NWIRP Research Study of Hurricane Maria (Puerto Rico)

## Infrastructure Systems Supporting Critical Buildings and Emergency Communications

Project Leader: Ken Harrison

Objective: From a study of power, water, transportation, and wireless communications infrastructure impacts, recovery, and decision-making, make recommendations for increasing resilience through changes to codes, standards and practice.

Background and Motivation: Importance of Dependencies on the Support of Critical Buildings

- Dependencies leading to loss of function
  - Propagation can impact the function of critical buildings
  - Redundancy can stem loss
- Dependencies in recovery phase, e.g.,
  - Repair of power lines can be dependent on road access
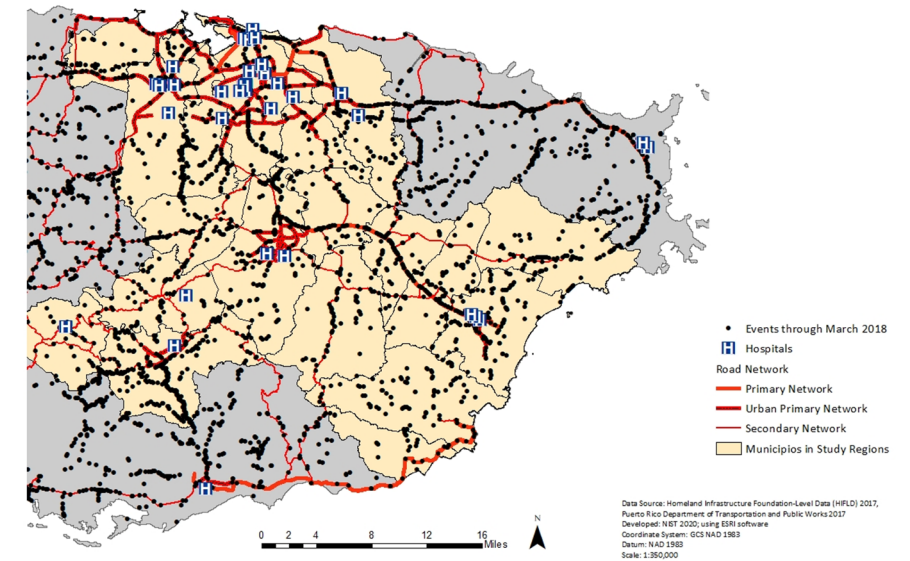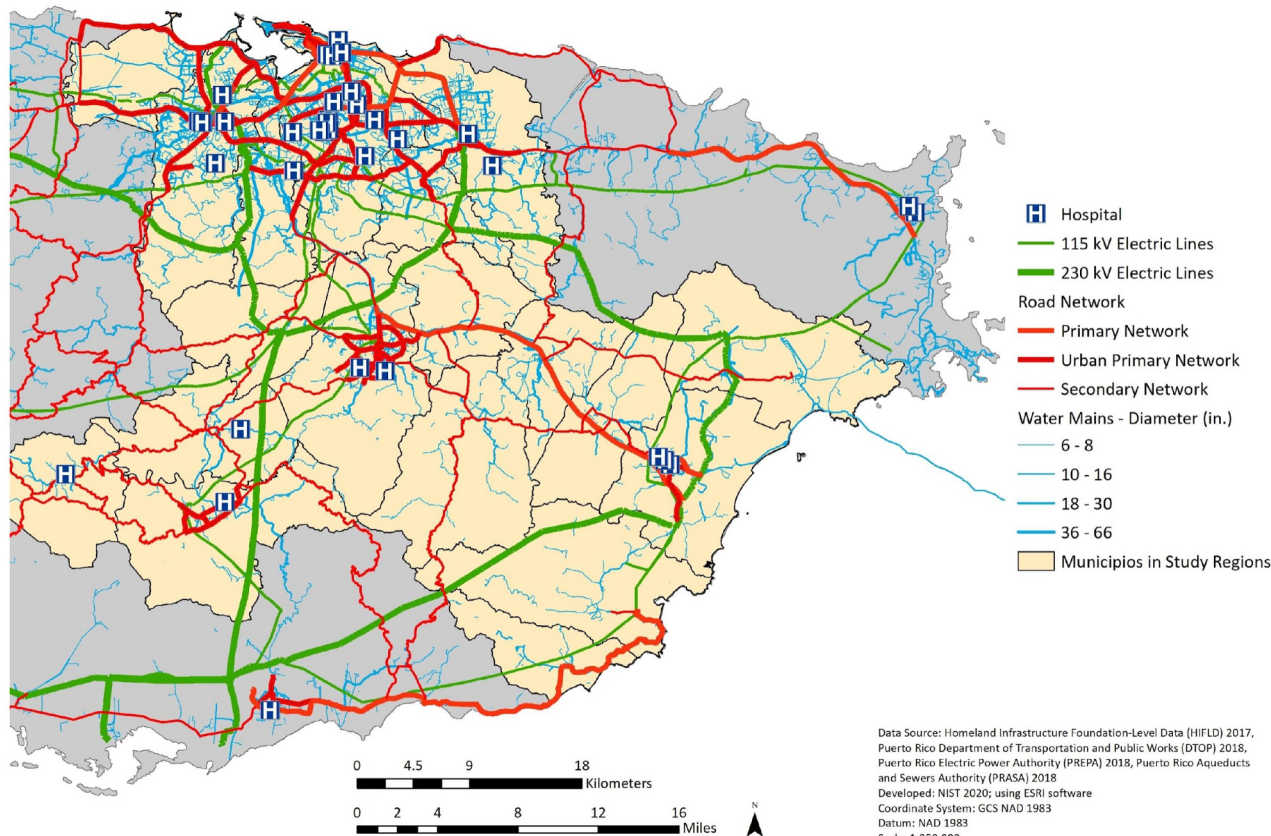
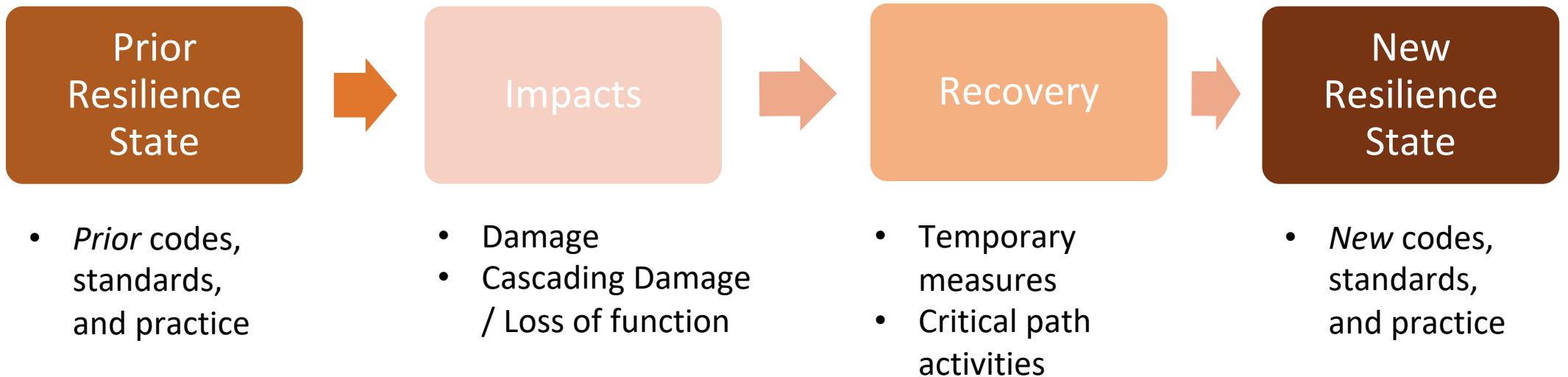**Transportation incidents: Hurricanes Irma/Maria**

Hospitals and high-capacity water, power, and transportation links

Source: FCC
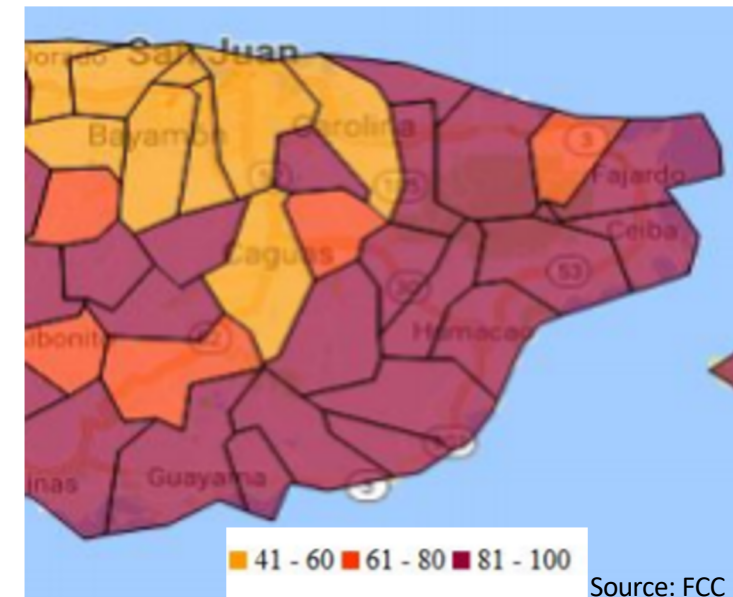
Cell Sites Out-of-Service 10/21/17, by Municipio (%)

Background and Motivation: Resilience and Recovery

"The term 'resilience' means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions."

-Presidential Policy Directive/PPD-21, 2013

Prior Resilience State	Impacts	Recovery	New Resilience State

- *Prior* codes, standards, and practice

- Damage
- Cascading Damage / Loss of function

- Temporary measures
- Critical path activities

- *New* codes, standards, and practice

Project Plan: Four Project Components

Dependencies

Objective: Evaluate dependencies in power, water, and transportation infrastructure impacts, recovery, and decision-making.
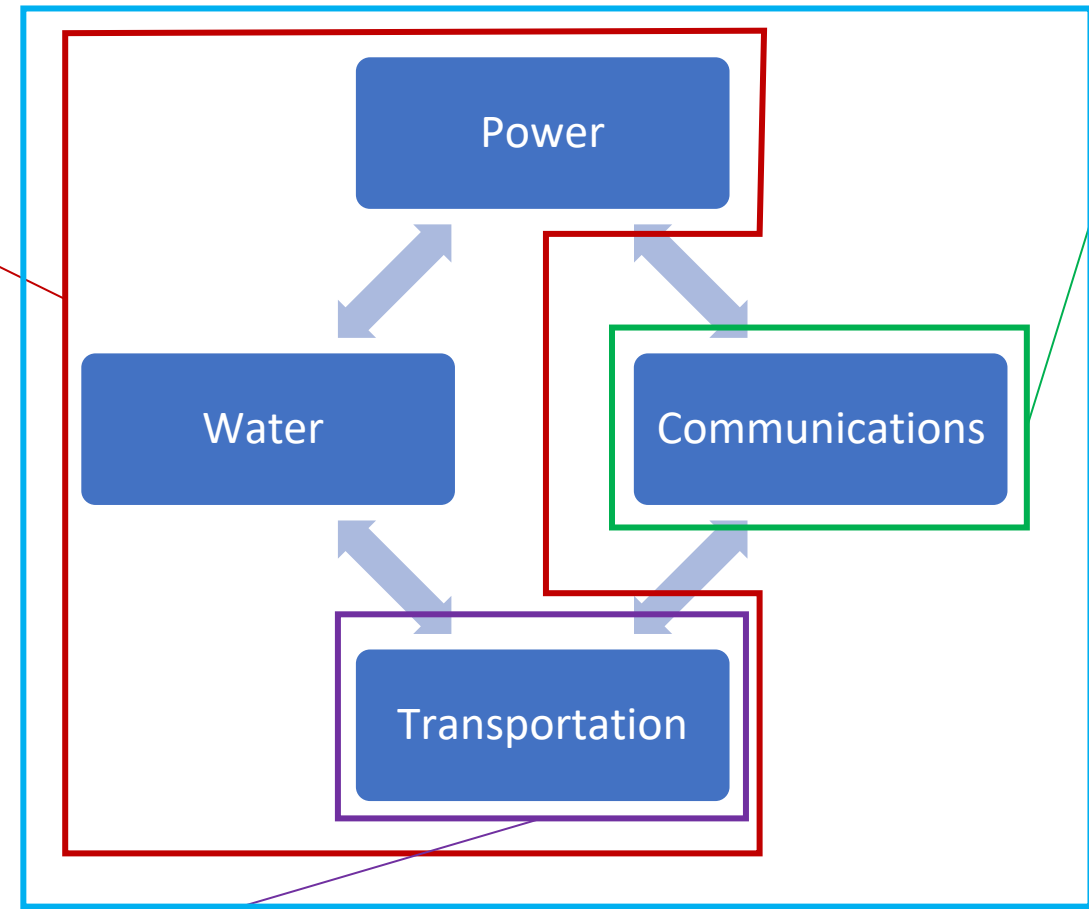
Wireless Communications

Objective: Investigate causes of the loss of functionality and extended-duration outage of the wireless communication system in Puerto Rico following Hurricane Maria.

Integrative Study

Objective: In a case study for a community in Puerto Rico, evaluate the potential for model support of resilience decision-making.
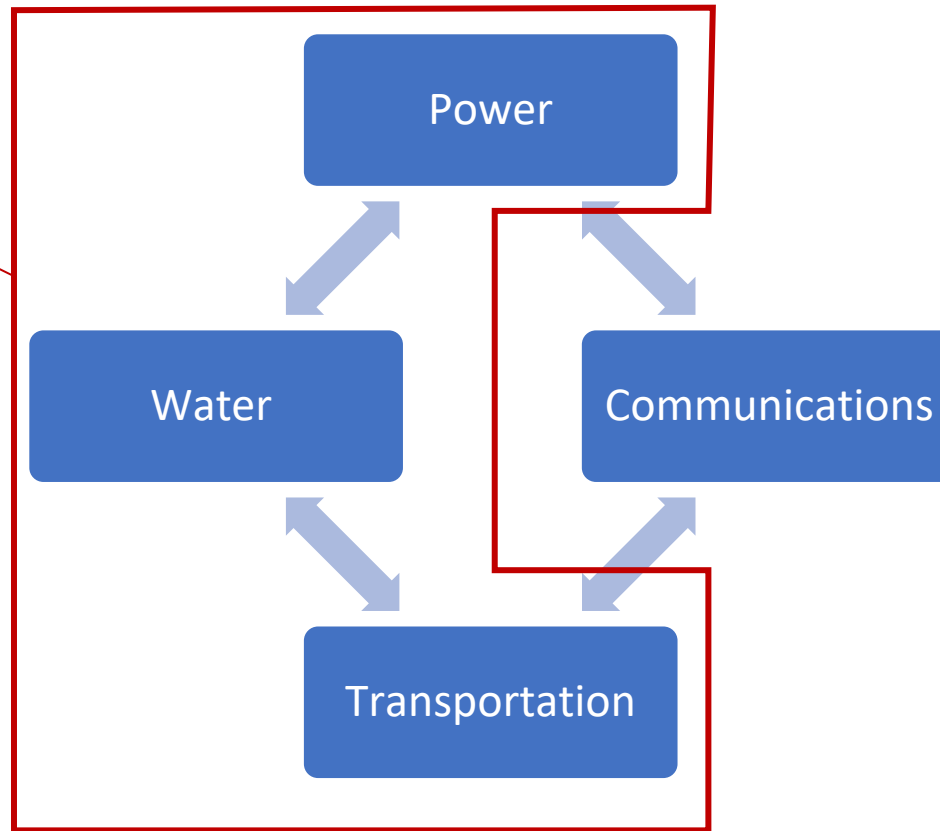
Transportation Incident Analysis (new project component)

Objective: Mine the PR DTOP Transportation Incident Database to answer HM program questions.

Power

Water

Communications

Transportation

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Project Plan: Data Collection and Analysis

Step	Dependencies	Transportation Incident Analysis	Wireless Communications	Integrative Study
Data Collection	Primary data collection: Semi-structured interviews of officials to gain community-scale information	PR DTOP Transportation Incident Database	Data from telecommunication companies, support industries, and regulatory agencies	Community data on infrastructure vulnerability and resilience actions
Data Processing	Response database	Recovery-oriented geospatial database	Geospatial database • Tower locations • Hazard exposure • Code requirements • Damage	NIST ARC model inputs
Analysis	Contributors to recovery delays	Assessment for each municipality	Evaluate performance against hazards	Evaluate infrastructure resilience alternatives
Case Study	Not applicable	Not applicable	Not applicable	Apply NIST ARC model to PR community
Make recommendations	Changes to codes, standards and practice			

Recent Progress: Dependencies (1/3)

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Recent Progress: Dependencies (2/3)

Prior Resilience State	→	Impacts	→	Recovery	→	New Resilience State
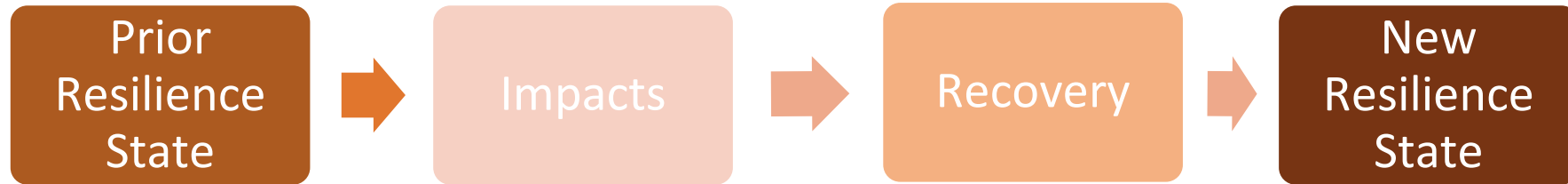
Primary Data Collection:

- Contact list for interviews (in progress)
    - Power (PREPA), water (PRASA) and transportation (DTOP), and at municipal level
    - In aggregate, 200 interviews of 1 hour duration
- Semi-structured Interview Instrument questions (in review; incorporating feedback)

Recent Progress: Dependencies (3/3)

Examples of draft interview questions; instrument currently undergoing review

Mark those activities that impacted the time to reach **/30%/** operation of the **/Water supply/** system.

- Securing new **/Water supply/** capacity
- Repair of the **/Water supply/** system
- Restoration of inputs needed for normal operation of the **/Water supply/** system (e.g., power)
- Restoration of the capacity of one or more other systems: ['Water treatment', 'Transmission', 'Distribution']

Indicate the approximate time, as referenced from the time of HM landfall, that it took to reach the milestone of **/critical buildings at 30% function/**, which is defined here as meeting all of the following minimums:

Access: 30% critical buildings receiving within /Caguas/
Reliability: 30%-of-day, min 5 days/week
Quantity: 30% of pre-HM total demand met
Quality: commensurate with boil water advisory

Was restoration of **/Power/** on the critical path to reaching the **/critical buildings at 30% function/** recovery milestone?

You indicated that **/Power/** was on the critical path to one or more of the recovery milestones. Which of the following were on the critical path to restoration of **/Power/**?

- Restoration of power service
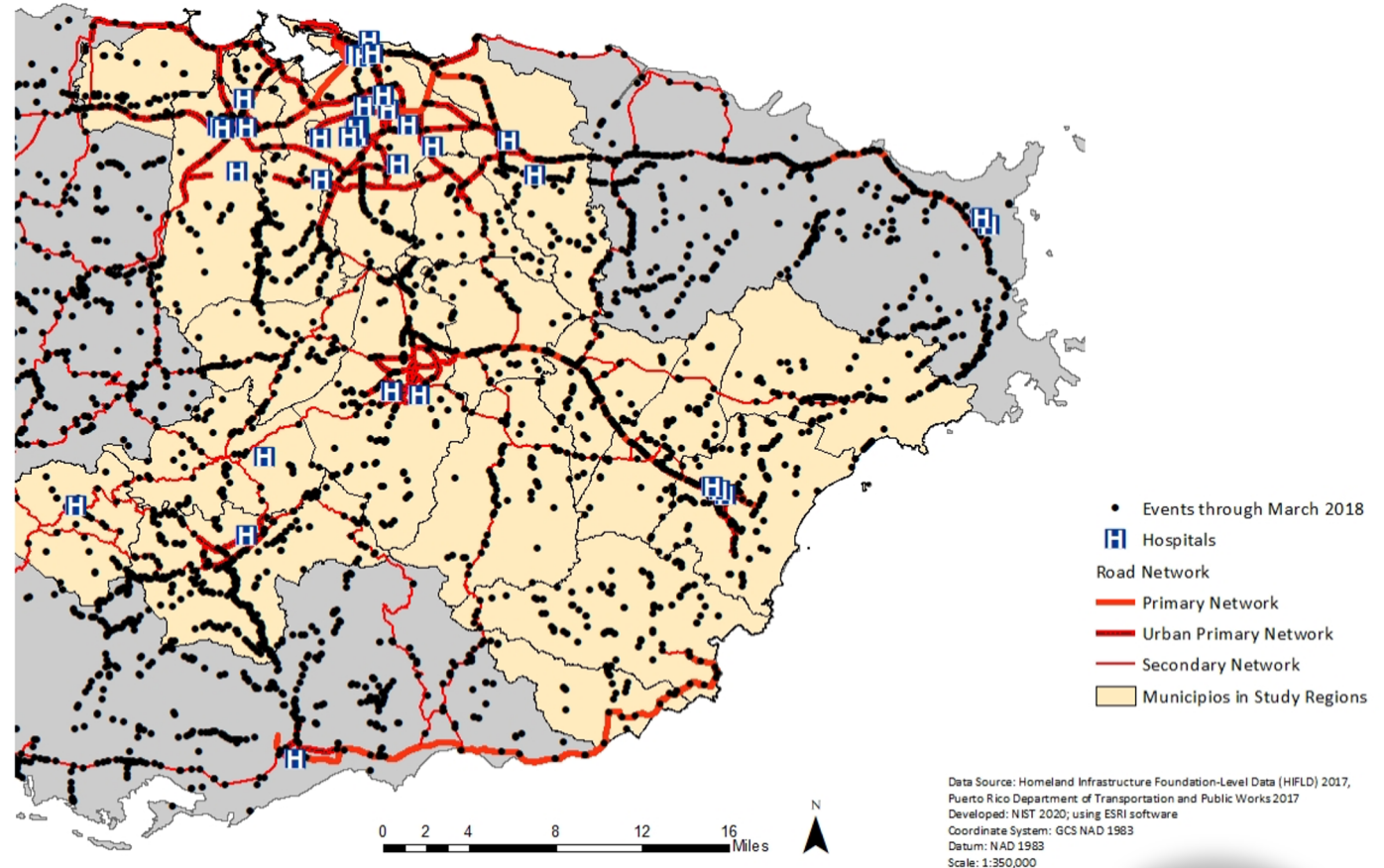- Repair of generator(s)
- Enough fuel on-site
- Other _____
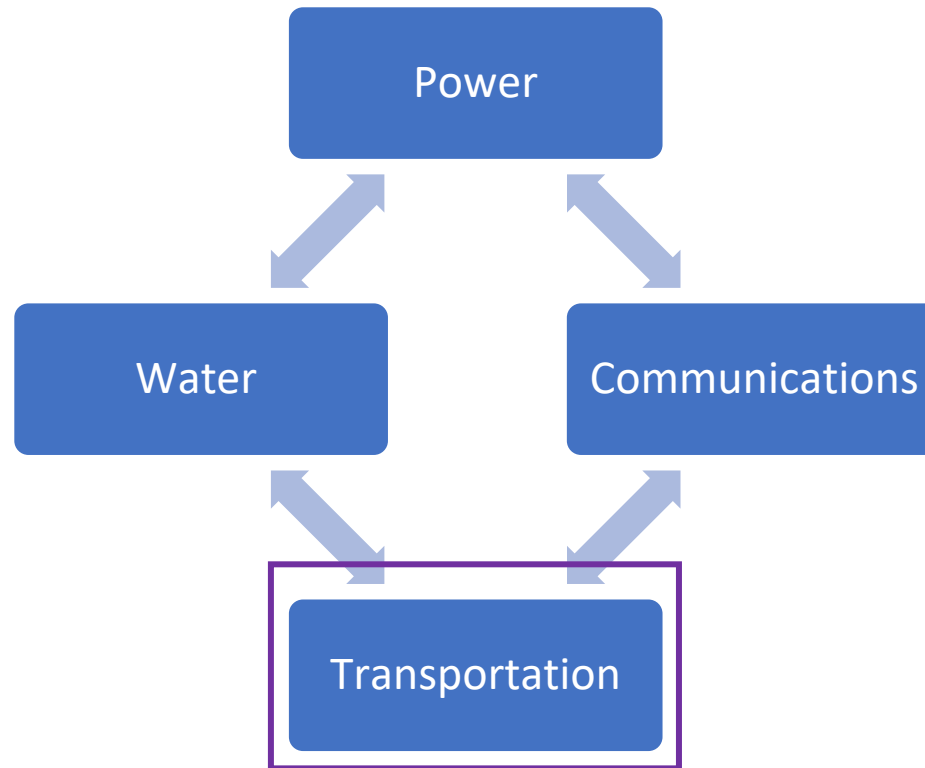
Transportation Incident Analysis (new project component)

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- *Transportation Incident Database* obtained from PR DTOP visit in 2019

- Aim: Process data to answer specific Hurricane Maria Program questions

- Requires mining database, primarily 'Incident Type' and 'Observations' fields

- Many data processing steps (see below)

Events through March 2018
Hospitals
Road Network
Primary Network
Urban Primary Network
Secondary Network
Municipios in Study Regions

Data Source: Homeland Infrastructure Foundation-Level Data (HIFLD) 2017,
Puerto Rico Department of Transportation and Public Works 2017
Developed: NIST 2020; using ESRI software
Coordinate System: GCS NAD 1983
Datum: NAD 1983
Scale: 1:350,000

0 2 4   8   12   16
Miles

Raw → **Translated** → **Quality Controlled** → **Processed** → **Results** → **Iterate**

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Recent Progress: Transportation Incident Analysis (3/4)

Classification of Incidents by Hazard and Impact
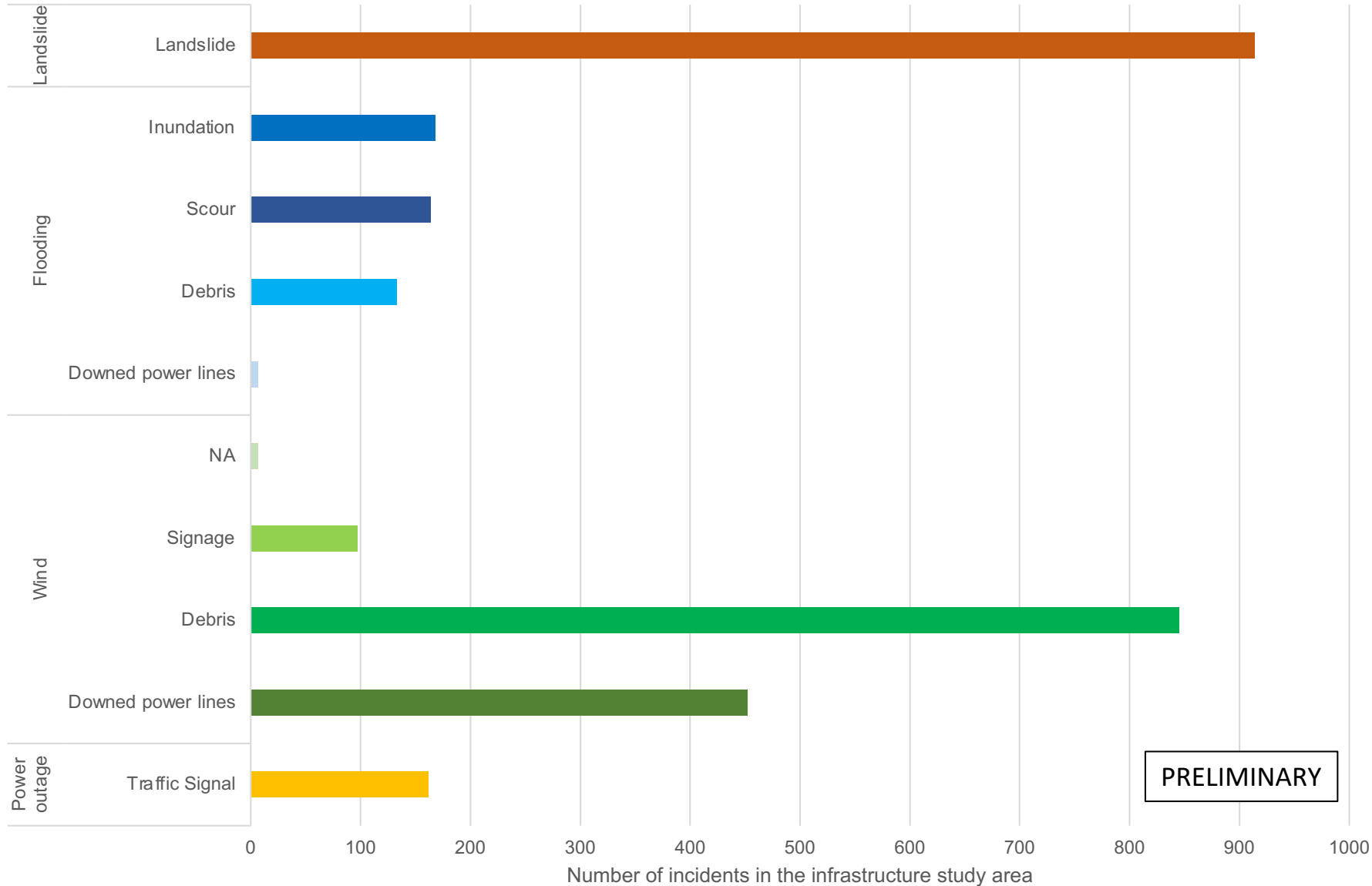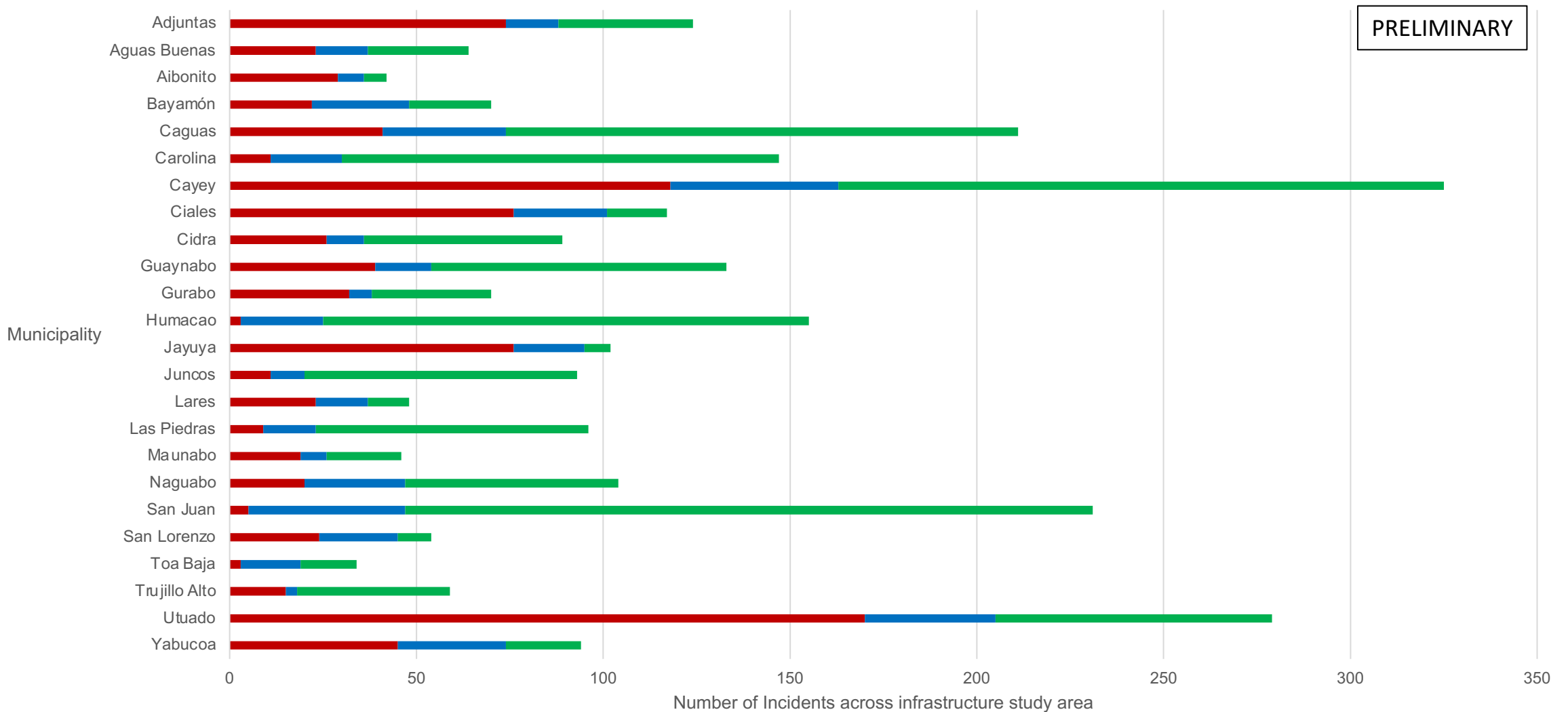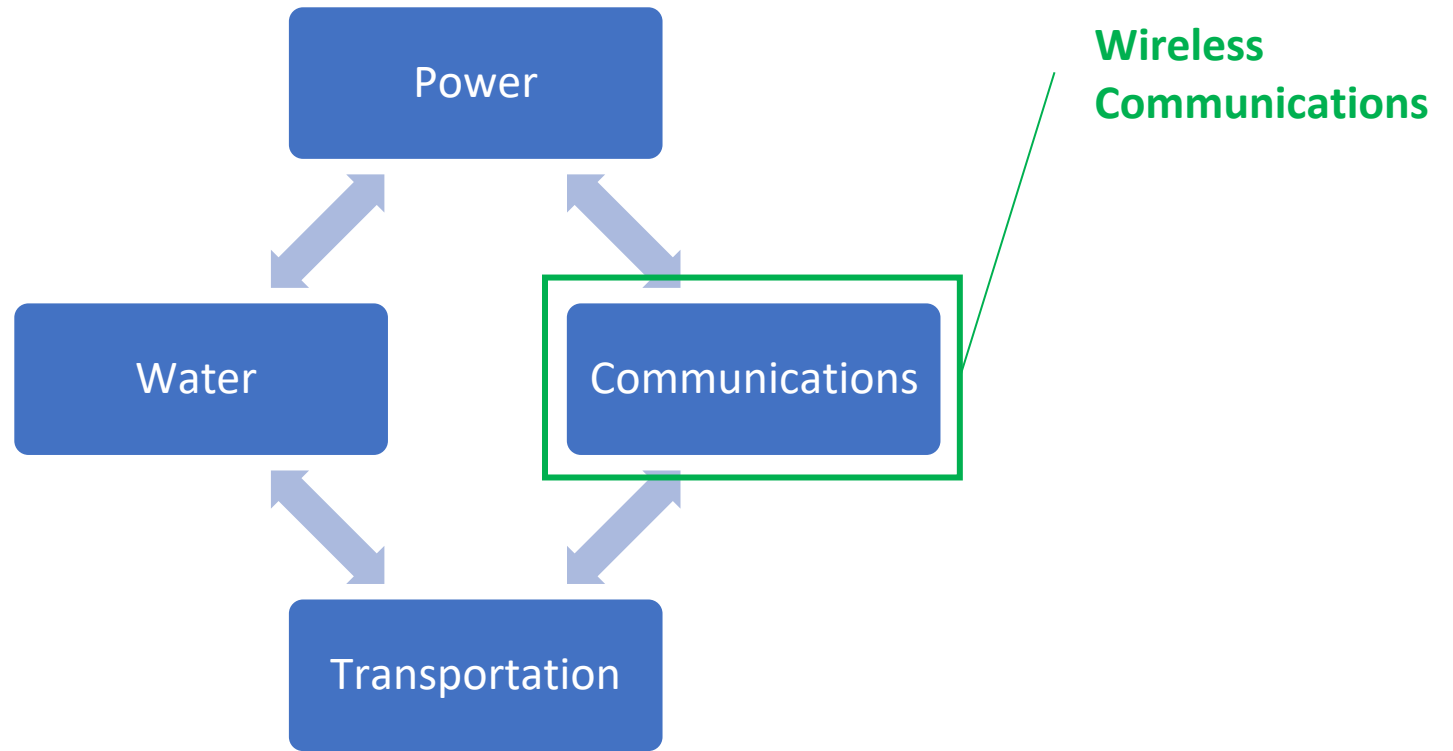
Recent Progress: Transportation Incident Analysis (4/4)
Classification of Incidents by Hazard and Municipality
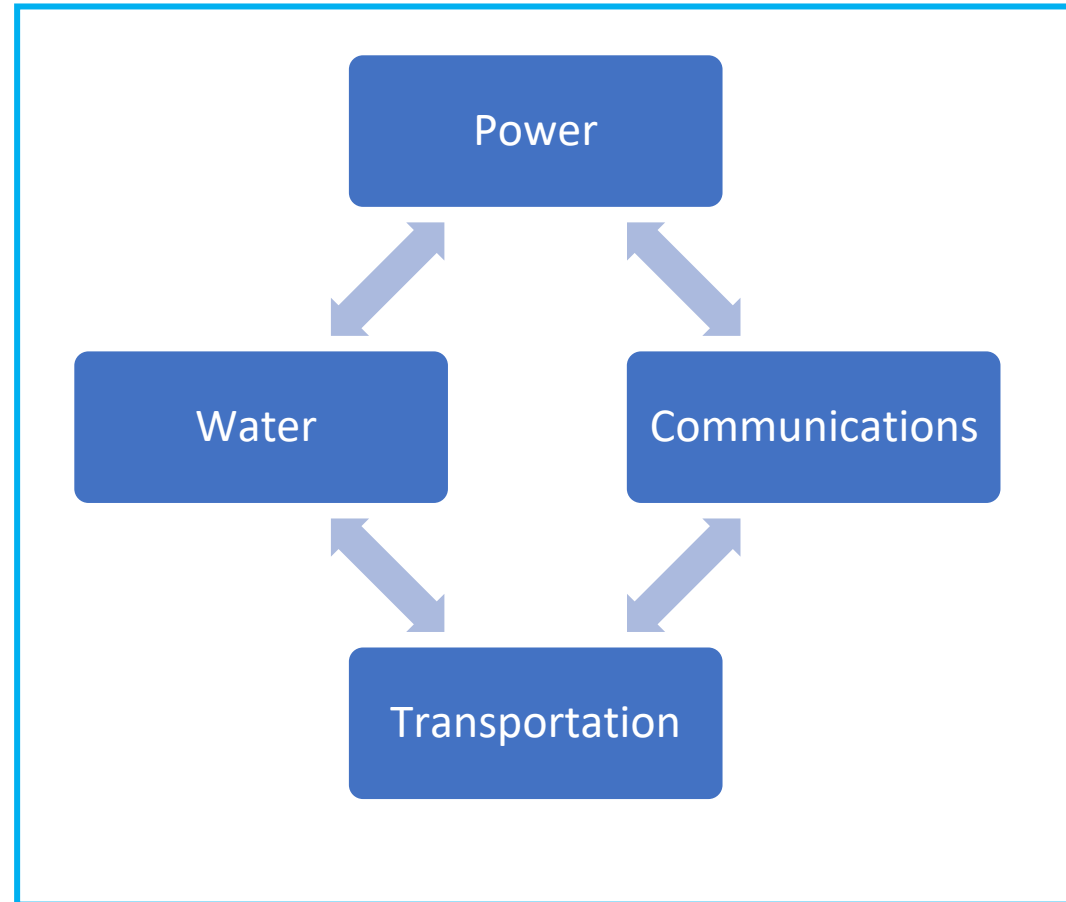
PRELIMINARY

Slide 12

Recent Progress: Wireless Communications (2/2)

- Conducted initial review of post-storm photo library received from American Tower Corporation
  - Documents post-storm conditions at 131 cell sites
  - Over 6,700 images

- Obtained additional data on cell site infrastructure from the Federal Communications Commission, including
  - Location of additional towers
  - Structure Type, such as
    - freestanding tower, guyed tower, mast, etc.
  - Construction Date
  - Ground Elevation
  - Tower Height

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Recent Progress: Integrative Study (1/2)

Integrative Study

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NIST ARC

An interactive tool for developing alternative sets of actions that meet community resilience and cost goals, given hazard and interdependency information, and socio-economic data.

Beta Version released 9/2020

Project Plan: Next Steps

Dependencies

- Complete pre-pilot draft of interview instrument
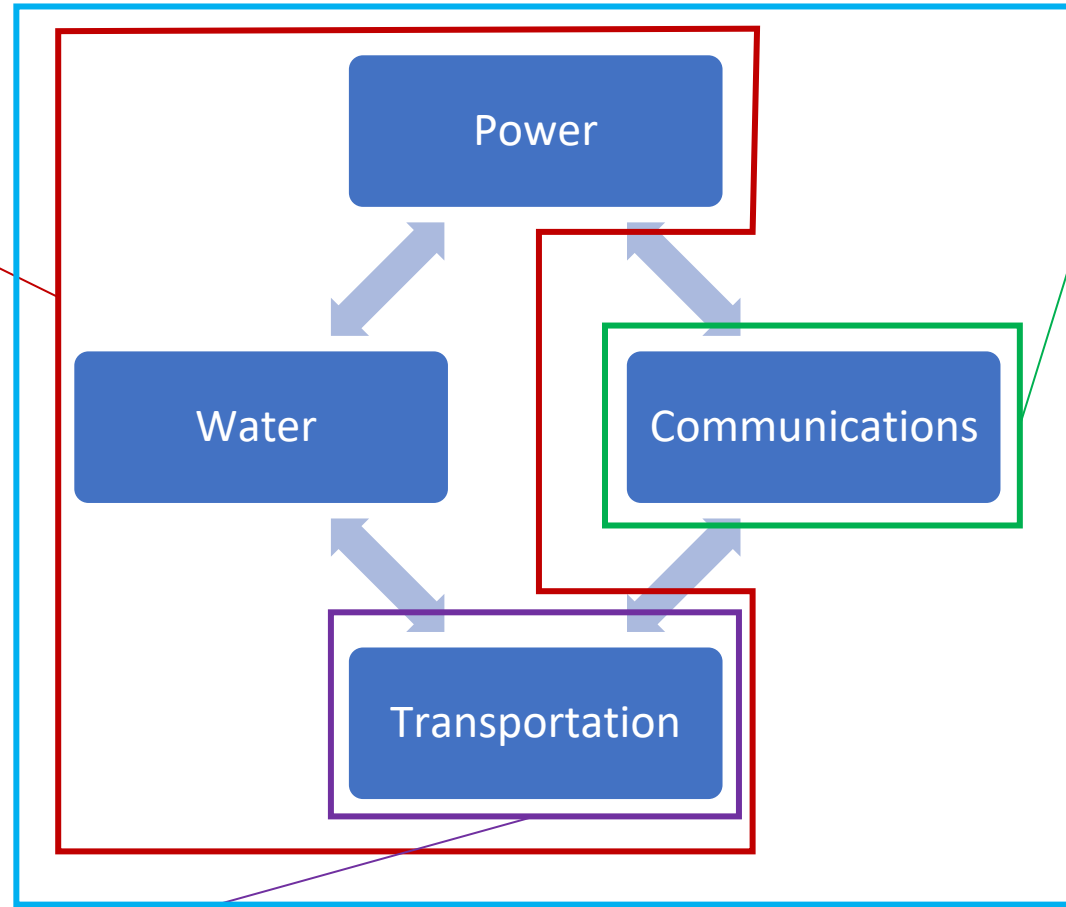
Wireless Communications

- Data collection/ processing/ mining
  - FCC cell site damage
  - American Tower Corp. photo library
  - Geo-database

Integrative Study

- New version of NIST ARC

Transportation Incident Analysis (new sub-project)

- Geospatial analysis

The diagram shows four blue boxes: Power, Water, Communications, and Transportation, connected by arrows.

NWIRP Research Study of Recovery from Hurricane Maria's Impacts on Puerto Rico

Infrastructure Systems Supporting Critical Buildings and Emergency Communications

Project Leader: Ken Harrison

Project Team: Marc Levitan, Jazalyn Dukes, Zeinab Farahmandfar, Horace Mitchell

Questions?

Please 'raise your hand' using the Blue Jeans Participant window and unmute your audio and video