Metrics for Resilience in Theory and in Practice – A Workshop

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70th Annual NECPUC Symposium,
Cape Neddick, ME
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Overview of this workshop

- Part 1 (25 min) Setting the stage – Eto
  - Distinguishing between reliability vs. resilience
  - DOE's Grid Modernization Initiative's grid resilience metrics
  - Sandia National Labs' grid resilience planning case study for the City of New Orleans
  - A structured approach for resilience planning
- Part 2 (50 min) An *interactive* application
  - Avangrid's Coastal Substation Flood Mitigation Study by David Bradt, Avangrid (CT) (20 min)
  - Directed Q/A – led/moderated by Joe Eto with audience participation (30 min)

Reliability vs. Resilience

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	Reliability	Resilience
Common features/ characteristics	Routine, not unexpected, normally localized, shorter duration interruptions of electric service Larger events will make it into the local headlines	Infrequent, often unexpected, widespread/long duration power interruptions, generally with significant corollary impacts Always front page news, nationally
Metrics	Well-established, annualized (SAIDI, SAIFI, MAIFI), with provisions for "major events" Not focused on non-electricity impacts	Not standardized, event-based (number of customers affected; hours without electric service) Routinely include non-electricity impacts (e.g., costs to firms; health and safety impacts)
Actions to improve	1. Plan and prepare; 2. Manage and endure event(s); 3. Recover and restore; and 4. Assess, learn, and update plan.	No qualitative difference But generally larger in scope/cost (see below)

Reliability vs. Resilience

	Reliability	Resilience
Entities involved in decision making	Electric utility and its regulator/oversight board, primarily	Electric utility and regulator But also and routinely in conjunction with parties that have responsibilities for other critical infrastructures, including local/regional/state/federal agencies/authorities, and communities/elected officials
Factors affecting decision making	Actuarial records on frequency of exposure – widely understood risks: insurable Well-understood/tested practices/approaches Understood to be an expected cost of doing business	No actuarial basis to establish likelihood of occurrence – widely varying perceptions of risk/exposure: un-insurable Limited opportunities to "test" strategies; emphasis on design standards Large dollar amounts/extraordinary expenditures may require special approval/vote Political judgements essential

Landscape of existing and proposed metrics
Resilience

Resilience

Existing (metrics)	Existing (data needed)
Cost of recovery	
Utility revenue lost	outage cost for utility ($)
Cost of grid damage	total cost of equipment repair
Cost per outage	

Proposed Metrics	Proposed (data needed)
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	
Cost of recovery	
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided
	$ / kVA
Critical services without power	number of critical services without power
	total number of critical services
Critical services without power after backup fails	total number of critical services with backup power
	duration of backup power for critical services
Loss of assets and perishables	
Business interruption costs	avg business losses per day (other than utility)
Impact on GMP or GRP	
Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

A structured approach to resilience planning

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- What resilience threat(s) is the focus?
- What aspect(s) of the threat(s) is of concern?
  - *Can we measure the extent to which these concerns are or will be addressed? How will we know if we have made things better or if they are getting worse (in the absence of an actual threat)*
- What is our design standard for addressing these concerns?
- What are the pro's and con's of available alternatives for meeting these standards?
  - *What is the lowest cost option?*
  - *What, if any, additional benefits might they provide? What are these worth?*
  - *Are there options for recourse?*

Exceptional service in the national interest

Sandia National Laboratories

Grid Analysis and Design for Energy and Infrastructure Resilience in New Orleans, LA

Robert Jeffers, Michael Hightower, Michael Baca, Nancy Brodsky,
Amanda Wachtel, Sarah Walsh, Bill Fogleman

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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GMLC Security & Resilience Project: New Orleans, LA

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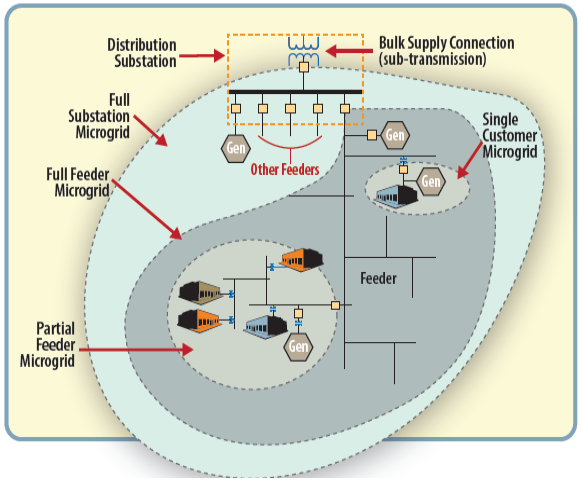
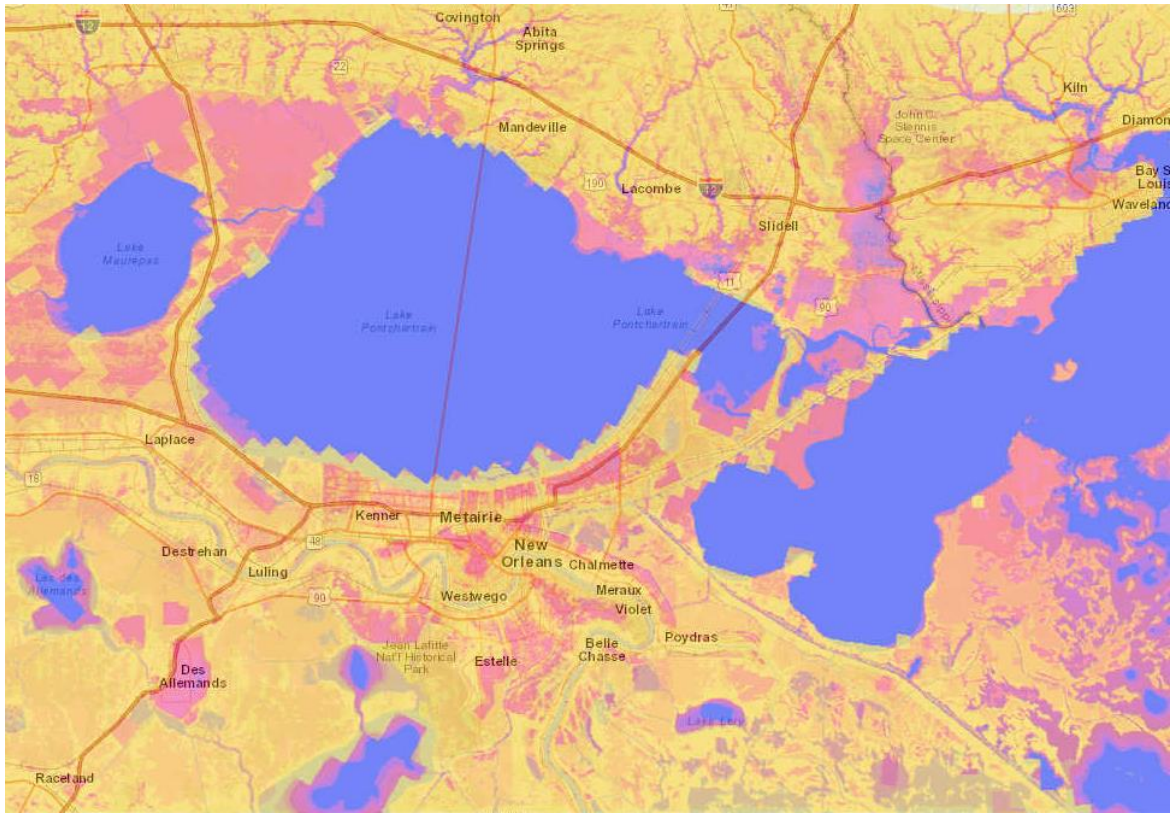




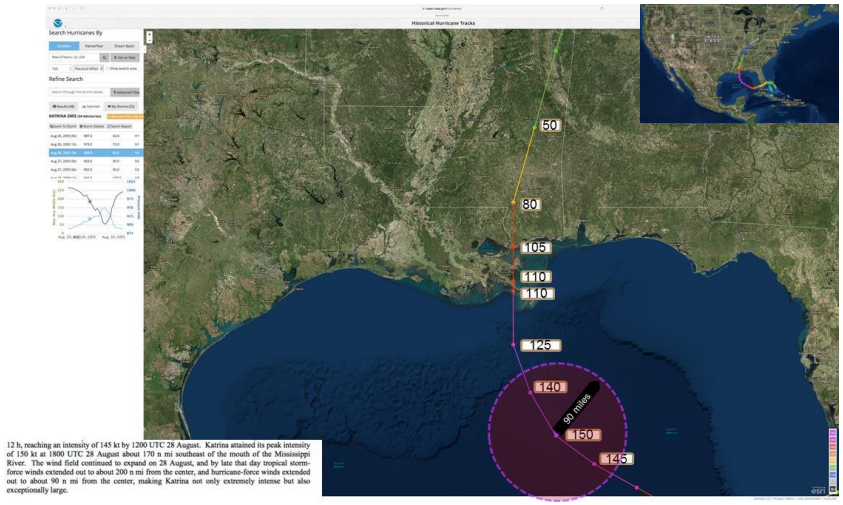
Results of Hurricane Inundation Modeling for New Orleans and surrounding regions

New Orleans is using technical assistance from Sandia and Los Alamos to determine grid investments that will improve their resilience to storms.

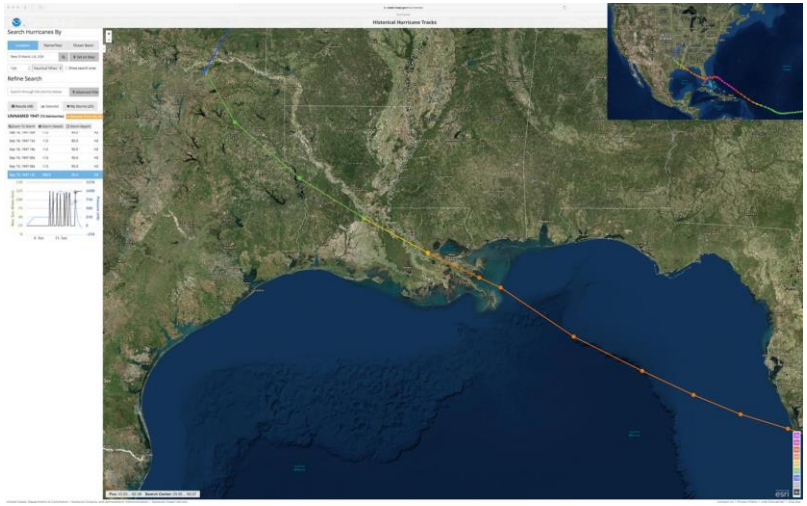
Consequence-focused Scenarios

A high category 2 or low category 3 may lead to worst reasonable consequence in NOLA

- If it stalls and drops >20" of rain quickly
- The city does not call for a mandatory evacuation
- Address potential worst case dewatering pump performance



Parameter	Track 1: Katrina 2005	Track 2: Unnamed Storm Sept. 1947
Storm Category	High Cat 2; surge <20 ft	
	Mid-range Cat 3; surge ?	
	Low – mid range Cat 4; surge likely > 24 ft	
Rainfall	20 inches over ~ 24 hours	
Drainage Pumps	Performing at 50% capacity	



Population movement to dry areas

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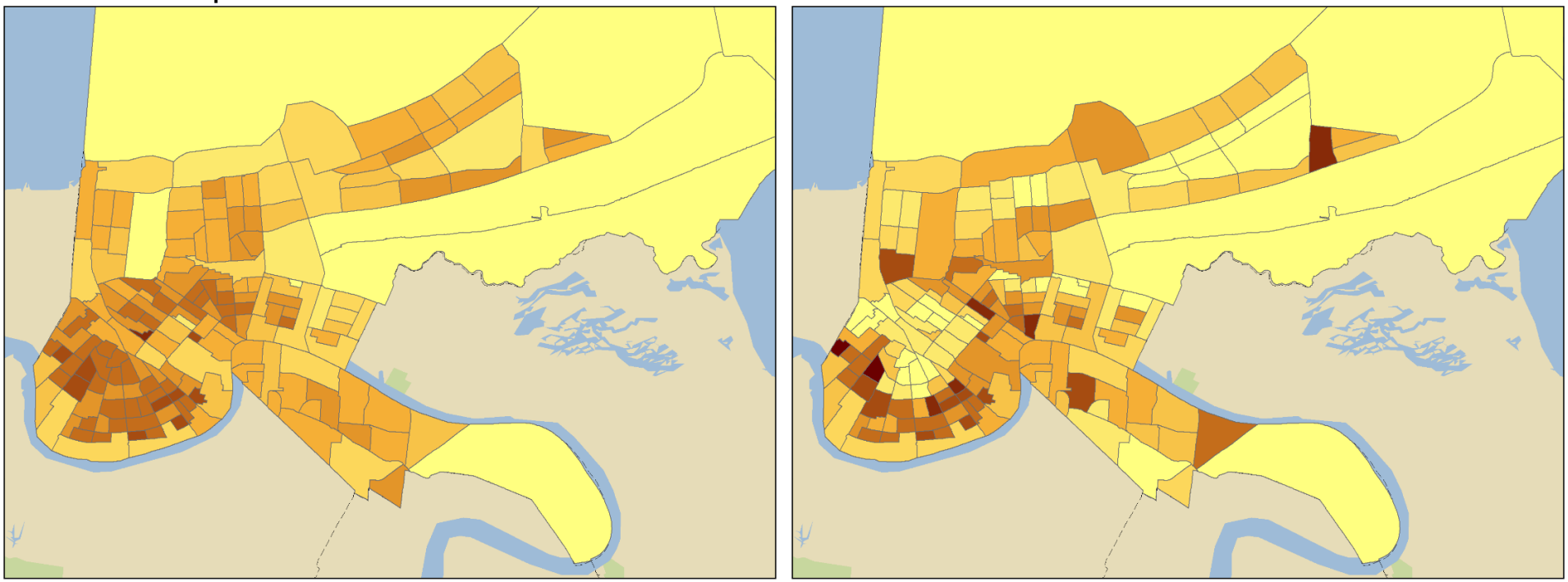
Baseline Population

Inundated Population (>2 Feet)
Movement to Potential Shelters



Population Density/Square Mile

0 - 370	6,213 - 8,926
370 - 1,482	8,926 - 13,157
1,482 - 2,660	13,157 - 17,831
2,660 - 4,341	17,831 - 38,254
4,341 - 6,213	38,254 - 58,882

Baseline Population 2014 data from the 2010-2014 American Community Survey, Table S0101, Orleans Parish

Decentralized Infrastructure and Inundation

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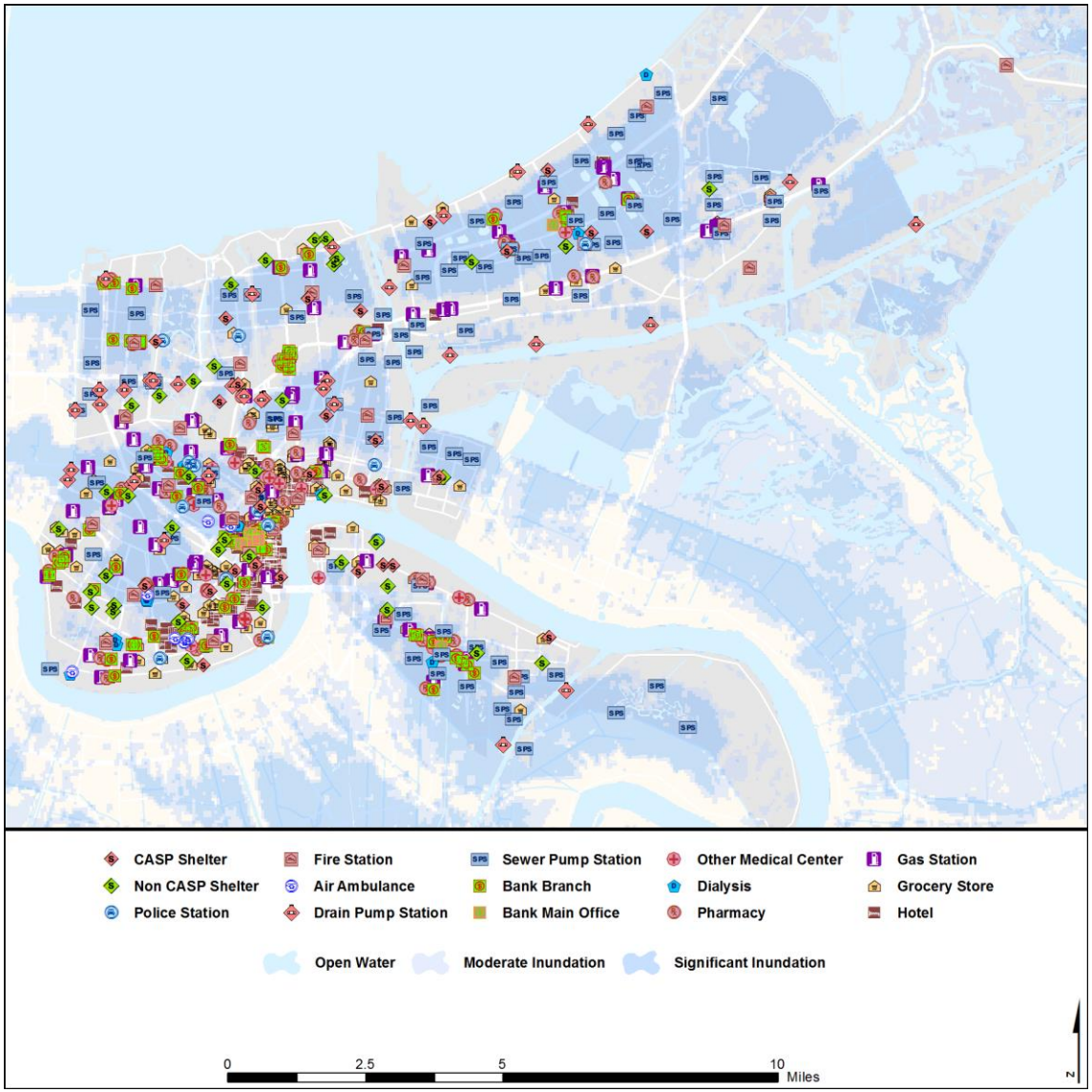
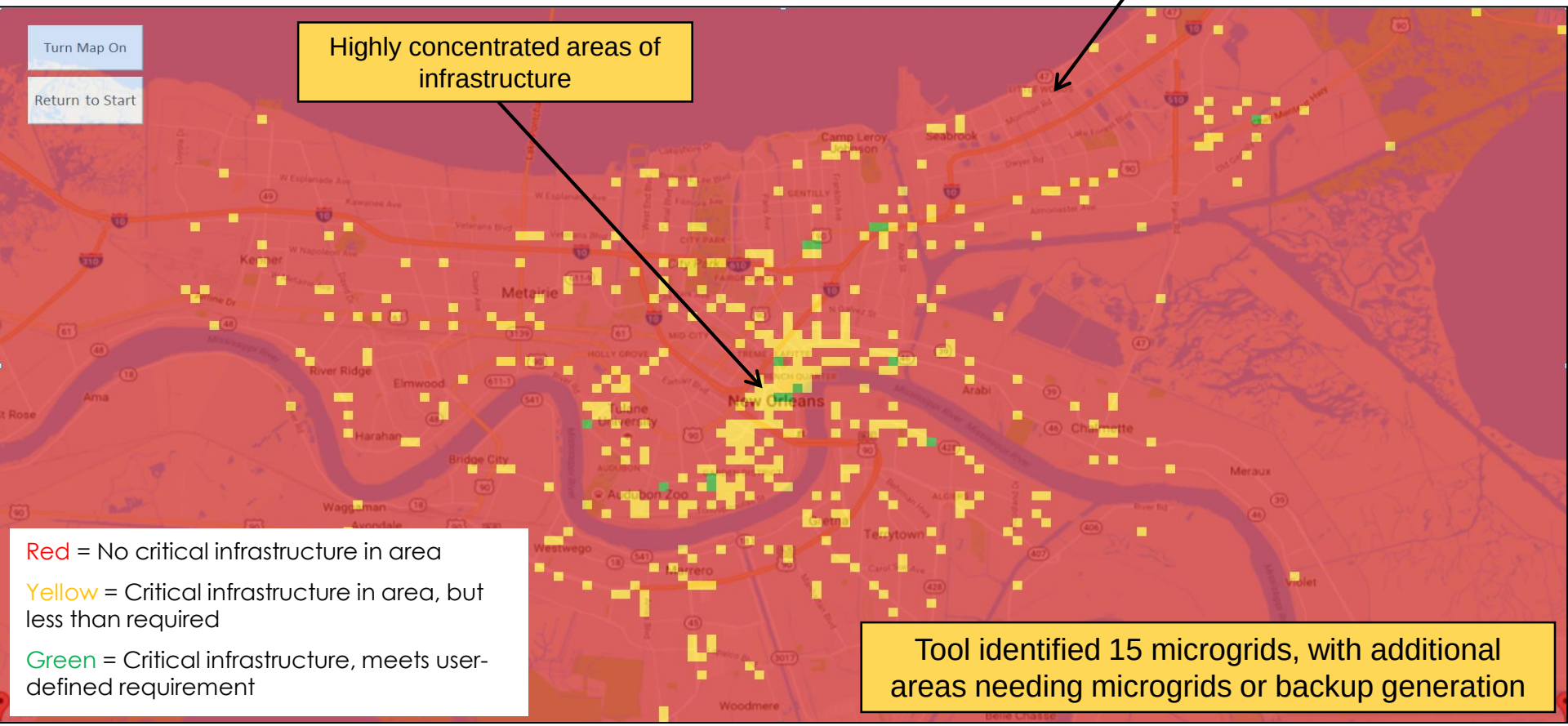
Note: purpose of inundation analysis is to guide energy system improvements, not to be used for facility elevation studies



Microgrid Screening



Area size of 1000 ft x 1000 ft

Minimum of 4 buildings per microgrid

Avangrid (CT)

May 22nd, 2018

Southwest Connecticut Coastal Flood Risk Assessment & Mitigation

Presentation to:

NECPUC Annual Symposium

David Bradt

Director – Transmission Planning

Today

Objective:

Share Avangrid's recent experience with increasing flood risk threats along the SWCT coastline along with actions to date.

Background

1970 thru 2010

- No record of disruptive coastal S/S flood events
- Design Levels
  100yr (pre-90's)
  100yr +1 (post 90's)

Storm Irene (August 2011)

Storm Sandy (October 2012)

2013

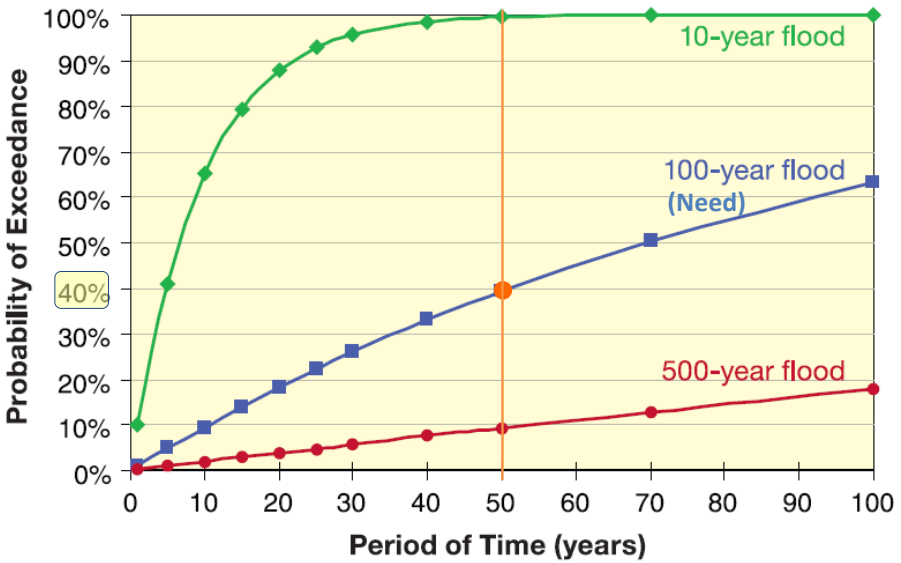
- FEMA revises Flood Maps 2-4ft (July 2013)
- Compelled to take Action
- Short Term Measures in place (August 2013)
- Initiate Long Term Assessment
- Stakeholder process

Study

Study / NE Stakeholder Process (2015 – 2016)

Risk Assessment

- A 50yr substation designed to the 100year flood level has a 40% chance of flooding over its useful life.
- 5 stations at risk from single flood event could destroy 5 BES stations



Reference: Designing for Flood Levels Above the BFE After Hurricane Sandy (FEMA HSFE60-13-0002, 0003, April 2013)

Establish Criteria

Industry, Regional, Sea Level Rise

Legacy Stations

100year flood level

New or Modified

Higher of:

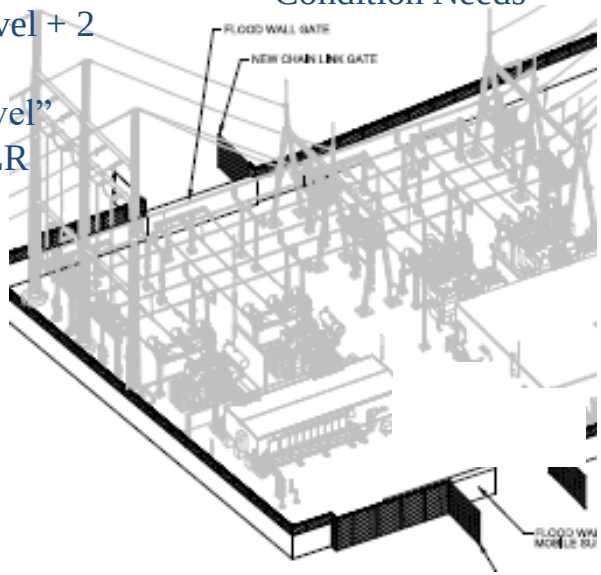
a) "100-year flood level + 2 feet" or,

b) "500 year flood level"

→ plus 1ft coastal SLR consideration

Alternative Development

- Raise equipment
- Flood wall system
- Raise/Rebuild
- Relocate inland
- Address Asset Condition Needs



Study

Southwest Connecticut Alternatives & Recommendations (Examples)						
Mitigation Strategies		Congress St	Pequonnock	Singer	Grand Ave/Mill River	East Shore
		Solution Alternative Cost ($M)	Solution Alternative Cost ($M)	Solution Alternative Cost ($M)	Solution Alternative Cost ($M)	Solution Alternative Cost ($M)
1	Raise Impacted Equipment	Infeasible (Control Building Impacted)	Infeasible	Infeasible	Infeasible	$0.33
2	Perimeter Flood Wall System	$16.50	Not pursued	$12.90	$17.50	$21.00
3	Raise and Rebuild "Adjacent"	$88.30	$171.30	$194.60	$88.30	Not pursued
4	Raise and Rebuild "In-Place"	Not pursued (Cost exceeds Rebuild "Adjacent")	$269.60	Not pursued	Infeasible	Not pursued
5	Relocate Inland	$233.30	$246.70	Infeasible	$207.40	Not pursued
6	Address Asset Condition Needs (non-flood related)	None Identified	Included in above costs	None Identified	Included in above costs	None Identified
Recommended Mitigation Strategy - Highlighted		**$16.5**	**$171.3**	**$12.9**	**$17.5**	**$0.3**

Total Estimated Solution Costs:	**$218.5**

Execution of Plans (in progress)

Continued Evidence of Coastal Flood Pattern Changes

2022 ISD

Mitigation Plans now Underway

- Raising Equipment
- Flood wall systems
- S/S Rebuild

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