Argonne NATIONAL LABORATORY

… for a brighter future

New Madrid and Wabash Valley Seismic Study: Assessing the Impacts on Natural Gas Transmission Pipelines and Downstream Markets by Using "NGFast"

"

Prepared for:

FEMA Region V New Madrid Seismic Zone Planning Workshop

Indianapolis, IN

February 24, 2009

Presented by:

Edgar Portante, Steve Folga, Shabbir Shamsuddin, Michael McLamore, Leah Talaber, Vic Hammond, Jim Kavicky, and Brian Craig

Argonne National Laboratory, Argonne, IL USA

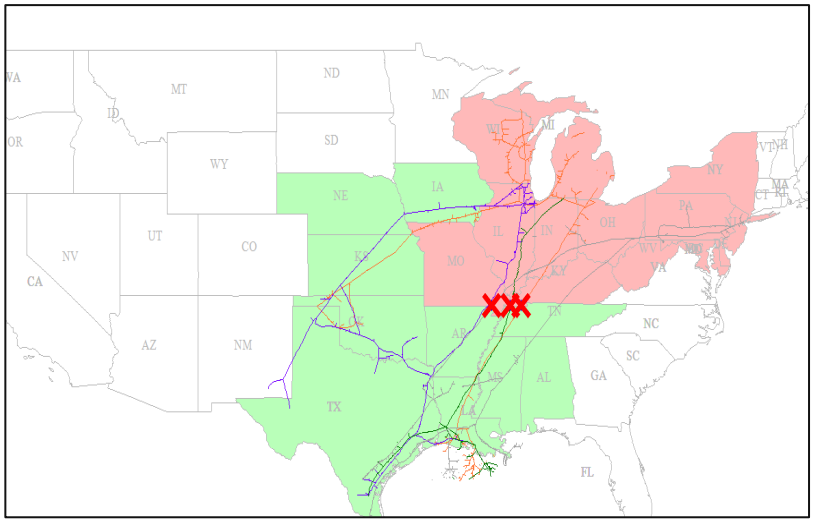
Work sponsored by FEMA Region V
Disaster Operations Division, Chicago, IL USA

Order of Presentation

- Brief Description of NGFast Simulation Model
- Objectives of the New Madrid Natural Gas Pipeline Study
- Scenarios Covered by the Study
- Major Assumptions and Methodology
- Overview of the U.S. Natural Gas Pipeline System
- Key Findings – New Madrid and Wabash Events
- Summary of Damages and Estimated Restoration Time
- Seismic Performance of Underground Storage Facilities
- Conclusions – Natural Gas Pipeline Study
- Conclusions – New Madrid Electric Transmission Line Study

NGFast: Model for Natural Gas Pipeline Breaks and Downstream Impacts – Salient Features

- **Linear, steady-state model provides a quick estimate of impacts on the downstream market of:**
  - single or multiple pipeline breaks
  - flow reduction problems
- **This national model includes:**
  - ~ 80 interstate and other pipelines
  - ~ 1,800 local distribution companies (LDCs)
  - ~ 800 state border points
- **Compensated/uncompensated modes account for effects of mitigating measures such as:**
  - underground storage (UGS)
  - liquefied natural gas (LNG)
  - production facilities
  - spare pipeline capacity
- **Graphical user interface (GUI) navigation uses "point-and-click" features, is super fast, and is easy to use**

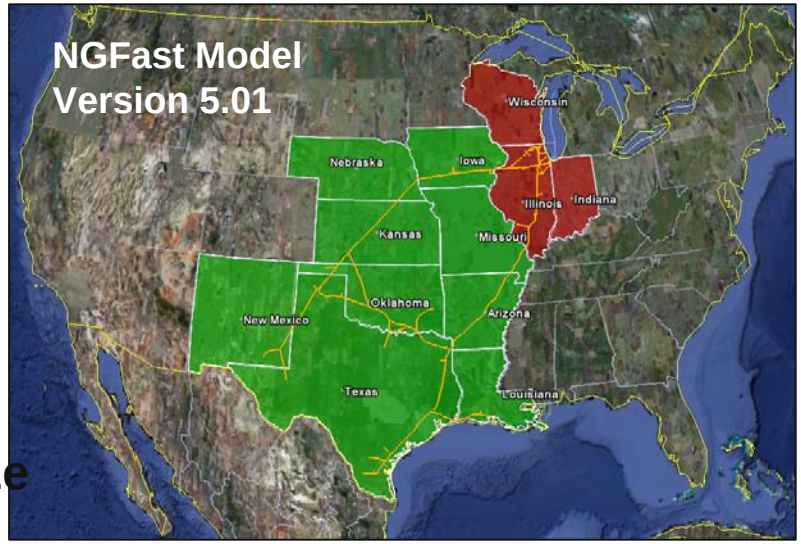


- **Graphical and tabular HTML – formatted outputs**
- **Applications**
  - DOE exercise analysis
  - hurricane analysis
  - seismic analysis
  - others as appropriate

NGFast Analysis Output

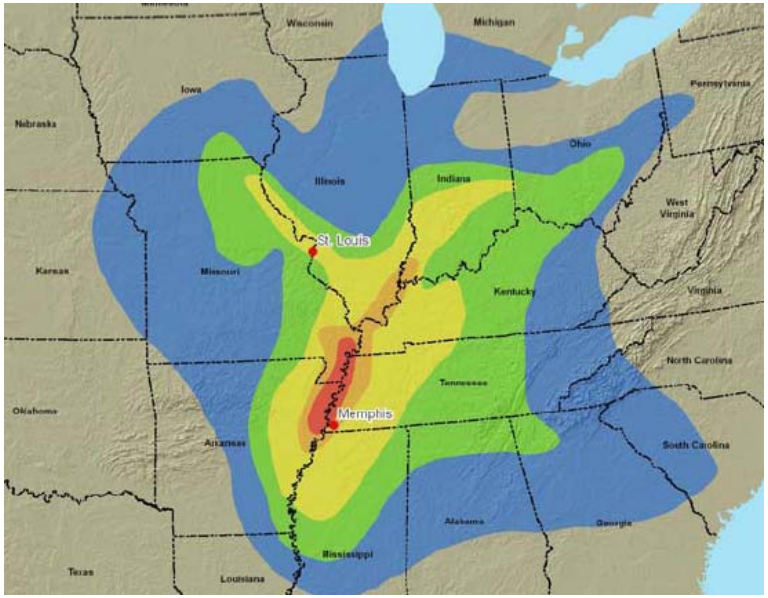
For a postulated flow disruption in a specific border point(s) and month of the year, NGFast assesses impacts, including:

- **Downstream states affected**
- **LDCs affected per state**
- **Load shed per customer class per LDC**
- **Number of customers per class type**
- **MW of electric power plants affected**
- **Detailed per state pre- and post-disruption load and flow levels**
- **Options on remedial actions to minimize overall impact**



Primary Objectives of the Current Seismic Study

- Assessment of impact on natural gas interstate transmission pipelines
- Identification of specific pipelines affected
- Identification of probable location of pipeline breaks
- Assessment of downstream impacts in terms of population and business customers affected
- Estimate of restoration time from the perspective of industry experts

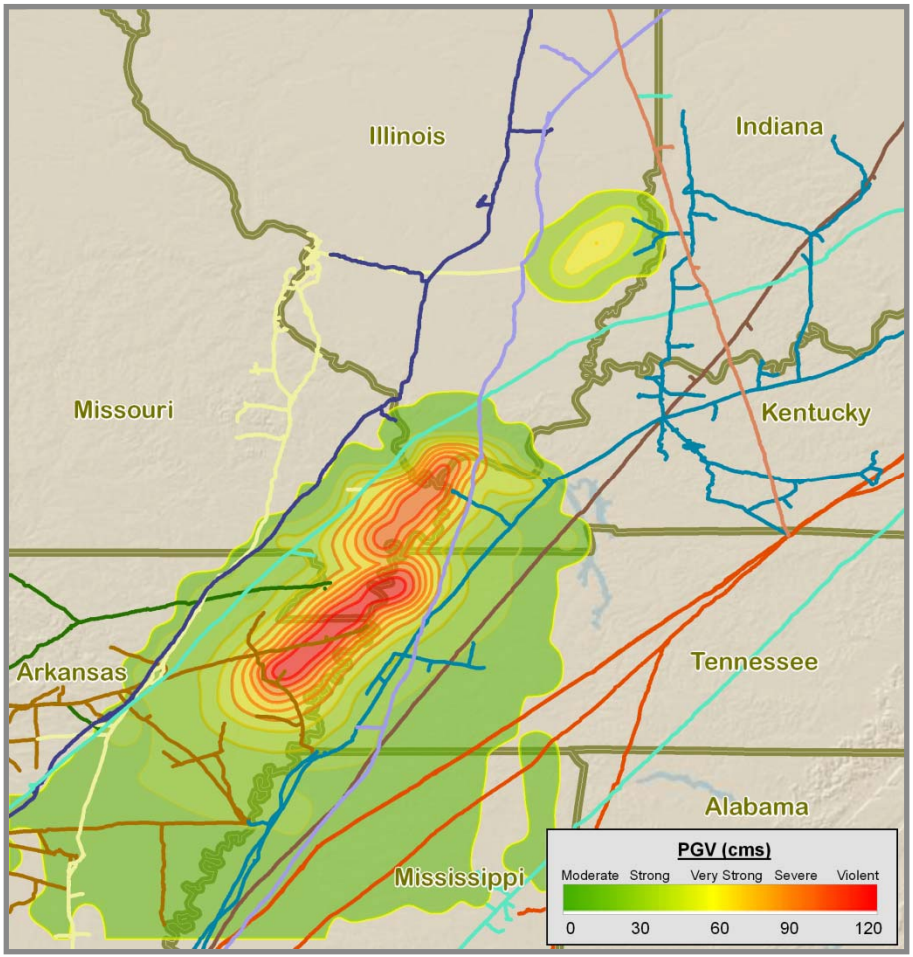


Scenarios Covered by the Study

Three Scenarios Covered

- **1: New Madrid Event with M 7.7 quake involving the northern segment and the Boot Heel of Missouri.**
- **2: Wabash Valley Event with M 6.8 quake**
- **3: Simultaneous New Madrid and Wabash Events with M 7.7 and 6.8, respectively**

.



Key Assumptions Used for Impact Assessment

- Events occurred on Feb. 24 at 2:00 a.m.
- A pipeline segment break triggered by the earthquakes implies 100% flow reduction along the pipeline
- Transmission pipelines through the seismic zones are generally ductile, made of steel, are arc welded, and are buried at an average of 4 to 6 ft below ground surface.
- Order of load shedding:
  - gas-fired power plants
  - industrial
  - commercial
  - residential

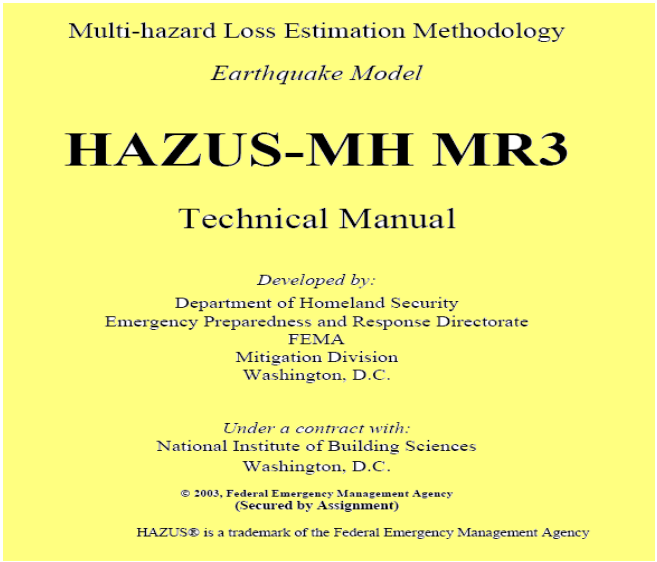
Methodology, Models, and Sources of Data

Methodology and Models

- Used HAZUS MH-MR3 for damage functions and fragility curves
- Used Argonne's NGFast model for pipeline break simulation and assessment of downstream impacts
- Used industry-based experience for estimating restoration time

Data Sources and Graphics

- For ground motion, used FEMA-provided shake maps (PGA, PGV, liquefaction)
- For NGFast and pipe characterization, used:
  - EIA 176
  - EIA state border files
  - FERC 567
  - Platts PowerMap
  - DOT's National Pipeline Mapping System
  - ESRI Arc Map
  - Industry experts
- Natural Gas Storage Assessment and Restoration: used inputs from industry subject-matter experts


Multi-hazard Loss Estimation Methodology

Earthquake Model

HAZUS-MH MR3

Technical Manual

Developed by:
Department of Homeland Security
Emergency Preparedness and Response Directorate
FEMA
Mitigation Division
Washington, D.C.

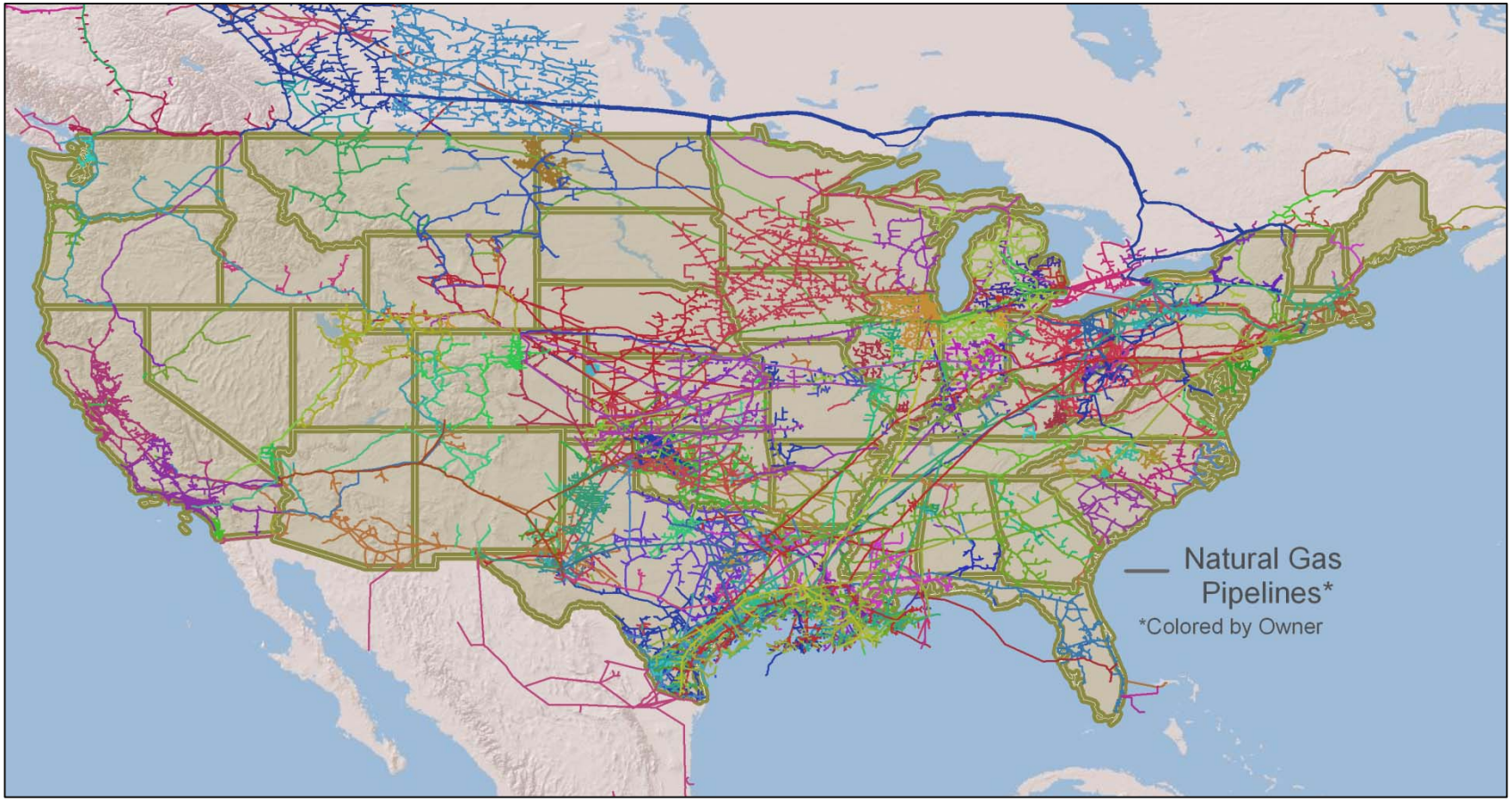
Under a contract with:
National Institute of Building Sciences
Washington, D.C.

NGFast: rapid assessment of impacts of natural gas pipeline breaks at U.S. borders and import points

Overview of U.S. Natural Gas Pipeline System

The U.S. natural gas system is a complex network of interconnected high-volume, high-pressure pipelines

.



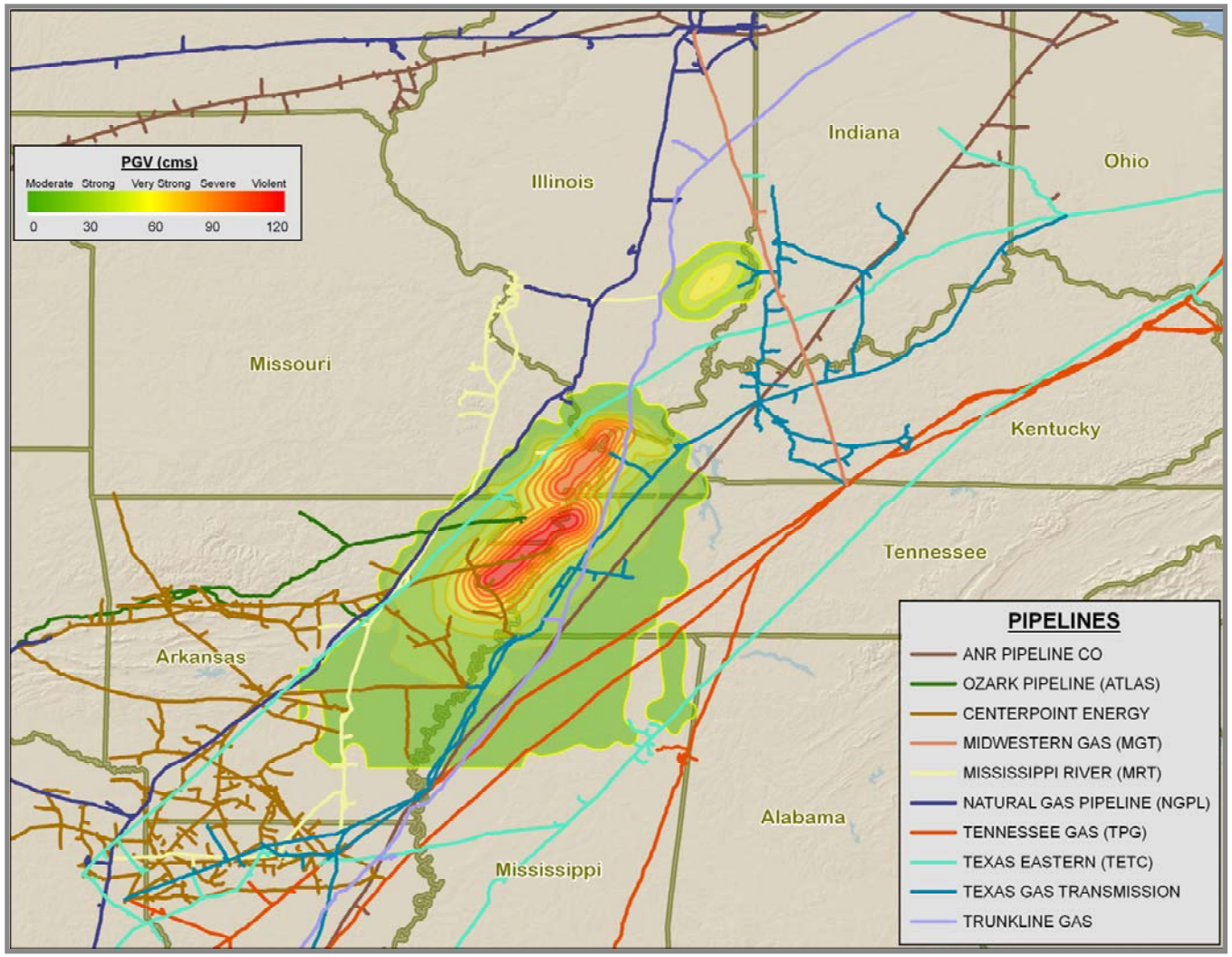
Scenario 3: Combined New Madrid and Wabash Valley Seismic Events

- Occurring simultaneously
- Emergency remedial actions implemented

Summary of Key Findings

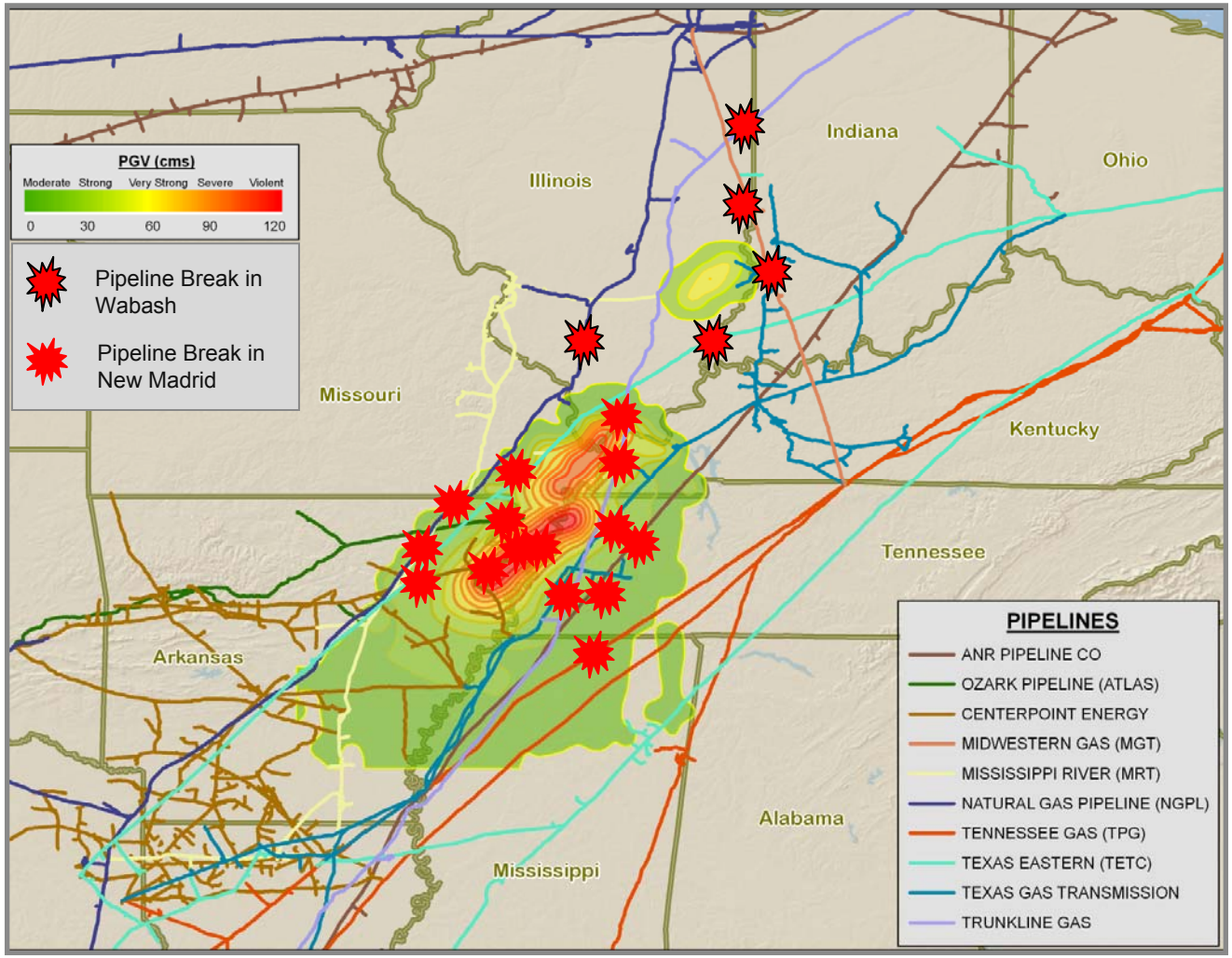
New Madrid and Wabash Valley: Key Finding 1

Ten interstate pipelines are at high risk for multiple damage from New Madrid and Wabash Valley earthquakes



New Madrid and Wabash Valley: Key Finding 2

All ten at-risk pipelines would be damaged by at least one break and several leaks due to PGA, PGV, and liquefaction with implications on Region V states



Typical Emergency Actions by Pipeline Companies to Mitigate Impacts

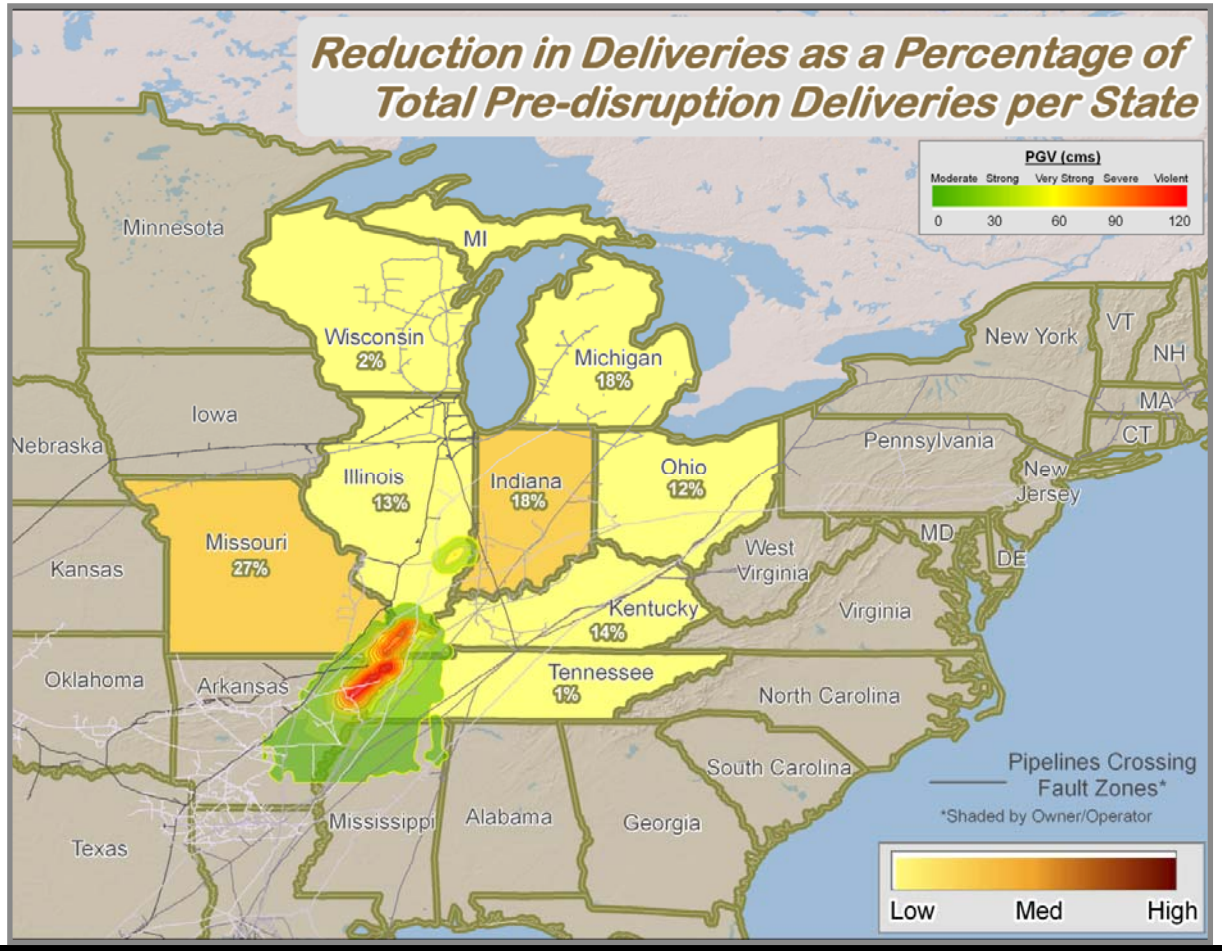
- Declare emergency gas days and enforce “force majeure” measures
- Coordinate, prioritize, decide, and implement gas re-routing options
- Prioritize, decide, and implement load shedding options
- As much as possible, spare residential customers from being shed
- Assess, prioritize, and implement temporary, quick work-around remedial actions on damaged pipes
- Organize crews, materials, supervisory personnel, and support staff to immediately commence temporary and permanent repair work

New Madrid and Wabash Events Emergency Remediation Measures before Permanent Restoration

- **Available Emergency Mitigation Measures**
  - selectively shed interruptible loads (e.g., power plants, industrial loads)
  - increase withdrawal from UGS
  - increase flow from spare capacity from interconnected but unaffected pipelines
  - withdraw LNG from storage
  - increase production from nearby fields
- **Other Possible Sources of Gas**
  - Rocky Mountains
  - Canada
  - Gulf of Mexico via other unaffected pipelines

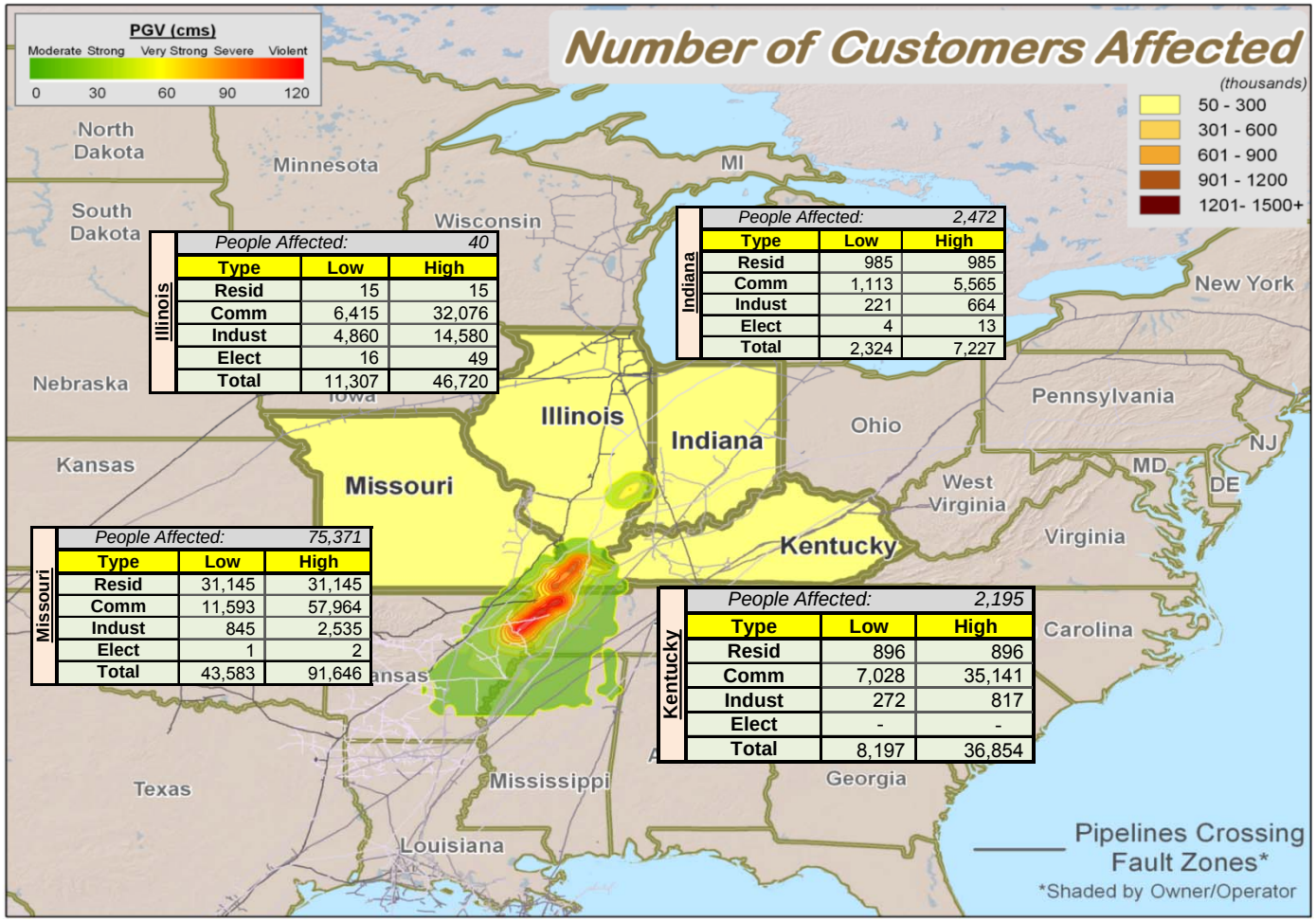
New Madrid and Wabash Valley Events Downstream Impacts with Emergency Remedial Actions: Key Finding 3

All FEMA Region V states, except Minnesota, would experience substantial delivery reduction, ranging from 2% to 27%



Downstream Impacts with Emergency Remedial Measures: Key Finding 4

Implementation of emergency remedial measures could limit the number of people affected to about 60,000–100,000 (or 20,000–33,000 households) across several states; a large number of electric, industrial, and commercial customers (50,000–140,000) would also be shed



Illinois	People Affected: 40		
	Type	Low	High
	Resid	15	15
	Comm	6,415	32,076
	Indust	4,860	14,580
	Elect	16	49
	Total	11,307	46,720

Indiana	People Affected: 2,472		
	Type	Low	High
	Resid	985	985
	Comm	1,113	5,565
	Indust	221	664
	Elect	4	13
	Total	2,324	7,227

Missouri	People Affected: 75,371		
	Type	Low	High
	Resid	31,145	31,145
	Comm	11,593	57,964
	Indust	845	2,535
	Elect	1	2
	Total	43,583	91,646

Kentucky	People Affected: 2,195		
	Type	Low	High
	Resid	896	896
	Comm	7,028	35,141
	Indust	272	817
	Elect	-	-
	Total	8,197	36,854

Residential Sector Not Affected

Michigan	People Affected: -		
	Type	Low	High
	Resid	-	-
	Comm	-	-
	Indust	4	11
	Elect	8	23
	Total	11	34

Ohio	People Affected: -		
	Type	Low	High
	Resid	-	-
	Comm	2,560	12,801
	Indust	458	1,375
	Elect	9	27
	Total	3,028	14,203

Tennessee	People Affected: -		
	Type	Low	High
	Resid	-	-
	Comm	2	11
	Indust	29	87
	Elect	0	1
	Total	32	99

Wisconsin	People Affected: -		
	Type	Low	High
	Resid	-	-
	Comm	-	-
	Indust	-	-
	Elect	2	5
	Total	2	5

New Madrid and Wabash Valley Downstream Impacts with Emergency Remedial Measures: Key Finding 5

In terms of amount of natural gas-fired power plants' capacity affected due to gas curtailment, the amount of megawatts of power at risk per state is low

State	Total Shed (MW)	2007 Capability (MW)	% of In-state Capacity
IL	330	42,300	0.78%
WI	280	16,400	1.71%
MI	270	30,200	0.89%
IN	110	26,900	0.41%
OH	30	33,900	0.09%
MO	15	20,600	0.07%
TN	10	20,900	0.05%
KY	0	20,100	0.00%
Total	**1,045**	**211,300**	**0.49%**

Summary of Damages in New Madrid Area

A. Pipeline Damage Due to PGV and Estimated Restoration Time

Item No.	Pipeline Company	No. of Leaks	No. of Breaks	No. of Pipes per corridors	Total Leaks	Total Breaks	Diameter (inches	Length Span involed Per Pipe corridor (km)	Total Restoration Days Leaks + Breaks	
									Low	High
1	TRUNKLINE	40	4	2	80	8	30,36	440	29	69
2	TEXAS GAS	17	2	4	68	8	30,36,26,26	250	32	87
3	TEXAS EASTERN	25	3	1	25	3	24	345	20	49
4	ANR PIPELINE	9	1	3	27	3	36,30,30	432	22	53
5	NGPL	9	1	3	27	3	36,36,30	520	22	53
6	MISSIPPI RIVER TRANS	9	1	3	27	3	26,26,22	470	22	53
7	Tennessee Gas TRANS	7	1	2	14	2	30,24	680	22	69
8	CENTERPOINT ENERGY	33	4	1	33	4	18	156	24	65
9	MOZARK GAS TRANS	8	1	1	8	1	16	503	17	41
	Total				309	35			210	539

Summary of Compressor Damages in New Madrid

B. Compressor Station Damage and Restoration

Owner	Name	Type of Damage	HP rating	Rated Suction Pressure	Rated Discharge Pressure	No.of Units	No. of Pipelines	Vol MMCf/D	Estimated Restoration (days)	
									Low	High
TRUNKLINE	JOPPA	Extensive	30,800	553	834	9	2 (30", 36")	1300	10	30
TRUNKLIE	DYERBERG	Moderate	30,000	564	840	8	2 (30", 36")	1380	4	10
TEXAS EASTERN	ORAN	Moderate	10,000	490	800	10	1 (24")	380	4	10
TEXAS EASTERN	POLLARD	Moderate	4,500	N/A	N/A	N/A	2 (24")	380	4	10
TEXAS EASTERN	WALNUT RIDGE	Moderate	8,000	628	800	4	2 (24")	300	4	10
TEXAS EASTERN	DICK CREEK	Moderate	-----	-----	-----	-----	-----	-----	4	10
TENN GAS PIPELINE	MIDDLETON	Minor	34,350	480	730	23	3(24", 26", 30"	1520	1	4
NGPL	308 BIGGERS	Minor	30,850	586	850	9	2 (30", 36")	1600	1	4
MRT	BIGGERS	Minor	12,150	573	720	7	2 (24", 26")	650	1	4
ANR	COTTAGE GROVE	Minor	30,830	600	855	8	1 (30")	1400	1	4
ANR	SARDIS	Minor	33,200	580	850	6	2 (30", 36")	1420	1	4
Total									35	100

Wabash Valley Area Summary of Underground Storage and Pipeline Damages

A. Underground Storage at Risk Due to PGA and Estimated Restoration Time

Owner	Name	Location	Types of Damage	Estimated Restoration (days)	
				Low	High
TEXAS GAS TRANS	OAKTON	INDIANA	Moderate above ground facitlities	2	10
SOUTHERN INDIANA GAS And EIECTRIC	MONROE	INDIANA	Moderate above ground facitlities	2	10
Total				4	20

B. Pipeline Damage Due to PGV, PGA, and Liquefaction and Estimated Restoration Time

Item No.	Pipeline Company	No. of Leaks	No. of Breaks	No. of pipes per corridor	Total Leaks	Total Breaks	Diameter (inches	Length Span involed Per Pipe corridor (km)	Total Restoration Days Leaks + Breaks	
									Low	High
1	TRUNKLINE	2	2	2	4	4	26, 30	650	15	44
2	MID WESTERN GAS TRANS	1	2	2	2	4	36,36	502	10	34
3	NGPL	0	1	3	0	3	36,36,30	3	5	14
4	TEXAS EASTERN	0	1	3	0	3	24	2	5	14
	Total				6	14			35	106

Wabash Valley Area Summary of Compressor Damages

C. Compressor Damage Due to PGA and Estimated Restoration Time

Owner	Name	Type of Damage	HP rating	Rated Suction Pressure	Rated Discharge Pressure	No.of Units	No. of Pipelines	Vol MMCf/D	Estimated Restoration Time (days)	
									Low	High
TRUNKLINE	JOHNSON VILLE	Moderate	30,000	597	900	8	2 (30", 36")	1250	4	10
MIDWESTERN GAS TRAN	2113 CARLISLE	Moderate	9,100	680	877	1	1 (30")	644	4	10
Total									8	20

Seismic Performance of Underground Storage Facilities

- In general, experts agree that UGS within 100 miles of the quake's epicenter may be at risk of some damage, depending on the intensity of the quake and the direction of the seismic wave
- In general, UGS fields are quite resilient against seismic disturbance unless the structure is located at the fault line
- According to seismologists, only the top 50 ft of soil is subject to liquefaction, meaning that little damage is expected to occur to subsurface UGS fields because the typical depth of sandstone and rock is 1,000–2,000 ft
- Most underground damage involves the vertical surface-to-underground cavern pipeline at a point where the pipeline meets the cap rock of the underground structure
- Other damage may involve the fracture of the cap rock that lines the storage core of the underground structure; the fracture may result in gas leaking or migrating to the surface
- Most UGS is located near the Wabash Valley, except for two small facilities whose surface structures may be at risk due to PGA; the other UGSs are assumed to be functional

Natural Gas Study: Conclusions and Summary of Key Findings

- **Key Finding 1: Ten interstate pipelines would be at risk of damage due to the events**
- **Key Finding 2: All ten pipelines would experience at least one break and several leaks due to PGA, PGV, and liquefaction**
- **Key Finding 3: Even with implementation of emergency remedial measures, all FEMA Region V states (except Minnesota) and other nearby states would experience a substantial reduction in delivery, ranging from 2% to 27%**

Indiana	~ 18%	Michigan	~ 18%	Illinois	~13%
Ohio	~12%	Wisconsin	~2%		

- **Key Finding 4: Even with emergency remedial actions, the seismic events would impact:**
  - **20,000–30,000 households (or 60,000–100,000 people)**
  - **50,000–140,000 Industrial and commercial customers or units**
- **Key Finding 5: A well-orchestrated implementation of remediation measures would limit impact on natural gas-fired power to insignificant levels (less than 2% of installed capacity)**
- **Key Finding 6: In general, all underground storage facilities (except for 2) would not experience any serious damage so as to make them dysfunctional**
- **Key Finding 7: Restoring damaged pipelines to full functionality would take about 1–3 months depending on how the pipeline companies subdivide and "phase" the work, the availability of crews, conditions of access roads, and resolved target completion times; restoration for residential and industrial customers would take 2–4 and 4–8 weeks, respectively**

Conclusions and Key Findings on Electric Transmission Study

- The New Madrid seismic event has a far more devastating potential impact than the Wabash Valley on the basis of all impact metrics used in the study
- The combined New Madrid and Wabash events could affect as many as 2–3 million people mostly in areas surrounding the epicenter of the earthquakes; blackouts mainly would be due to equipment failures and ensuing line de-energization
- The combined events could put about 190 high-voltage towers at risk for possible physical damage; most towers are located along or near the New Madrid fault lines
- The events could potentially de-energize 52 high-voltage transmission lines in both the New Madrid and the Wabash areas
- The possible line failures would not cause downstream electric supply shortfalls in any of the Region V states because of high reserves during February and a reduction in the possibility of transient stability problems
- Towers can be procured fairly quickly because there are many approved local suppliers; a new tower could be ordered and erected in about 1–4 months
- The equipment with the longest lead time is the transformer (8–12 months), but details of substation damages are beyond the scope of this presentation

Contact Information

Edgar C. Portante

Argonne National Laboratory

E-mail: ecportante@anl.gov

Phone: 630-252-7965

Stephen M. Folga

Argonne National Laboratory

E-mail: sfolga@anl.gov

Phone: 630-252-3728