Modeling Disaster Habitation for Improved Mitigation Project Analysis and Selection

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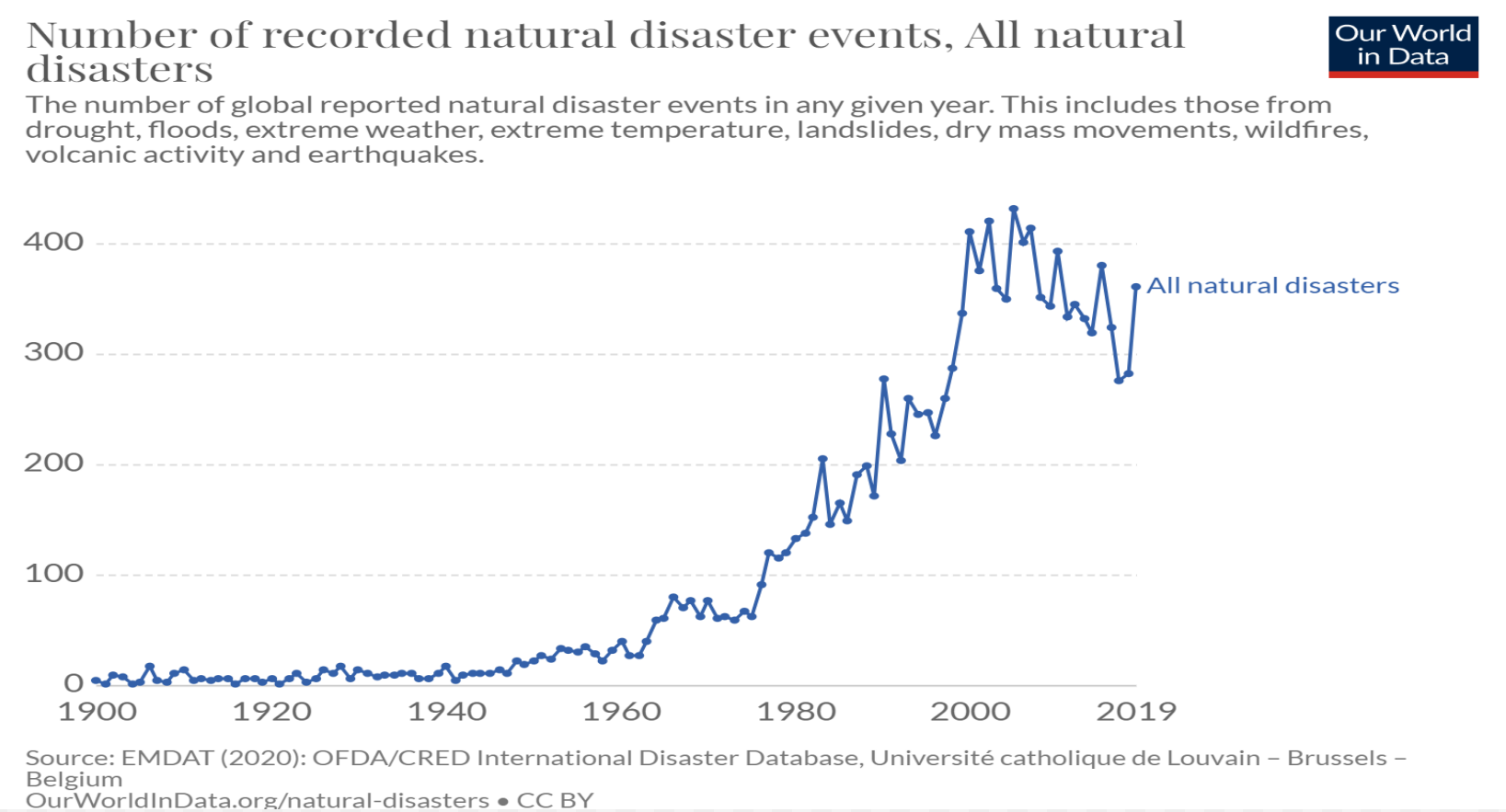
Context

Increasing Natural Disaster Risk



International Disaster Database EMDAT (2020)

1.3 billion people and **$158 trillion in assets** at risk due to **natural disasters** by 2050 (World Bank 2021)

The Natural Disaster Mitigation Project Analysis Challenge

Q.: How can proposed natural disaster mitigation projects be analyzed and selected to accurately reflect societal values?

Relevant Societal Values:

- **Humanitarian** - "Reduce the Nation's {natural disaster} risk and increase resilience to disasters" (USACE objective 2.1)
- **Efficient use of public funds** – "Effectively and efficiently execute response, recovery, and mitigation." (USACE objective 2.3)

Current Practice
(US Army Corp of Engineers)

- **Benefit:Cost Ratio (BCR) analysis for project selection**
  - BCR >> 1.0 and Max(BCR)
  - Biased toward easily-monetized benefits, e.g., rebuilding costs, lost incomes, national economic impacts
  - Focus on physical damage prevention and emergency cost savings
- **Fails to justify projects that primarily protect residential areas**
  - League City, Tx study – only 1 of 25 proposed projects BCR>1.0

Mitigation project analysis and selection based only on money leaves the humanitarian value out of consideration. Need to focus on *money and people, not just money*.

The Habitation Gap

Benefits of Habitation not in Current Analyses

Increased disaster habitation provides:

- Maintained demand for community enterprises
- Volunteers & participants of *NGO, houses of worship, etc*.
- Reduced *private disaster costs* to evacuate, relocate, re-habitate
- More operating schools - *less loss of learning* & required caregiving
- Reduced psychological *trauma & anxiety* due to evacuation/ relocation/ re-habitation
- More *trust in government's ability* to manage natural disasters
- More *public participation in governance* (e.g., public meetings, voting)
- Reduced shift of government and public focus & efforts to disaster

Improved mitigation project analyses need to include the benefits of habitation.

The Policy Change

In 2021, the USACE expanded the breadth of impacts to be included in natural disaster mitigation project analyses to include:

1) Regional economics
2) Environments
3) **Other social effects**, including "urban, rural and community impacts; ***life, health***, and safety factors; ***displacement***; and long-term productivity."

Modeling habitation provides the opportunity to measure life, health, and displacement impacts.

But this requires rigorous methods and tools to meet the "efficient use of funds" requirement.

The Research Question

How can the impacts of proposed natural disaster mitigation projects on habitation be rigorously modeled and quantified for project analysis and selection?

A Framework for Modeling Disaster Habitation

- Focus on Disaster Mitigation
- Disaster Habitation Definition – a fully operational residence
- Critical Internal Infrastructure Systems (CIIS)
- Disaster Habitation Experience Zones
- Rich measuring of Habitation Performance…

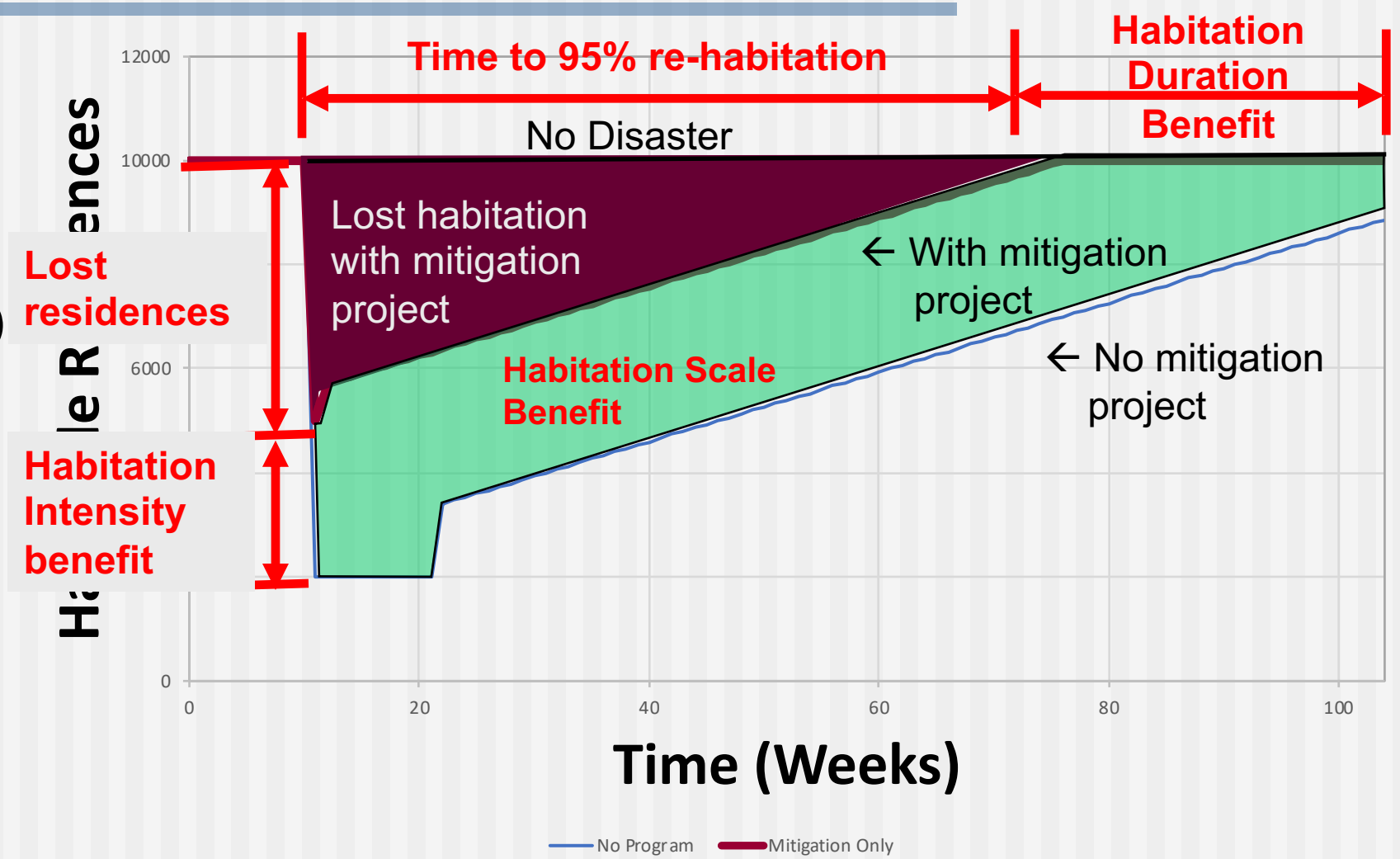
Focus: Pre-event system design and construction to control post-event dynamic habitation behavior

Measuring Disaster Habitation

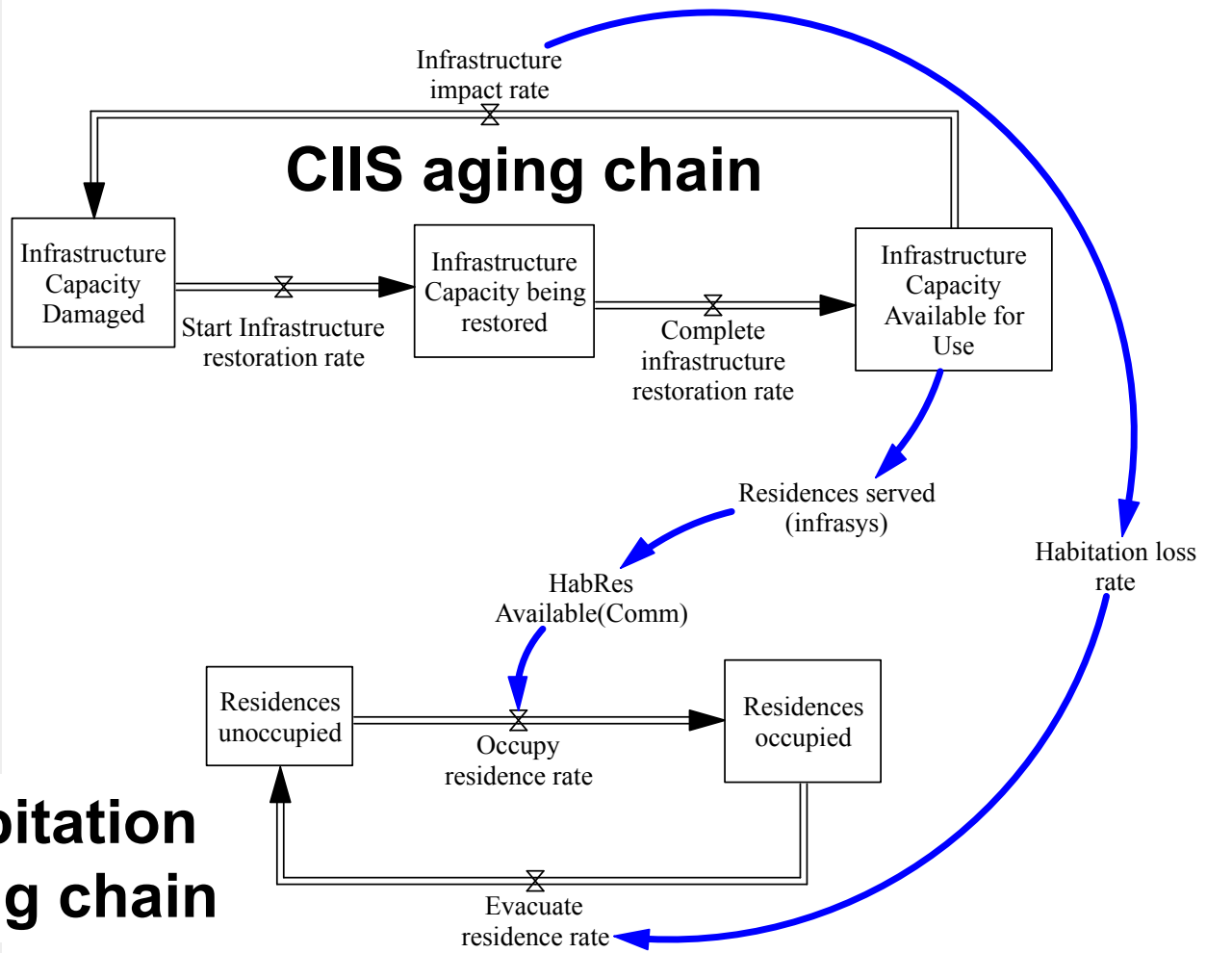
Stylized Behavior over Time Graphs

Habitation Performance Measures

- **Intensity** (res. or % lost)
- **Scale** (res.-wk. or %)
- **Duration** (time to 95% re-habitation (wk.))



Core Model Structures



- One aging chain structure per CIIS
- Linked CIIS structures (through calibration)
- CIIS damage(t) → Displacement
- CIIS restoration(t) → Re-habitation
- **Scenario**: community, event, mitigation

Case Study of Proposed Flood Mitigation #1

Halls Bayou Watershed Study Area

Halls Bayou: 20 miles long, 37 tributaries
Area: 60 square miles
Population: 200,489 (2020)
% Low-Moderate Income: 70%
Residences: 64,655 (2020)

2018 Harris Co (Houston) Flood Mitigation Bond Program

$2.5 billion with $350 million for Halls Bayou Watershed

- 11 stormwater detention basins
- Channel improvements

Data Sources and Uses

Halls Bayou Watershed Study, Houston, Tx

Data Sources

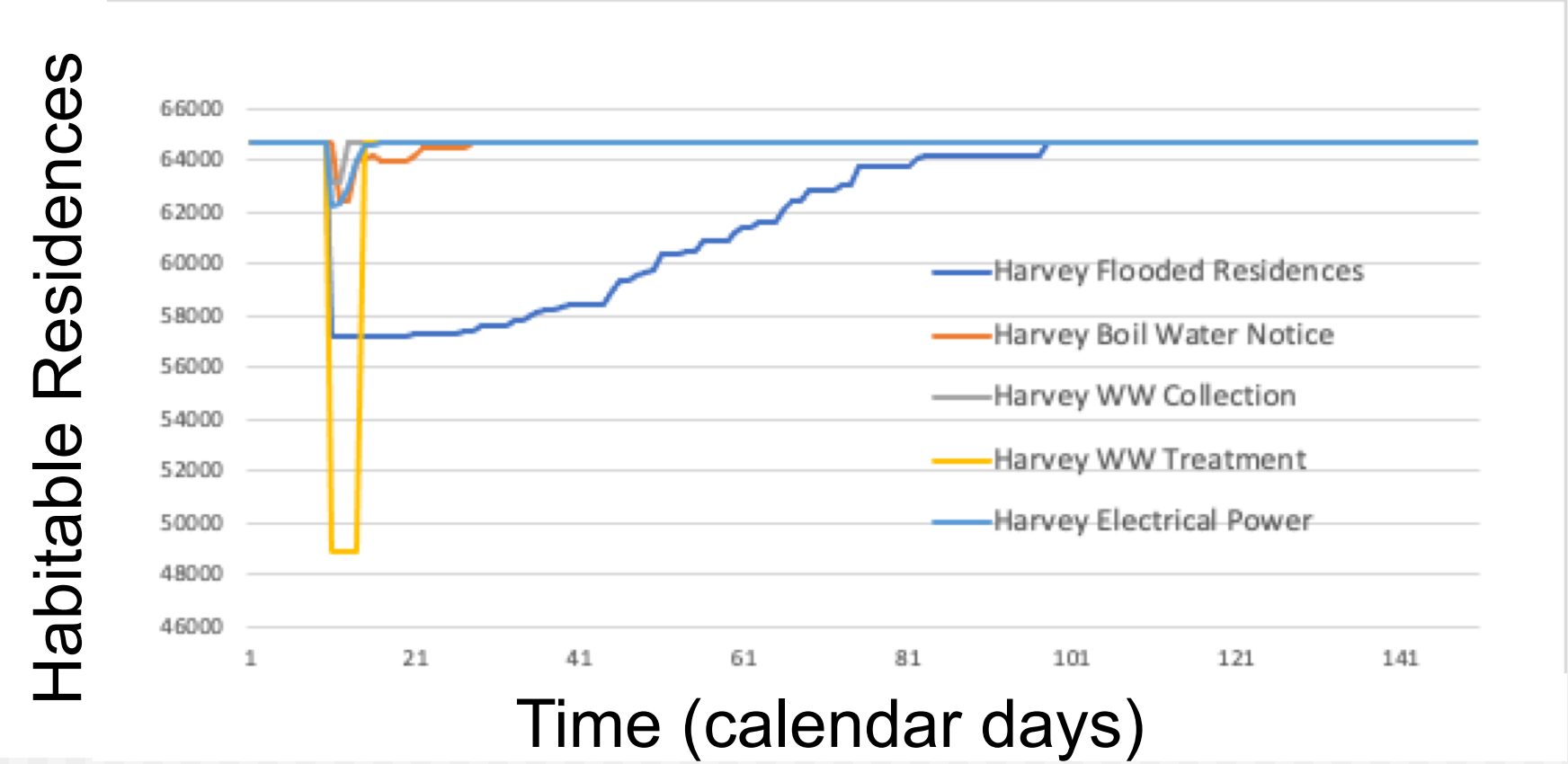
- Structure Inventory, HCFCD (residence locations and elevations)
- 2020 US Census data (populations in 115 census block groups)
- Hurricane Harvey flooding records (water surface elevations)
- Hydrologic / Hydraulic flood simulation output (100-yr & 500-yr flooding)
- Public utilities and TCEQ (Hurricane Harvey service losses)
- Subject Matter Experts (infrastructure damage and restoration processes)

Data Uses in Modeling

- Model structure development
- Model calibration (to Hurricane Harvey & simulated storms)
- Model validation (data-based reference modes, parameter estimation)

Example Simulation Results

Halls Bayou Watershed, Houston, Tx after Hurricane Harvey (2017)

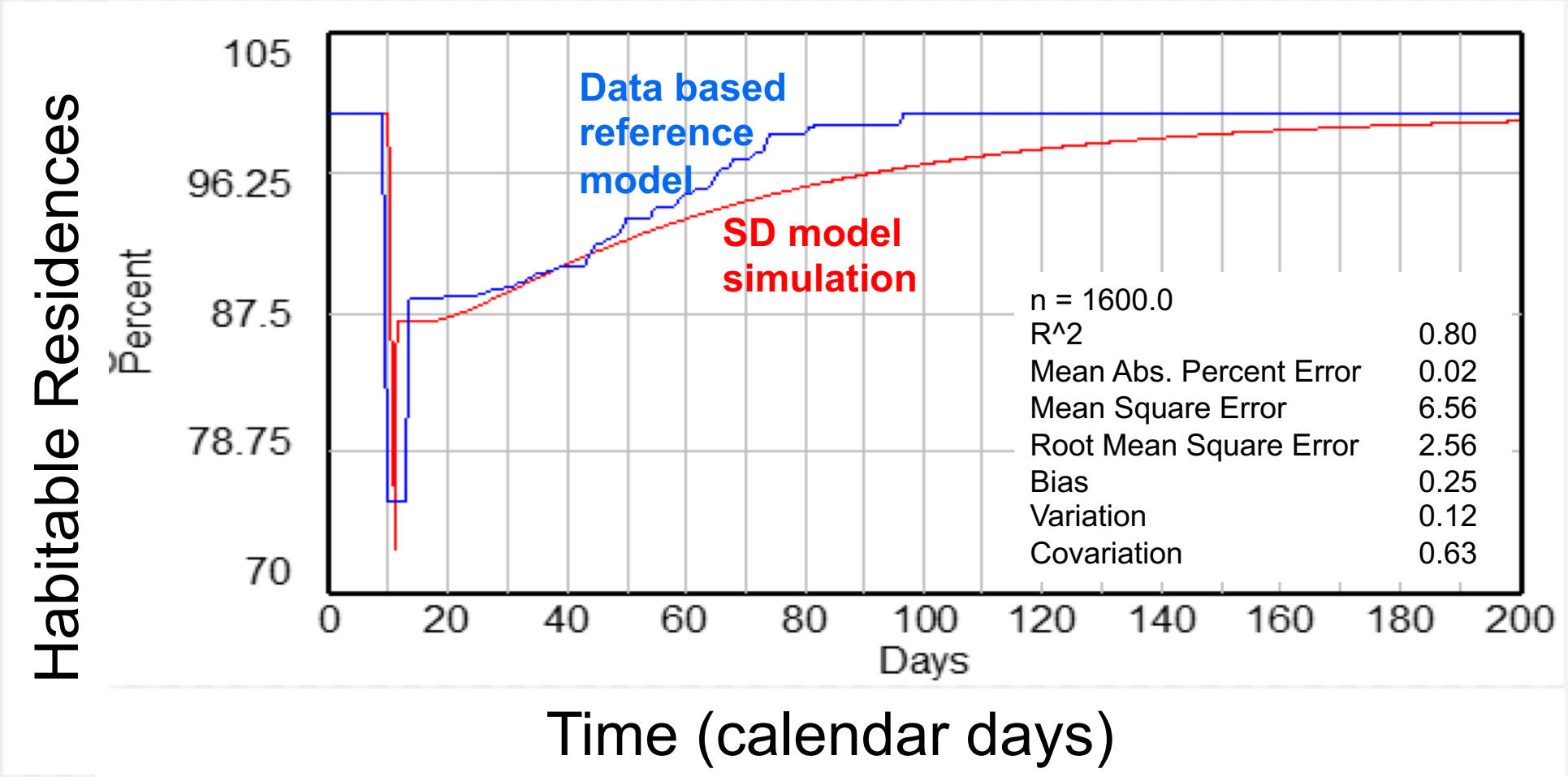


Modeling infrastructures separately and then integrating their habitation impacts is critical to explaining habitation BOT

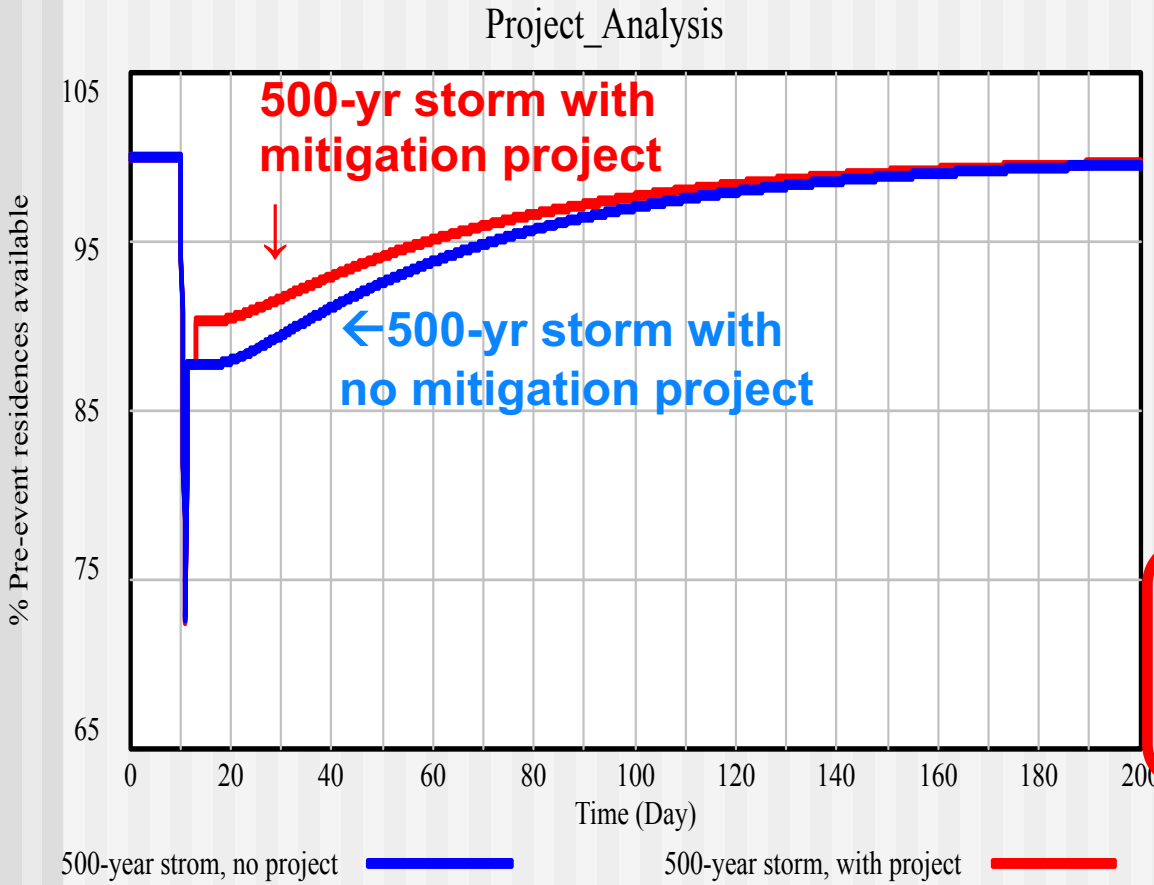
Individual infrastructure BOTG reveal the drivers of specific habitation performance metrics.

Model Behavior Validation

Halls Bayou Watershed, Houston, Tx after Hurricane Harvey (2017)



Disaster Mitigation Project Analysis



	Habitation Loss Metric		
	Intensity	**Scale**	**Duration**
Unit of Measure	Residence	Res*Days	Days
500 Yr event - No Project	15,734	554,323	148
500 Yr event - Project	15,734	454,003	134
Improvement	**0**	**100,320**	**14**
Percentage Improvement	**0%**	**18%**	**9%**

Halls Bayou Watershed, Houston, Tx after Hurricane Harvey (2017)

Case Study of Proposed Flood Mitigation #2

Buffalo Bayou & Tributaries (BBTR)

Buffalo Bayou: 20 miles long
Area: 487 square miles
Population: 1,684,626 (Census 2020)
% Low-Moderate Income: 41%
Residences: 520,244 (2020)

Proposed BBTR Flood Mitigation Project

$30 billion, 10-15 year construction

- 130 miles of tunnels up to 40' diameter
- Inverted siphons discharge into Houston Ship Channel

Contributions

MODELING

- Dynamic framework for modeling disaster habitation
- Validated system dynamics model of disaster habitation

DISASTER PLANNING, ANALYSIS, AND MANAGEMENT

- Rigorous inclusion of habitation benefits in project analysis
- Basis for improved federal policies for mitigation project analysis and selection
- Potential for saving more lives and property
- Improves adaptation to climate change

Other Recent, Current, and Future Work

- Model analysis to identify high leverage points - *completed*
- Model four watersheds in Houston to analyze proposed community-wide mitigation programs – *just completed*
- Formal method and model review (and approval) by USACE – *in progress*
- Meet (again) with congressional representatives and staff concerning inclusion in federal policy
- Expand models to investigate mitigation project impacts on sub-populations (equity issues)
- Expand to model disaster recovery phase management