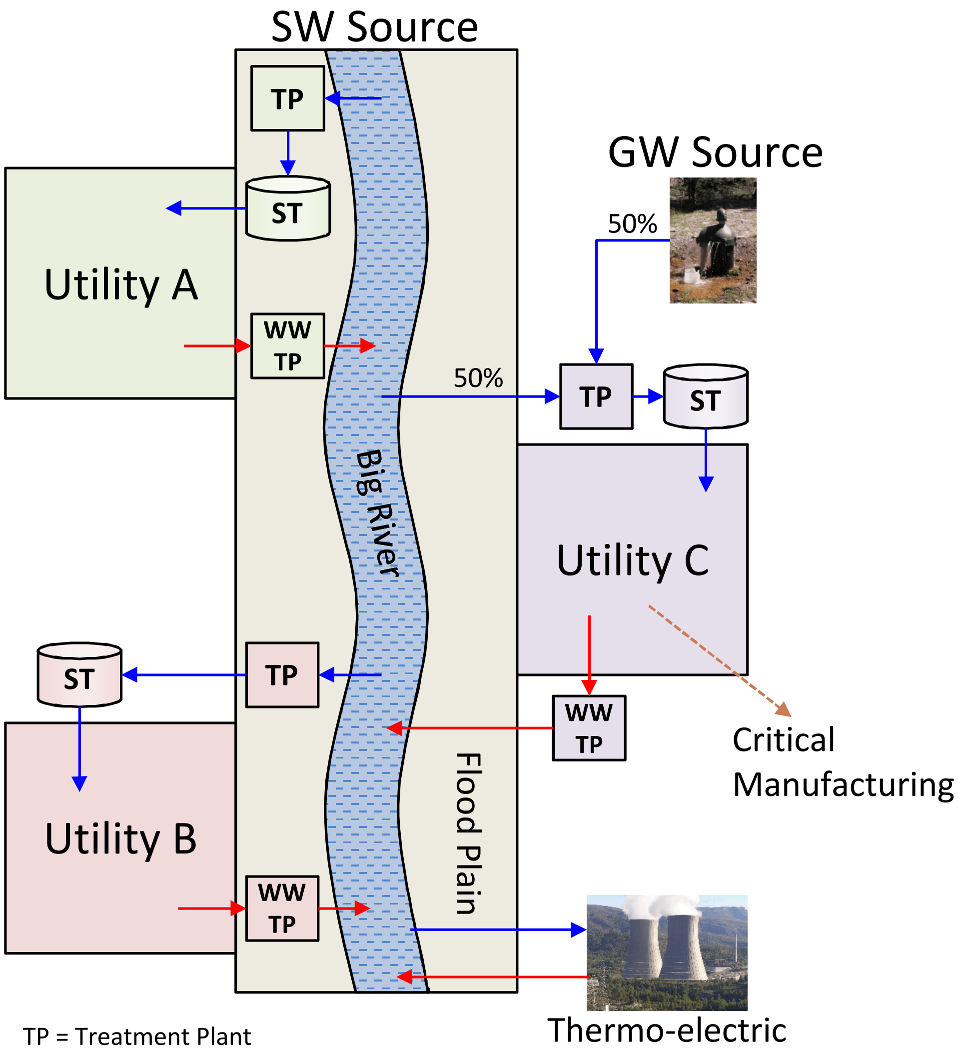
NNSA National Nuclear Security Administration

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.

Introduction

- Drinking Water Resiliency Project (DWRP)
- Impacts of Disruptions to Liquid Fuels Infrastructure
  - National Transportation Fuels Model (NTFM)
- Other Relevant Capabilities
  - Dependencies modeling and visualization
  - Resilience quantification
  - Climate Infrastructure Impact Modeling

DWRP – Project Concept

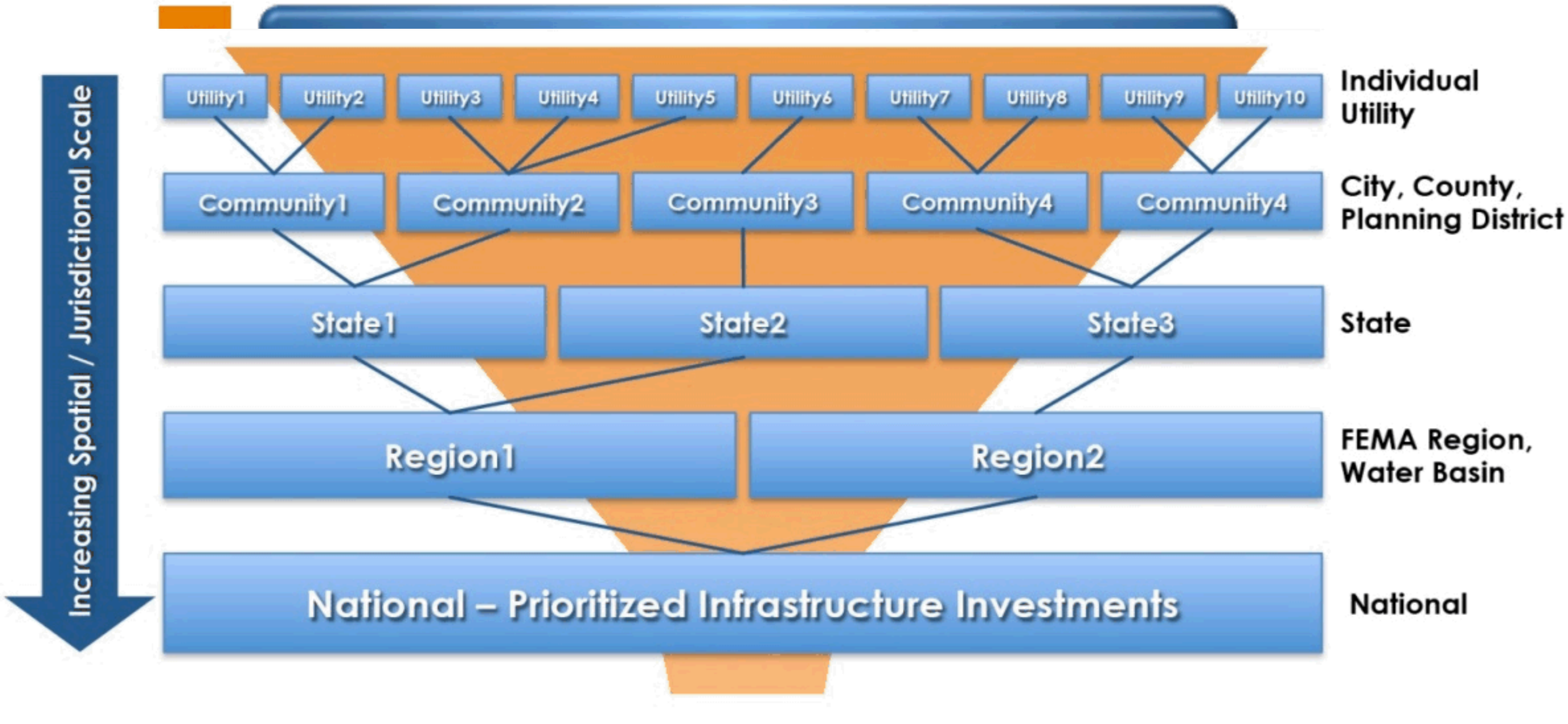


TP = Treatment Plant
WWTP = Waste Water Treatment Plant
ST = Storage Tank

- Develop framework for rapid risk assessment and analysis:
  - Easy access to relevant data, maps, etc. that have been screened
  - Graphical interface to identify assets and visualize risks for different hazards
  - Imbedded algorithms / computational tools for calculating risk, cost-benefit analysis, etc.
  - Fast and cheap for utilities to use

- Extension platform:
  - 'Roll-up' individual assessments to local, regional, and national scales
  - Rank and prioritize risks and investment areas
  - Include a wide range of hazards and infrastructure
  - Identify and link shared risks at local, regional, and national scales
  - Provides consistent and comparable basis for risk analysis

Drinking Water Resiliency Project



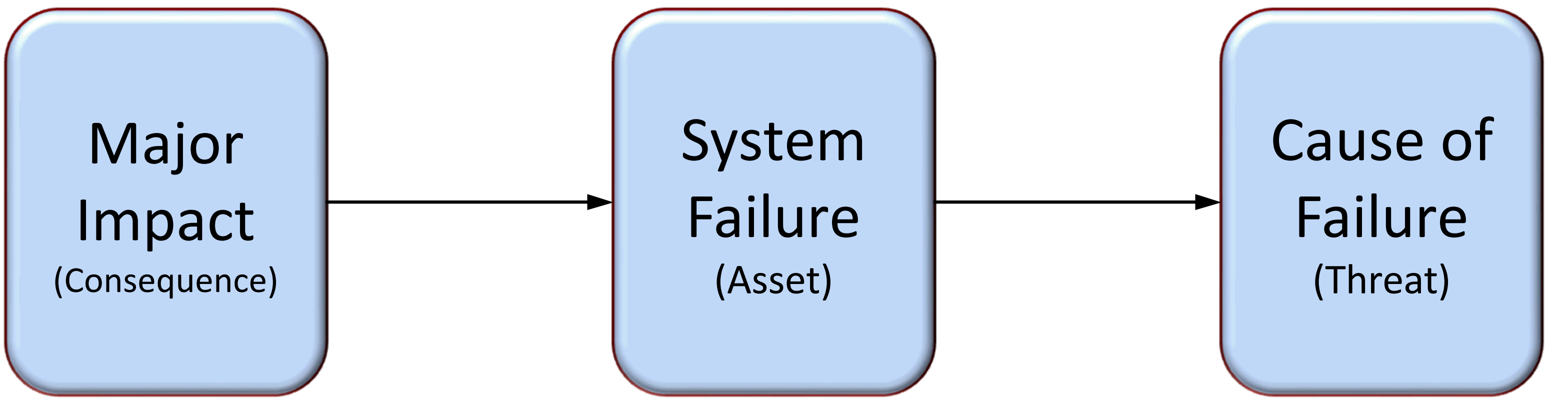
Prioritized Infrastructure Investments

The risk framework enables data-rich, tool & model-enhanced assessments of the health (ability to provide vital & necessary services) and future capabilities of lifeline infrastructures and communities. At every level, *ACTION ITEMS* are prioritized and funded within each jurisdiction's ability, means and jurisdiction--based on risk calculations and other factors.

ORPHAN ACTIONS—those too costly or broad in scope filter to the national scope for prioritization & reporting at the Executive level.

Drinking Water Resiliency Project

Begins w/ Major Impacts/Consequences



- Impact/System (DWRP) vs. Asset/Threat (J-100)
- Rapid ‘Systems Level’ Risk Assessments
- ‘Normalized’ for Direct Comparisons

Impact Categories

- Community Disruption Costs
  - Cost to community due to interruptions to normal operations
- Health and Safety
  - Deaths & illnesses
- Financial
  - Lost revenue
  - Repair costs
  - Other costs

Only look at major impacts

Impact Consequences

Impact Category	Consequence
Community Disruption Costs	$outage\ time \times PUD \times PDS \times \frac{GDP}{day}$ PUD = % unmet demand, PDS = % demand served
Health Costs	$\#Deaths \times SVL + \#Ill \times SVI$
Financial	$LR + RC + OC$ LR = lost revenue = PUD * PDS * daily service * rate * outage time RC = repair cost OC = other cost

Threats and Systems

Scaled from J100

Threats

- Aging Infrastructure
- Contamination
- Direct Attacks
- Human Error
- Loss of Employees
- Loss of Suppliers
- Loss of Utilities
- Loss of Customers
- Natural
  - Drought
  - Earthquake
  - Flood
  - Hurricane
  - Ice Storm
  - Tornado
  - Tsunami
  - Wildfire
- Sabotage
  - Cyber
  - Physical
- Other

Systems

- Employees
- Finished Water Distribution
- Information Technologies
- Knowledge Base
- Maintenance and Administration
- Operations
- Raw Water Conveyance
- Source Water
- Source Water Infrastructure
- Storage
- Treatment
- Other

WURA

Risks | Countermeasures | Analysis

Delete | Edit

Risks		
	System Name	Threat
○	Reservoir 1	Contamination
●	Reservoir 1	Natural - Drought
○	Reservoir 1	Natural - Earthquake
○	Treatment Plant	Natural - Earthquake
○	Reservoir 1	Natural - Flood
○	Treatment Plant	Natural - Flood
○	Treatment Plant 2	Natural - Flood
○	Reservoir 1	Direct Attacks

Risk

* System: Source Water

* System Name: Reservoir 1

* Replacement Value ($1000's): 50000.0

* % Demand Served: 100.0

Description: The reservoir in the hills

* Threat: Natural - Drought

Description:

Impacts for Risk: Reservoir 1 / Natural - Drought

Severity	Probability	Vulnerability	Outage Time	# Deaths	# Illnesses	# Exposed	Other Costs ($1000's)
D2	0.1	0.2	60.0	0	0	0	3000.0
D3	0.05	0.05	0.0	0	0	0	0.0
D4	0.02	0.002	0.0	0	0	0	0.0

Cancel | Submit

Risks | Countermeasures | Analysis

Delete | Edit

	Countermeasure	Risk	
	Name	System Name	Threat
○	none	Reservoir 1	Natural - Earthquake
○	none	Reservoir 1	Contamination
○	none	Reservoir 1	Natural - Flood
○	none	Reservoir 1	Direct Attacks
○	none	Treatment Plant	Natural - Flood
○	none	Treatment Plant	Natural - Earthquake
○	none	Treatment Plant 2	Natural - Flood
○	CM 2	Treatment Plant 2	Natural - Flood
○	none	Reservoir 1	Natural - Drought
○	new supply	Reservoir 1	Contamination
●	new supply	Reservoir 1	Natural - Drought

Countermeasure

* Countermeasure Name: new supply

Description: The new values for System: Source Water and Threat: Natural - Drought

Cost ($1000's): 1000000.0

Delete Selected Risk | Edit Selected Risk | Add Risks

Risks Mitigated

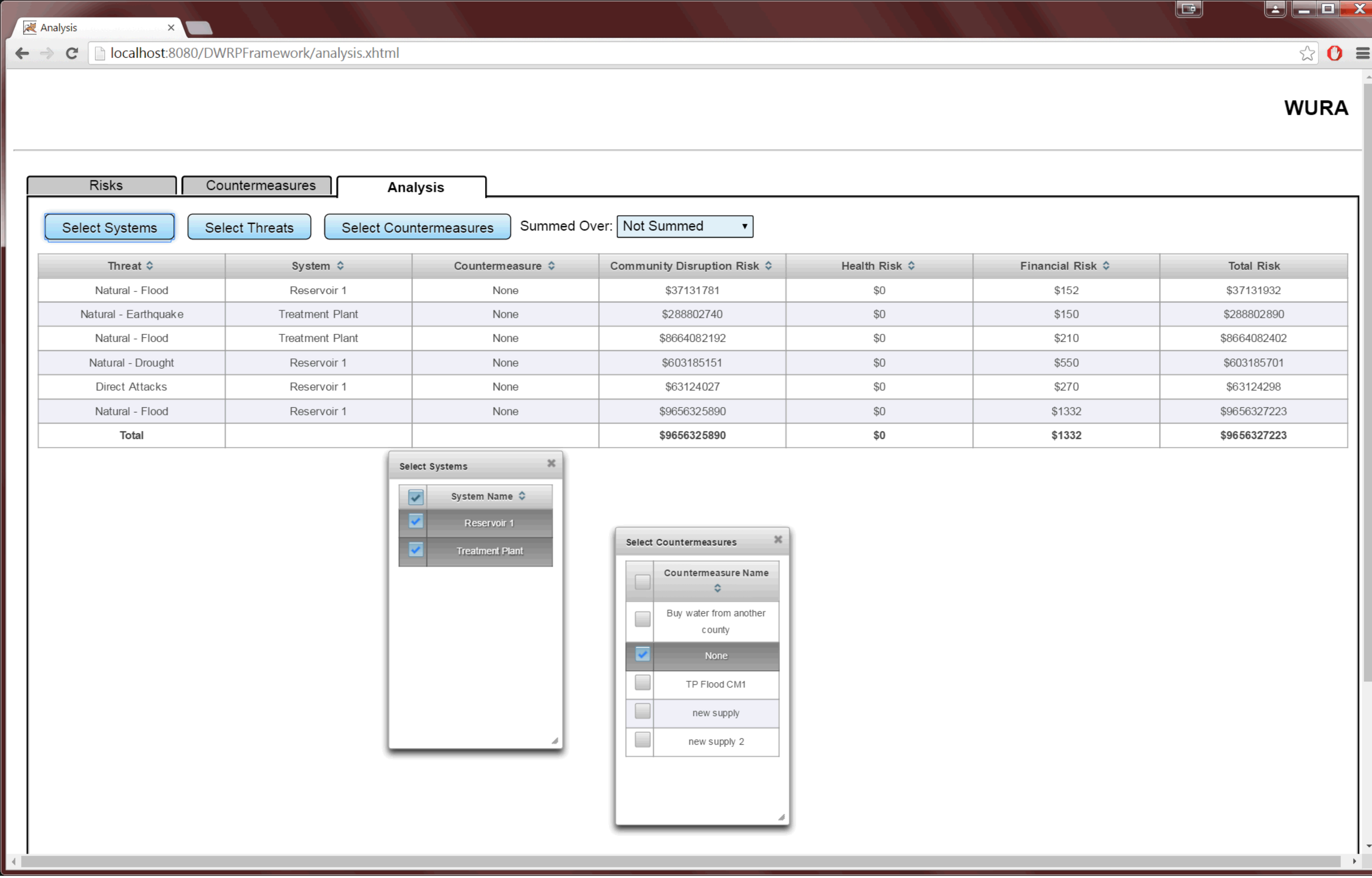
	System Name	Threat
○	Reservoir 1	Contamination
●	Reservoir 1	Natural - Drought

Cancel | Submit

New Impacts for Risk: Reservoir 1 / Natural - Drought

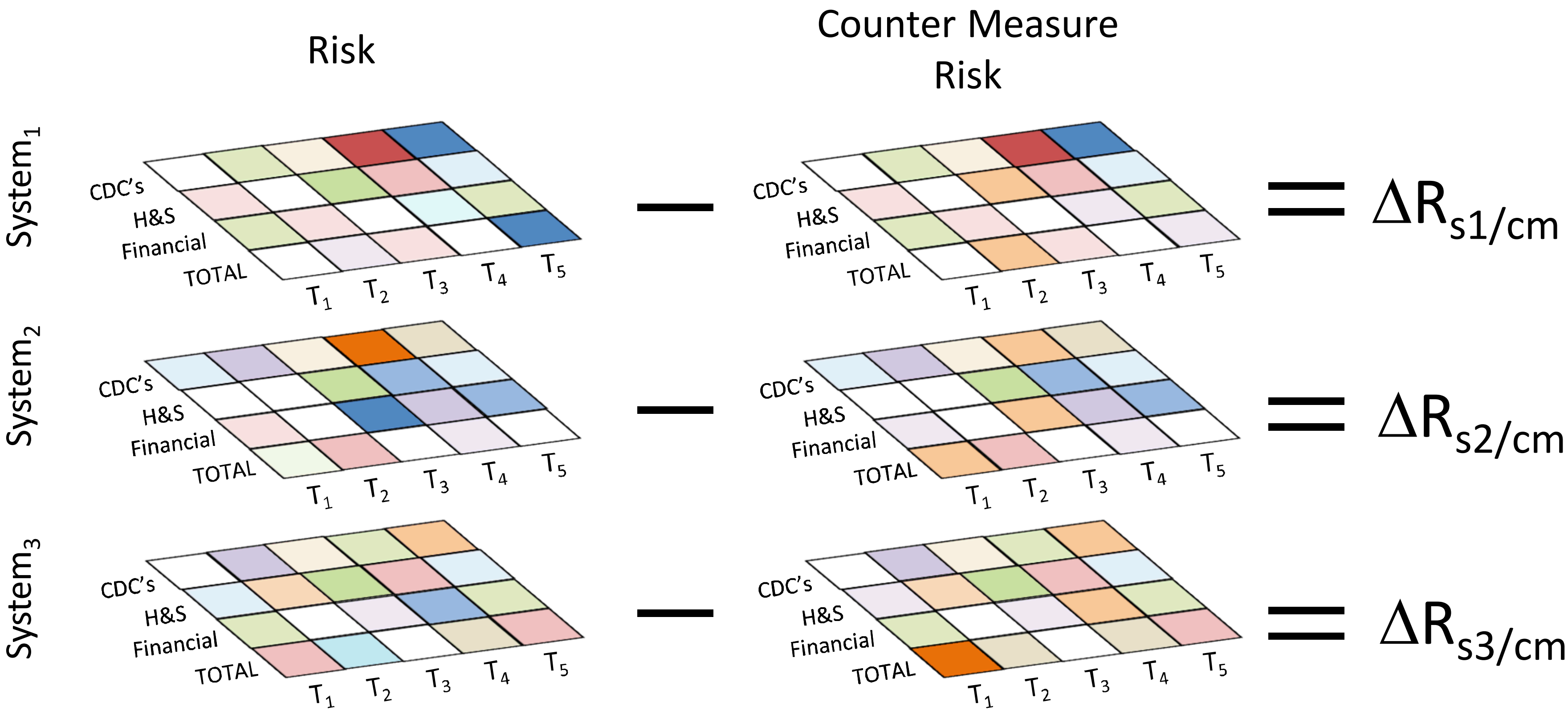
Severity	Probability	Vulnerability	Outage Time	# Deaths	# Illnesses	# Exposed	Other Costs ($1000's)
D2	0.1	0.2	60.0	0	0	0	3000.0
D3	0.05	0.05	0.0	0	0	0	0.0
D4	0.02	0.002	0.0	0	0	0	0.0

Cancel | Submit



Threat	System	Countermeasure	Community Disruption Risk	Health Risk	Financial Risk	Total Risk
Natural - Flood	Reservoir 1	None	$37131781	$0	$152	$37131932
Natural - Earthquake	Treatment Plant	None	$288802740	$0	$150	$288802890
Natural - Flood	Treatment Plant	None	$8664082192	$0	$210	$8664082402
Natural - Drought	Reservoir 1	None	$603185151	$0	$550	$603185701
Direct Attacks	Reservoir 1	None	$63124027	$0	$270	$63124298
Natural - Flood	Reservoir 1	None	$9656325890	$0	$1332	$9656327223
Total			**$9656325890**	**$0**	**$1332**	**$9656327223**

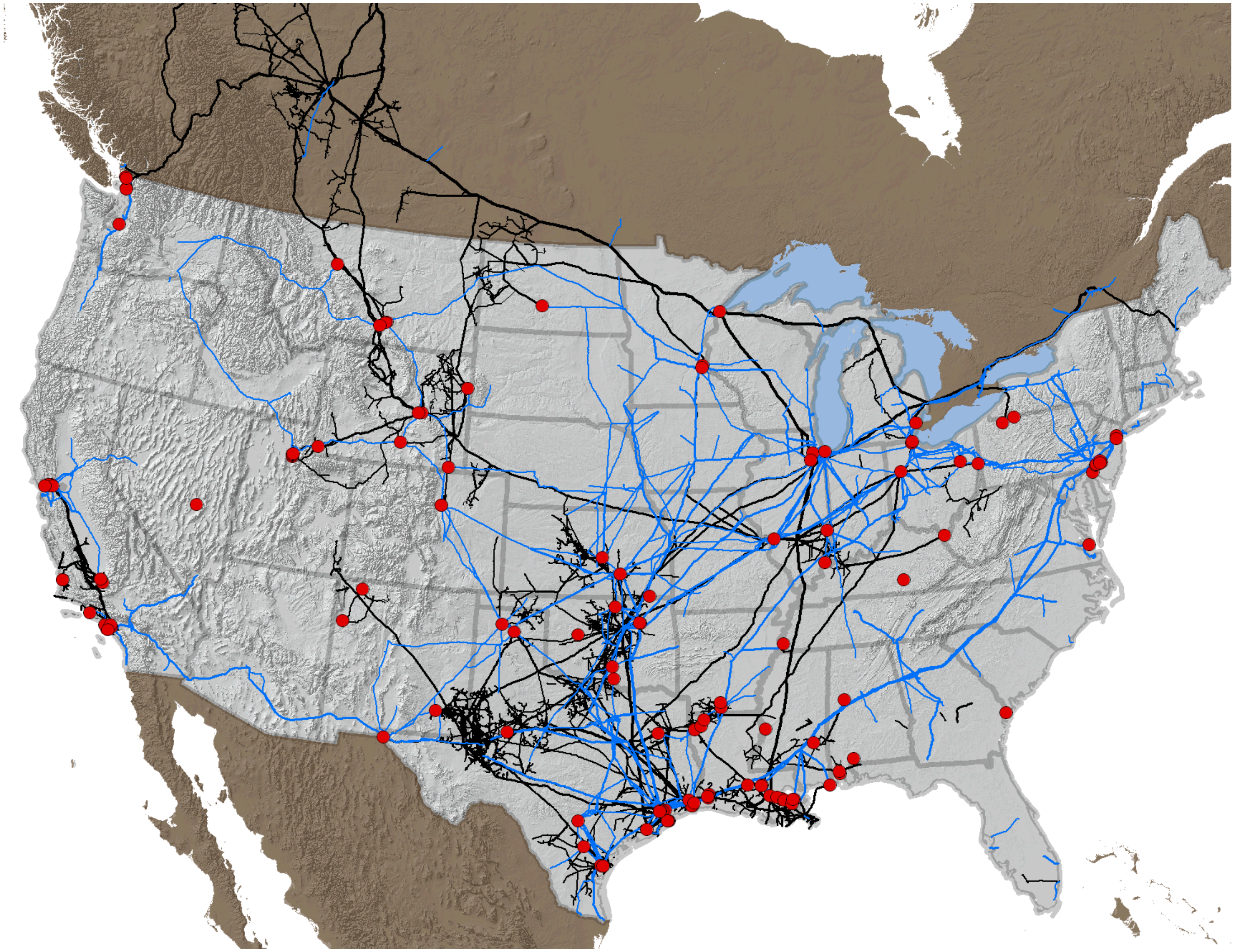
For Each System and Countermeasure



Example Decision Metric:

ΔR / $$ = Risk Improvement per $ spent

Transportation Fuels



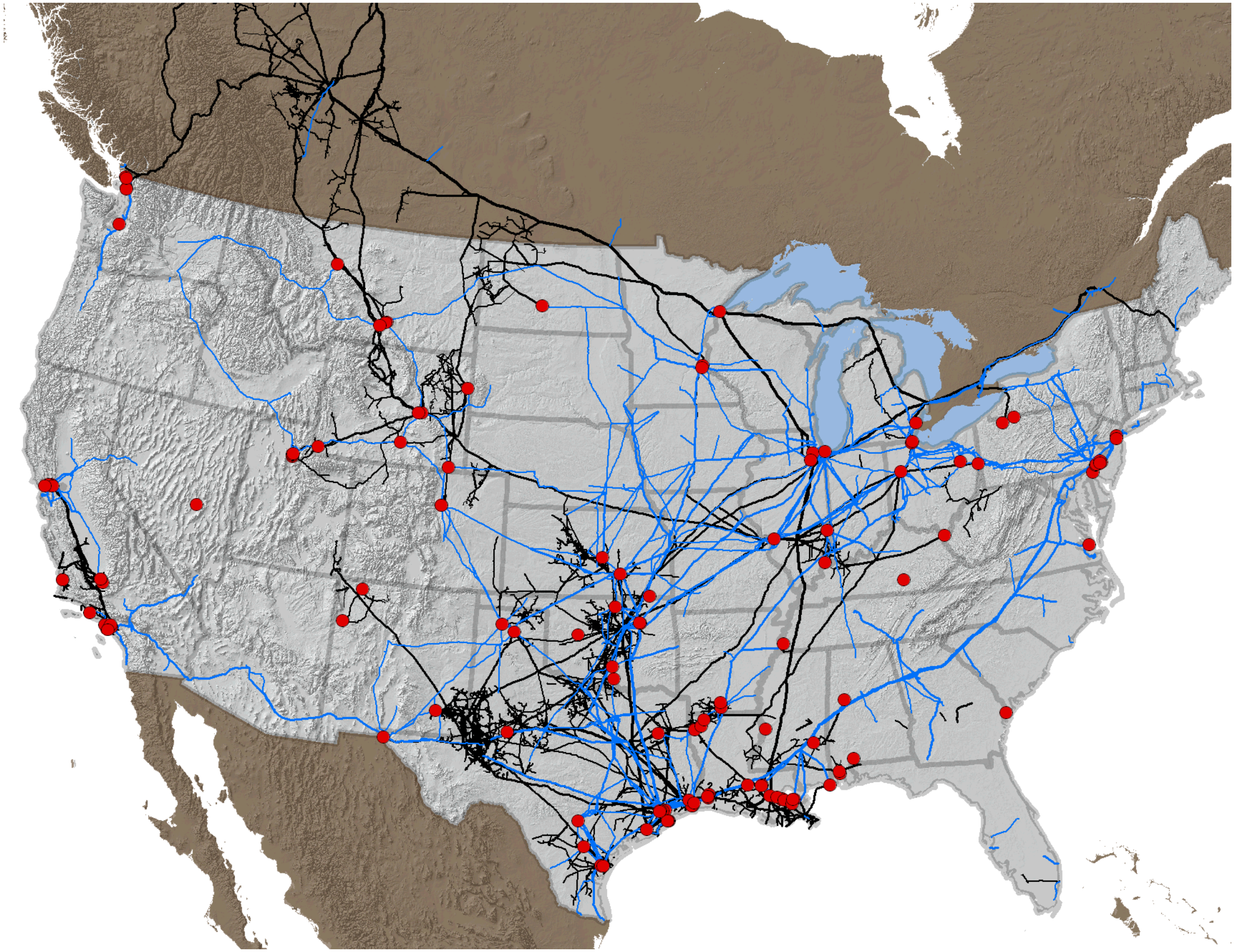
NISAC National Transportation Fuel Model

- Developed to give our petroleum analysts the capability to:
  - connect data from multiple sources in a internally-consistent and balanced representation to maximize understanding of the system-level operation
  - perform simulations of the system-level operation of the petroleum infrastructure under a wide range of disruption scenarios
- Designed to answer questions of the form:
  - Which regions of the United States would experience shortages of transportation fuel after a specified disruption to one or more components of the fuel infrastructure?
  - What would be the duration and magnitude of the shortages?

NTFM High Level Objectives

- Analysis of the *dynamics* and *consequence* of disruptions to US petroleum infrastructure
- Simulate:
  - Physical infrastructure capacity (refineries, pipelines, ports, oil fields, terminals)
  - Human decisions resulting in system-level adaption to disruption
    - Re-routing
    - Drawdown of storage
    - Use of surge capacity

North American Oil Infrastructure

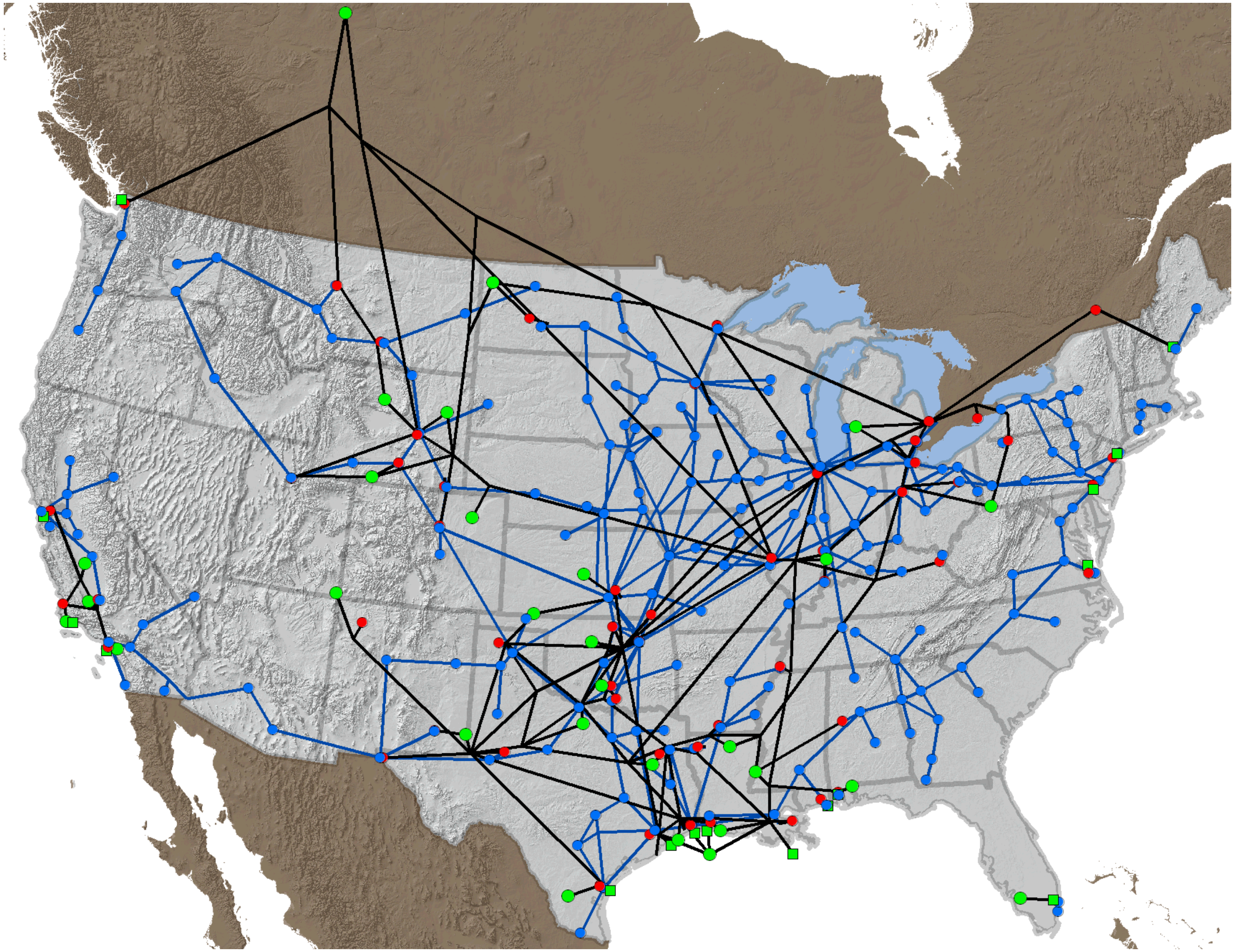


17

Network Model Description

- Market-driven Resilience Attributes minimize fuel shortages
  - Re-routing shipments
  - Drawdown of inventory
  - Use of surge capacity
  - Increasing imports
  - Reducing consumption
- Constrained by connectivity of the system and capacity of individual system components:
  - Pipeline flow
  - Refinery throughput
  - Tank Farm storage
  - Import terminal throughput

National Transportation Fuels Network Model



Some Model Assumptions and Limitations

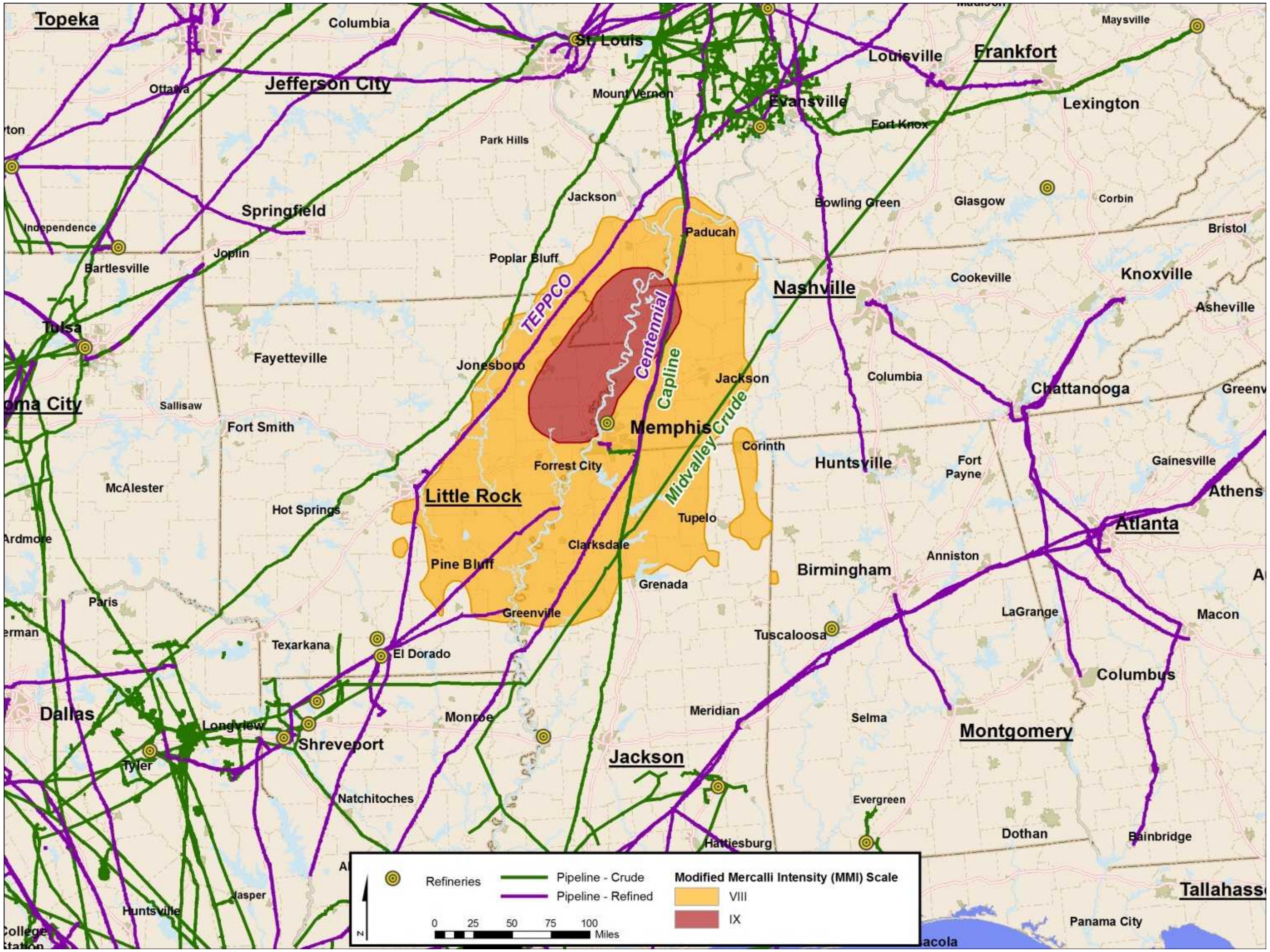
- Includes transmission system (pipelines, rail, water), but not distribution (trucks)
  - For example, the model does not know that fuel can't be delivered because roads are damaged
- Market behavior is based on fuel availability
  - No hoarding behavior (by consumers or suppliers)
  - No price increases until inventories decline

New Madrid: Extensive Damage is Likely

- The New Madrid Seismic Zone is the site of some of the largest historical earthquakes to strike the continental U.S.
- The last of these very powerful earthquakes occurred in the winter of 1811-1812
- Thick, unconsolidated, saturated sediments along the Mississippi River valley amplify shaking and could liquefy
- In the next 50 years, the New Madrid region faces a 7 to 10% probability of a repeat of the 1811 - 1812 type earthquakes

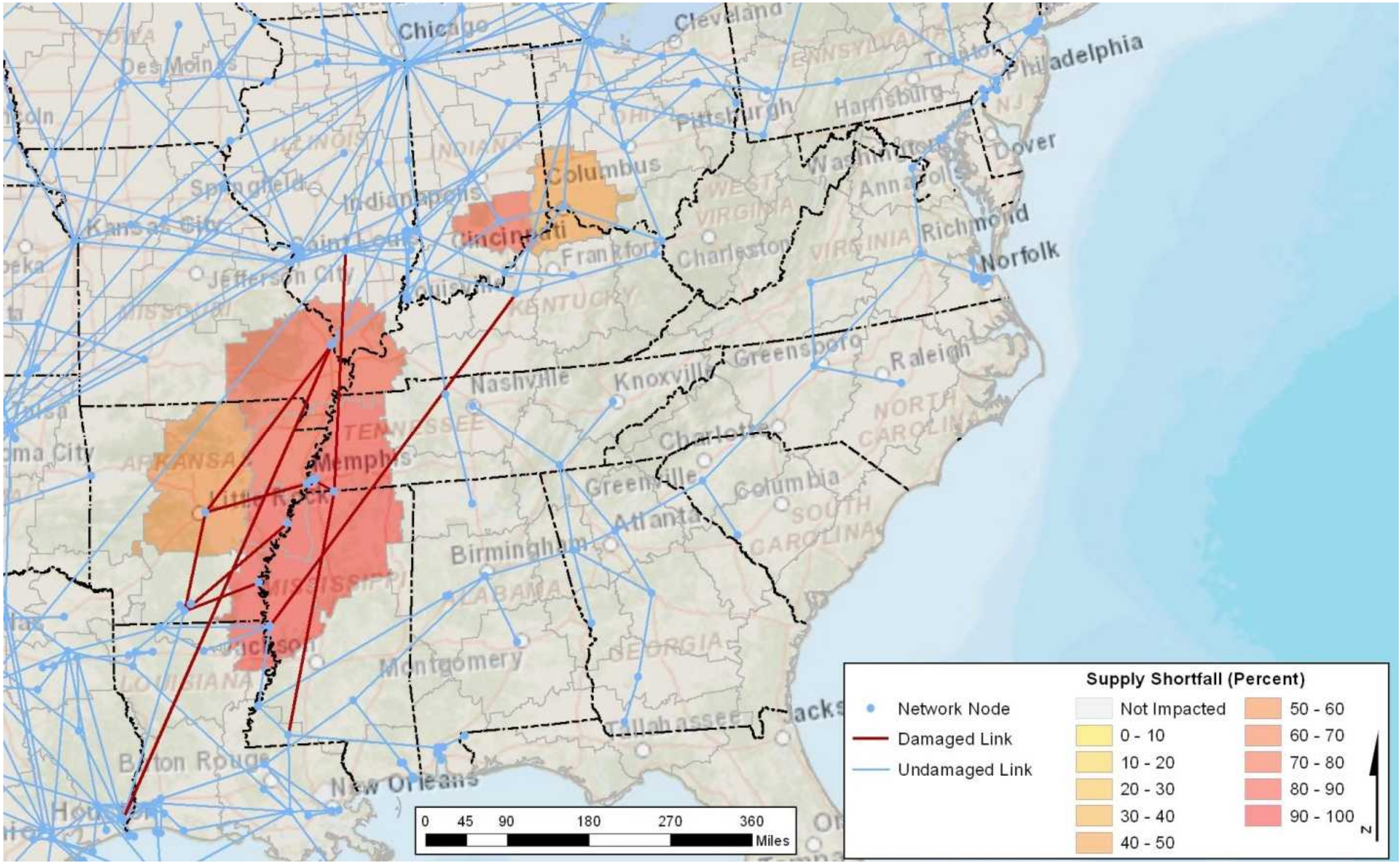
USGS, Center for Earthquake Research and Information Fact Sheet 2006-3125

Four Transmission Pipelines Could be Damaged by a New Madrid Earthquake

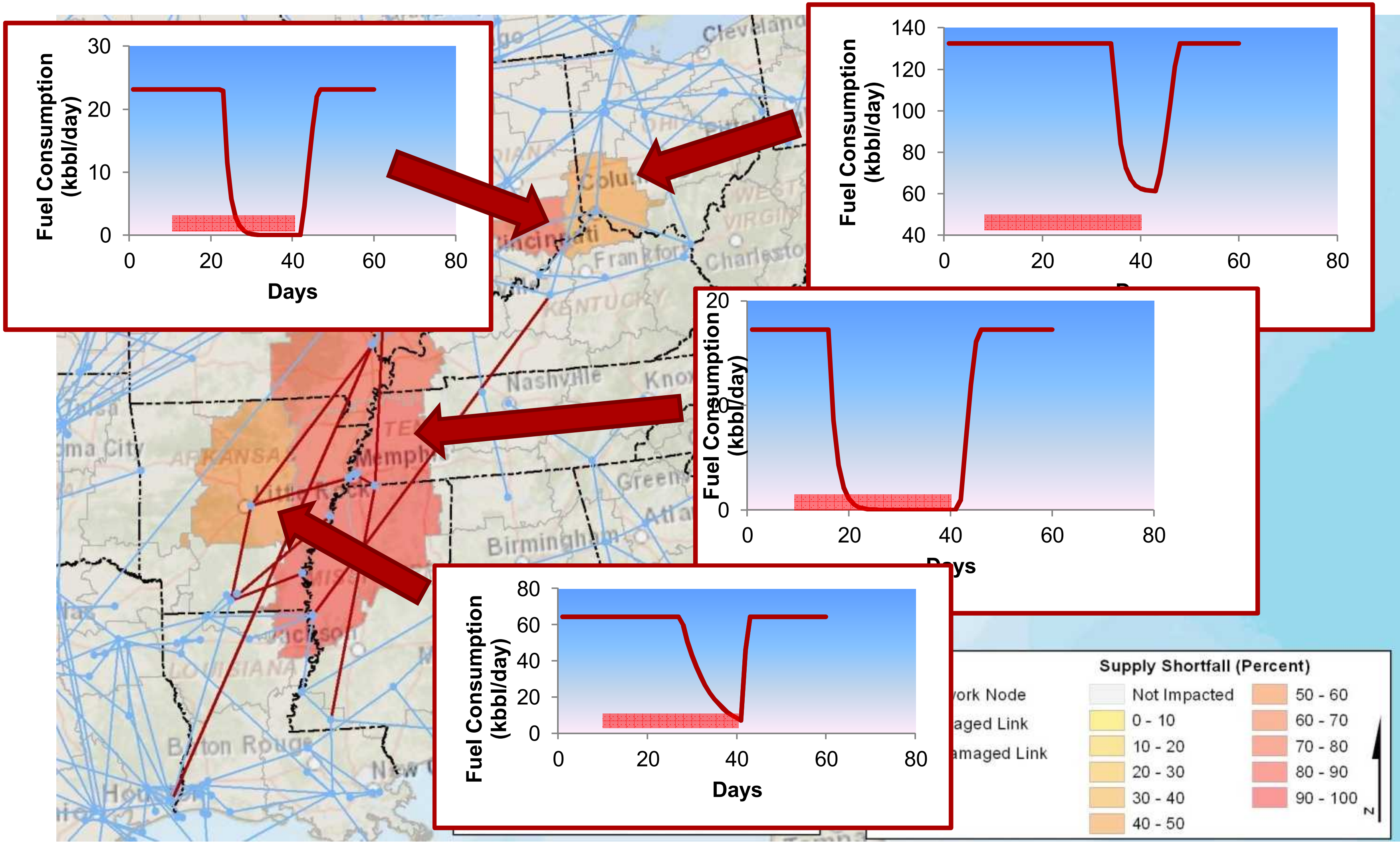


Calculated Consumption Shortfall of Fuel Due to a New Madrid Earthquake

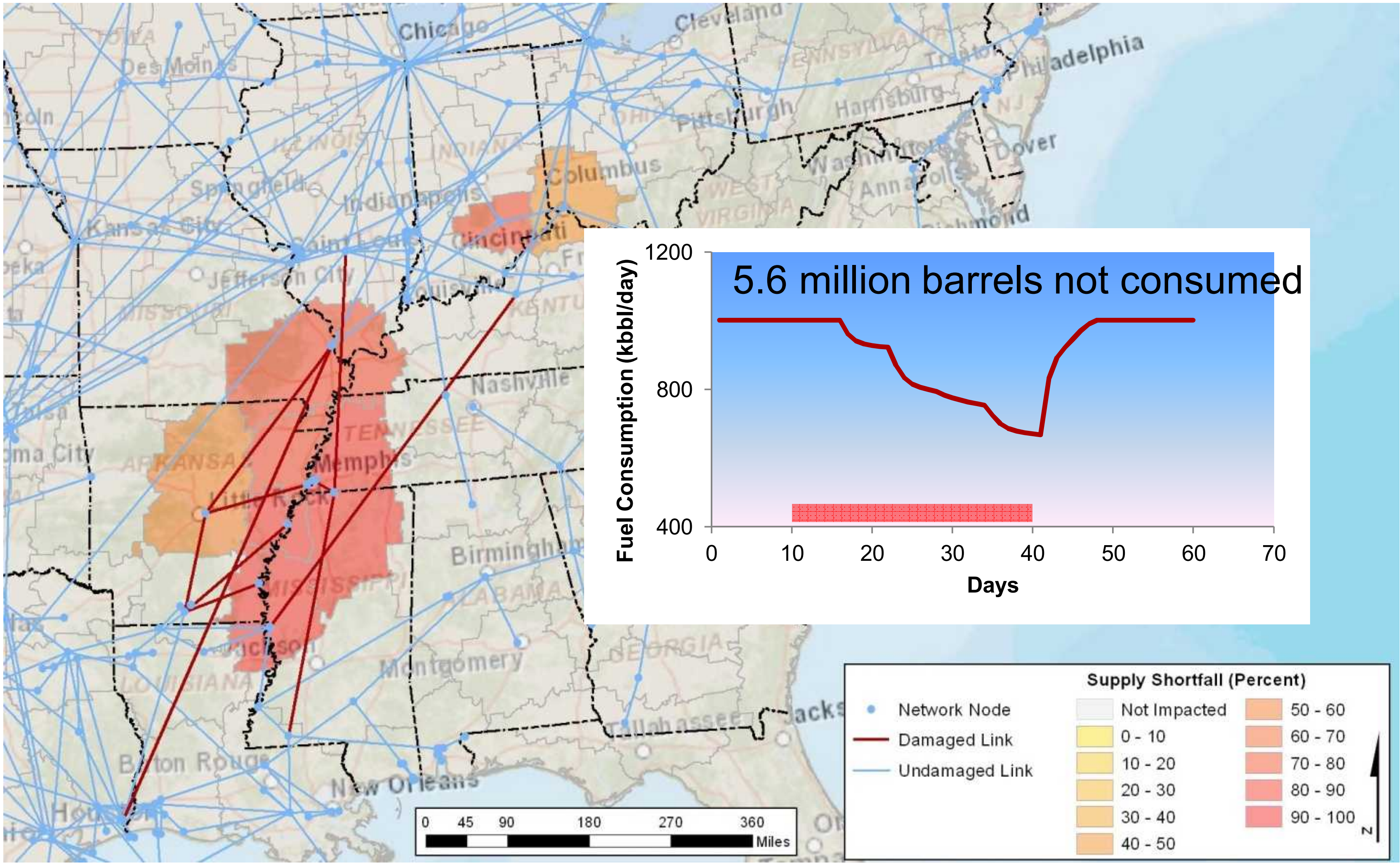
Sandia National Laboratories



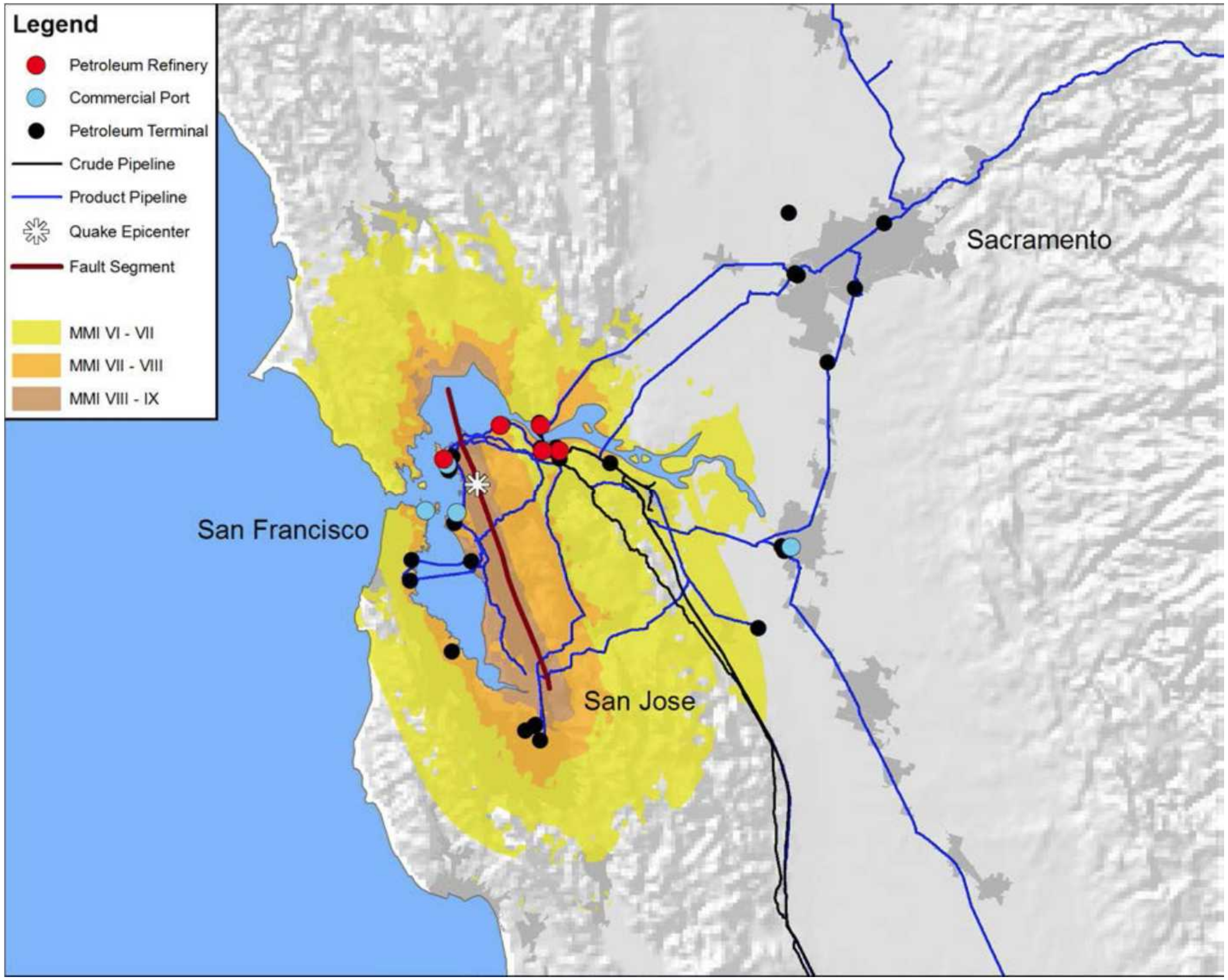
Calculated Consumption Shortfall of Fuel Due to a New Madrid Earthquake



Calculated Consumption Shortfall of Fuel Due to a New Madrid Earthquake



Hayward Fault: 7.0



Refineries, ports, pipelines, and terminals relative to shaking intensity

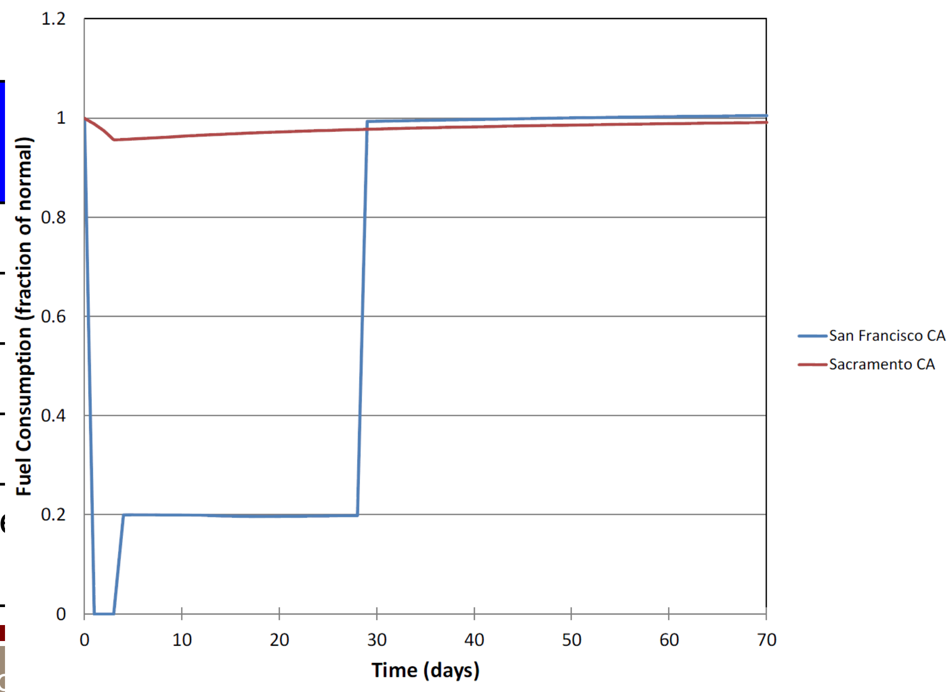
Wilson, M.L., Corbet, T.F., Baker, A.B., O'Rourke, J.M., 2015, Simulating Impacts of Disruptions to Liquid Fuels Infrastructure, Sandia National Laboratories, SAND2015-2696, April

Hayward Fault: 7.0

Sandia National Laboratories

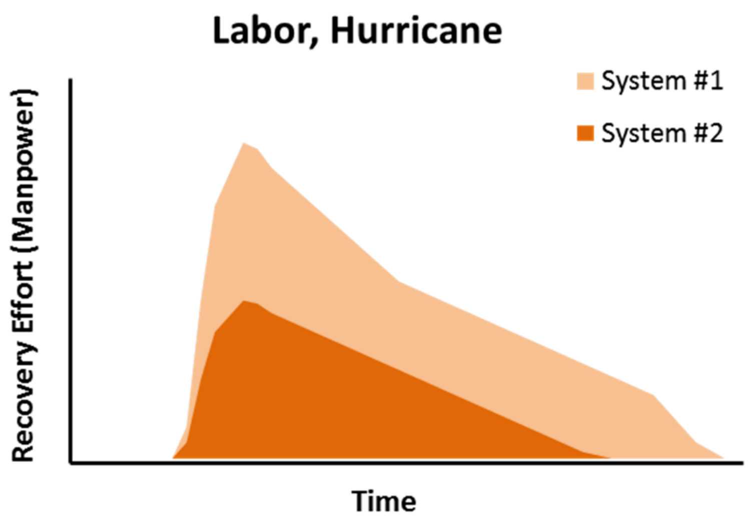
- Main damage is to refined product pipelines that cross the fault
- 70% of Bay Area refining capacity is east of the fault
- Pipelines crossing the fault out for 28 days
- Refineries out for 14 days
- Fuel consumption is 20% of normal

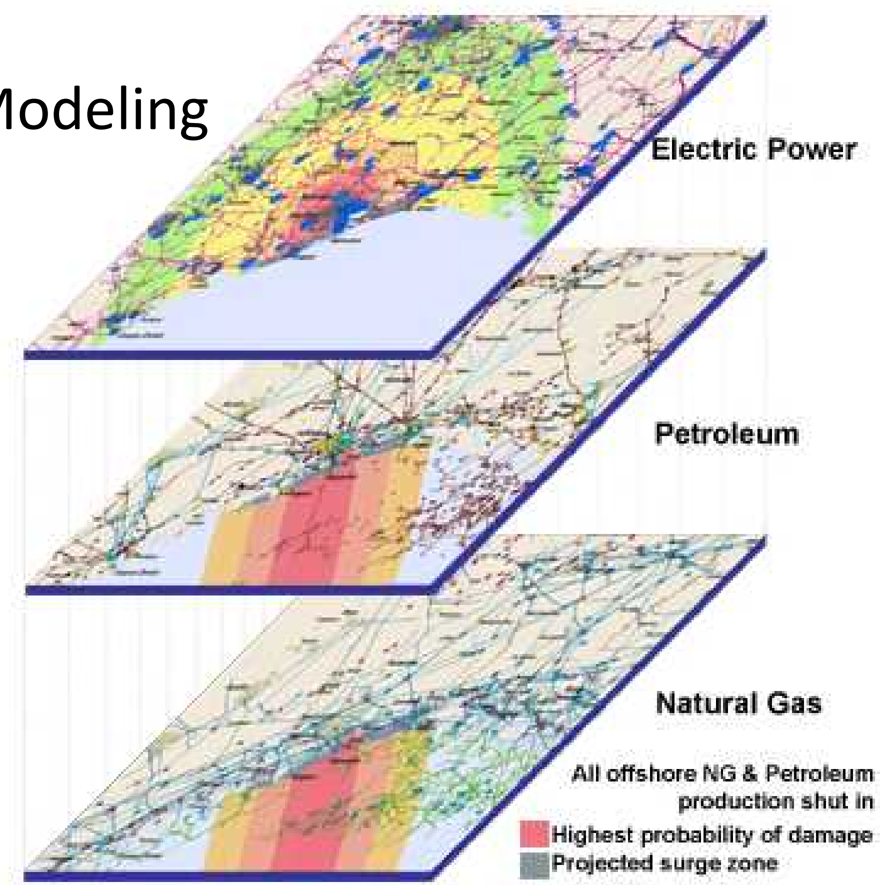
Refiner	Modified Mercalli Intensity Zone
Chevron USA Inc.	VII-VIII
Phillips 66 Co.	VII-VIII
Valero Refining Co.	VI-VII
Shell Oil Products, US	VI-VII
Tesoro Refining & Marke Co.	VI-VII



Other Capabilities

- Dependencies modeling and visualization
- Resilience Framework
- Climate Infrastructure Impact Modeling





Dependencies Modeling

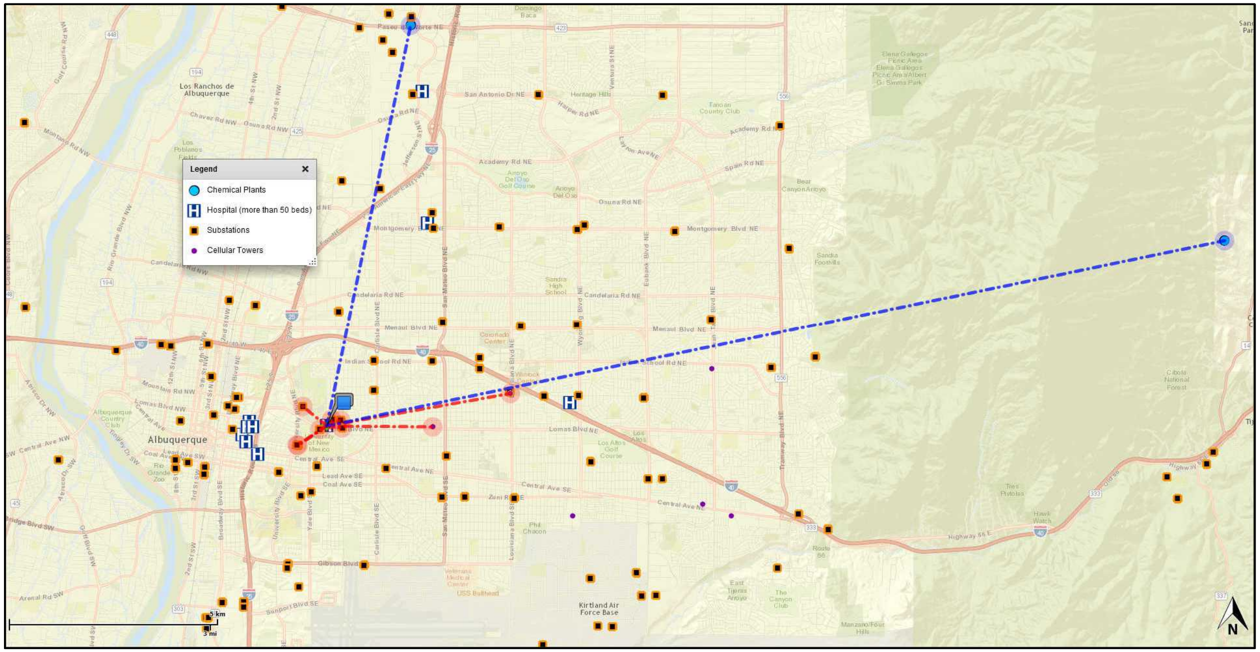
- What is it?
  - An interactive graphical analysis tool that assists in identifying upstream and downstream asset dependencies
- Value
  - Allows RAPID understanding of infrastructure dependencies
  - Uses very flexible FASTMap environment.
  - Analysts can tailor with local knowledge that would override or supplement the rulesets.
- Features
  - Visualize dependencies for infrastructure assets across infrastructure sectors
  - Visualize potential infrastructure assets of concern
  - Visualize essential support to emergency services
  - Reporting

Dependencies Modeling

- Current status
  - Infrastructure sectors:
    - Model includes chemical, energy (electric power, petroleum, natural gas, nuclear), communications, and emergency services.
    - Model does not include all asset classes for these sectors but does include many asset classes for other sectors.
- Intended use:
  - For analysts supporting OCIA crisis response and planned analyses.
  - Supplement to the analytic process.
- Value
  - Allows analysts RAPID understanding of infrastructure dependencies
  - Uses very flexible FASTMap environment.
  - Analysts can tailor with local knowledge that would override the rulesets

Example: UNM Hospital – Regional Trauma Center

APPLICATION OF RULES AS APPLIED TO THE UNIVERSITY OF NEW MEXICO HOSPITAL IN ALBUQUERQUE



- Select asset. Flag shows selection of University of NM Hospital, regional trauma center.
- Upstream dependencies: Red lines and red halos around assets
  - Hospital potentially dependent on a set of substations and two cell towers.
- Downstream dependencies: Blue lines and blue halos
  - Two chemical plants potentially depend on the hospital.

Resilience Framework

- What is it?
  - A set of definitions that provide the context for infrastructure resilience metrics and analysis
    - Key among the definitions is a formal mathematical definition of resilience
  - A process for creating sector-specific resilience metrics that centers on estimating infrastructure consequences due to a disruptive event
    - Systemic impacts – cumulative consequence from decreased output
    - Total recovery effort – Cumulative cost of responding and recovering
  - Provides a general set of infrastructure attributes to quantify resilience, determine infrastructure weaknesses, and identify opportunities to increase resilience

Capacities	Prepare	Withstand	Adapt	Recover
Example Infrastructure Attributes	Advance warning	Robustness	Rerouting	Mutual Aid Agreements
	Prepositioning	Redundancy	Substitution	Situational Awareness
	Stockpiling	Storage	Rationing	Resource Availability
		Separation	Reorganization	

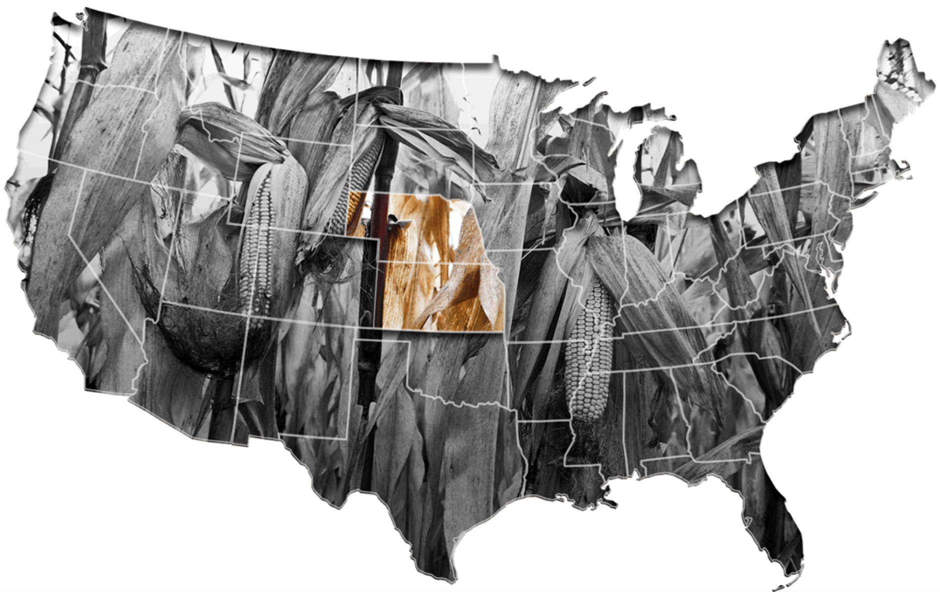
General Infrastructure System Attributes Affecting Resilience

Resilience Framework

- Value
  - Assess resilience of infrastructures prior to acute disruptive events
  - Inform decision making
    - Policy – how to direct, local, regional, state, and national strategies
    - Planning – whether to inform capital investments
    - Operational – informing real-time decision making
  - Optimizable
- Applications – Case Studies
  - Electric power – Deciding between two different system improvements
  - Oil pipeline networks – Reassessing system resilience after changes
  - Natural gas - Set policy for 'use rules' of assets in emergencies to maximize resilience

Climate Infrastructure Impact Modeling

- What is it?
  - An approach to understand the implications of climate change on integrated infrastructure
  - Deterministic or ensemble approaches
- Value
  - Evaluate risk and vulnerability
  - Inform decision making
  - Determine what infrastructures are most affected
- Applications
  - High Plains / Ogallala
  - San Juan



Key Analytical Questions

How will climate variability and groundwater depletion impact agricultural production in the High Plains?

- *Reduced yields*
- *More dryland farming*

How do current water practices affect groundwater depletion?

- *Changes in groundwater level and supply*

Which economic activities are vulnerable to groundwater depletion?

- *Farming and livestock*
- *Agriculture support*
- *Food manufacturing*
- *Animal processing*

What are the local, regional, & national economic impacts of ground water depletion?

- *Farm exit*
- *Loss of irrigated acreage*

What are the affected Critical Infrastructures?

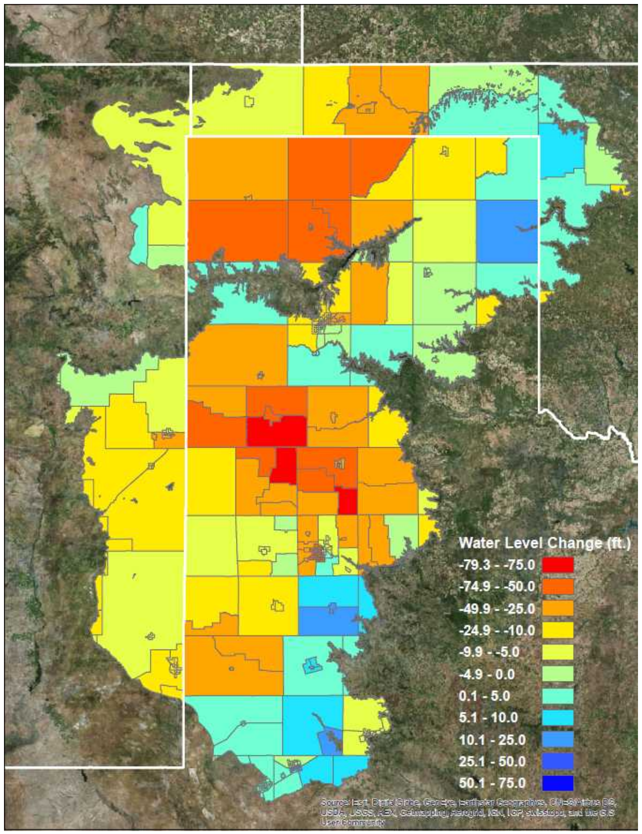
- *Food and Agriculture*
- *Water and Wastewater*
- *Chemical (Ethanol)*
- *Energy (Ethanol)*

Sandia National Laboratories

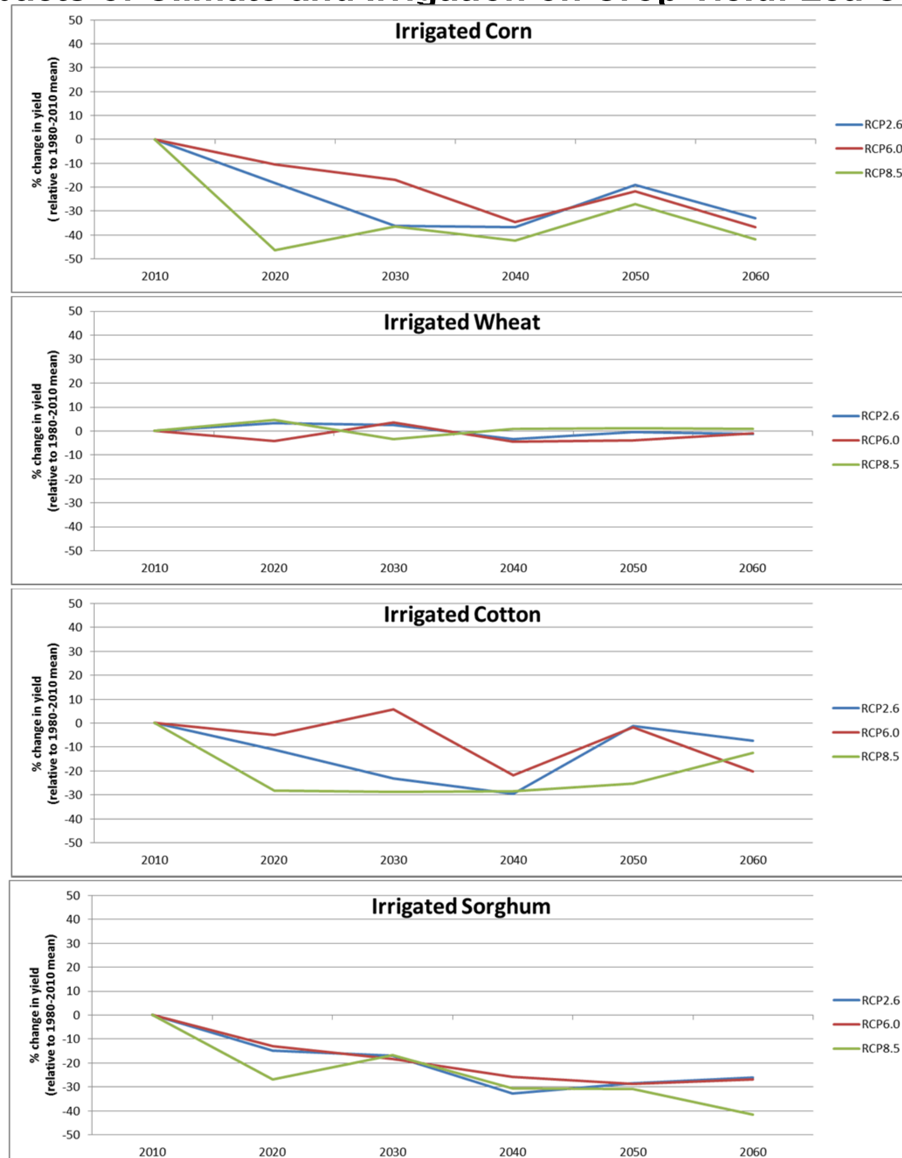
High Plains Resource Risk Phase 2
Region VI – Texas, New Mexico, and Oklahoma

Sandia National Laboratories

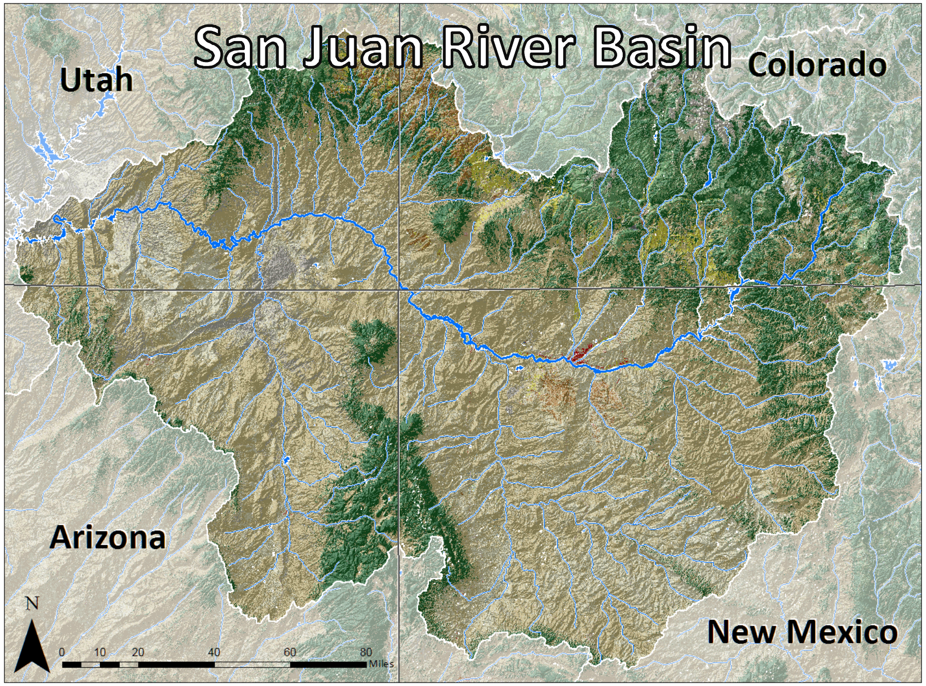
Projected Groundwater Depletions



Impacts of Climate and Irrigation on Crop Yield: Lea County,



San Juan River Project



Partners: *National labs, industry, federal agencies*

- Questions:
  - Impact of climate change and disturbance on San Juan inflows.
    - Static vegetation
    - CMIP5 vegetation change
    - Integrated disturbance
  - Changes to deliveries for:
    - San Juan Power Plant
    - Four Corners Power Plant
    - Hydropower production
    - Oil and gas development
    - Competing needs
  - How best can the system adapt:
    - Technology options
    - System operations