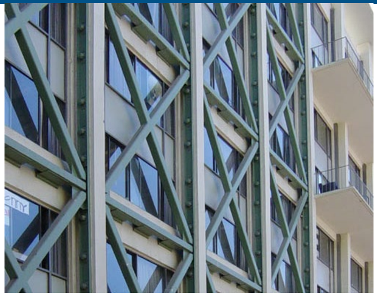
Assessing the Losses Avoided from the Adoption of Building Codes: A Multi-Hazard Nationwide Study


FEMA Resilience Lunch and Learn

Wednesday, August 7, 2019

Presented by: Ed Laatsch (FEMA), Nathan Montague (ABS Group), and Nick Thompson (AECOM)

Disclaimer

- FEMA does not endorse any non-government entities, organizations, or services.
- This slide deck has been amended as of August 26, 2019

Introduction

Brief History of Project

NMIS Goal 3, Recommendation 3.1:

- Encourage Communities to Adopt and Enforce Up-to-Date Building Codes.

Mitigation Saves 2.0

- NIBS found that designing buildings to the 2018 I-Codes results in a national benefit of **$11 for every $1 invested**, when compared to earlier codes and NFIP regulations.

2017 MAT Report: Hurricane Harvey in Texas

- The MAT found that in one neighborhood NFIP Regulations reduced average claim payments by almost half and including freeboard (as required in modern building codes) further reduced the average claim payments by an additional 90%.

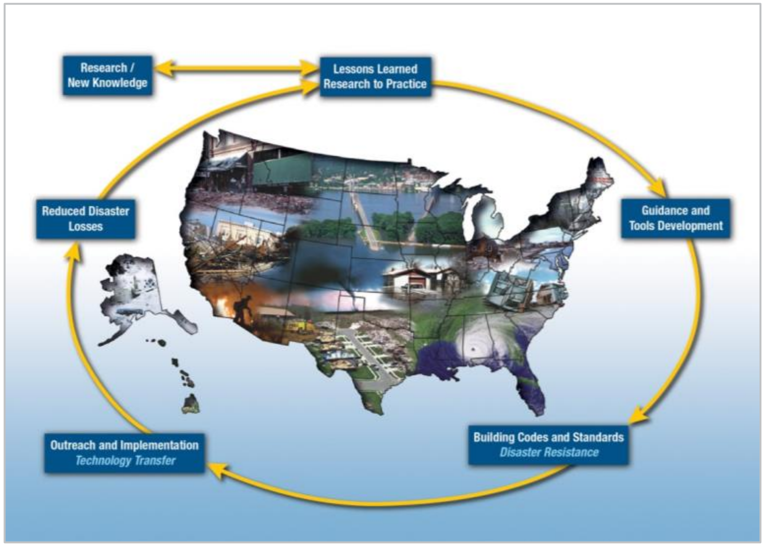
Overall Project Objective

Incentivize Community Mitigation

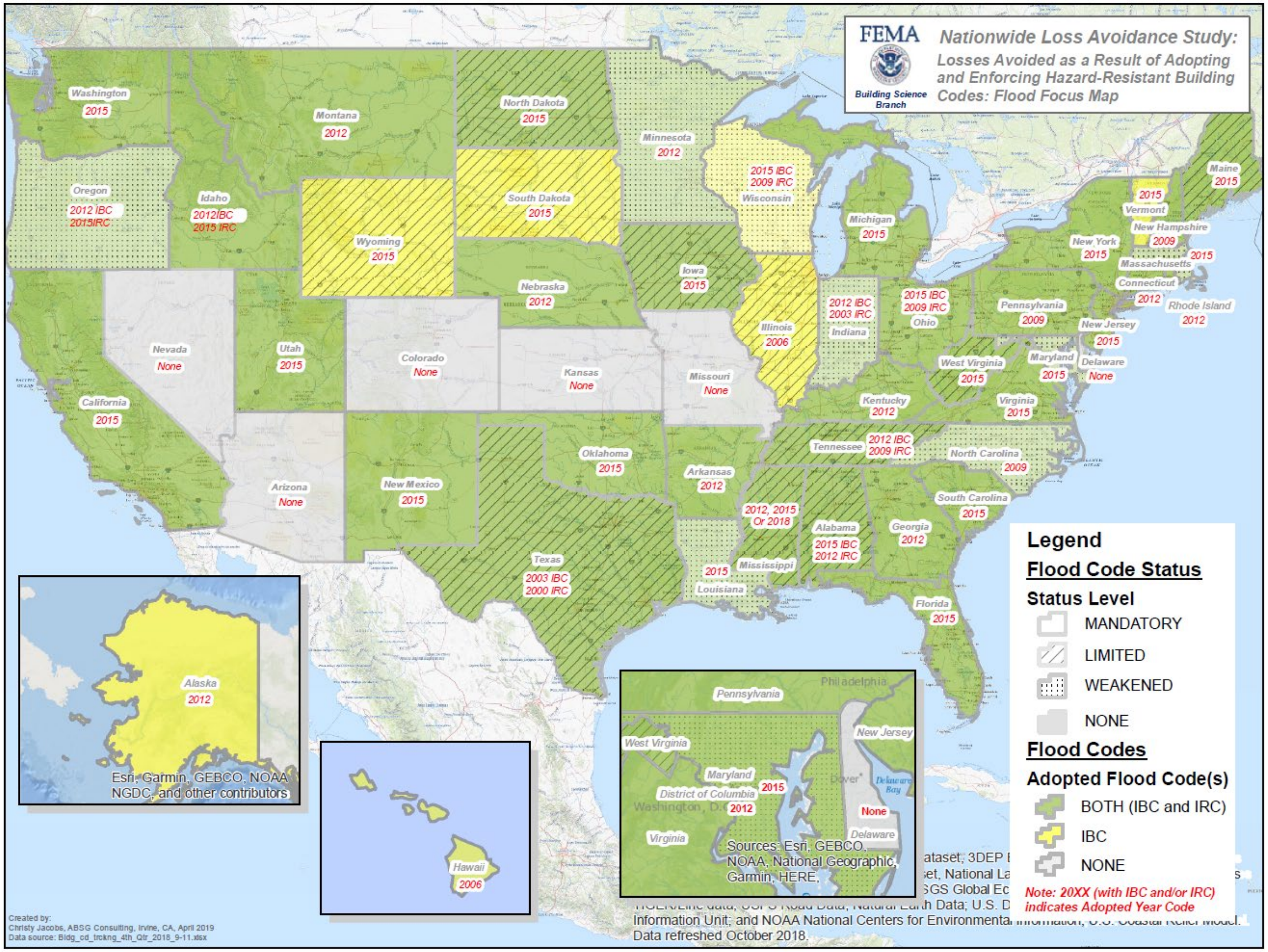
- Demonstrate the value of adopting and enforcing hazard-resistant building codes nationwide
- Incentivize building code adoption to reduce disaster losses
- Inform local investment decisions to increase resilience

Quantify Disaster Risk Reduction

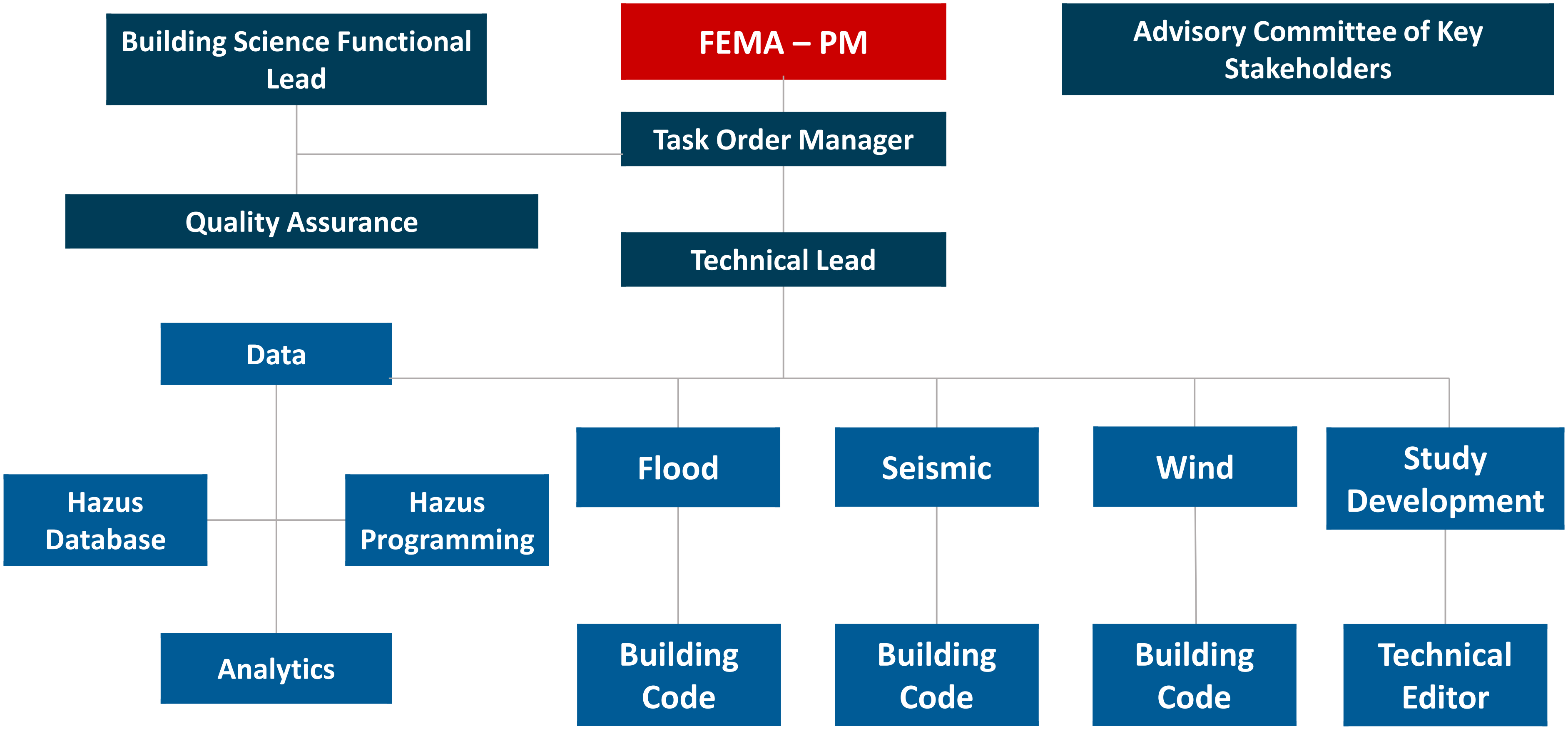
- Identify anticipated damages prevented during natural hazards due to provisions in modern building codes.
- PPD-8, PPD-21, Federal Flood Risk Reduction Standard, BW-12, FIMA Strategic Plan, NMIS



Code Adoption Status



Team


FEMA – PM
Building Science Functional Lead
Advisory Committee of Key Stakeholders
Task Order Manager
Quality Assurance
Technical Lead
Data
Hazus Database
Hazus Programming
Analytics
Flood
Seismic
Wind
Study Development
Building Code
Building Code
Building Code
Technical Editor

Study Phases

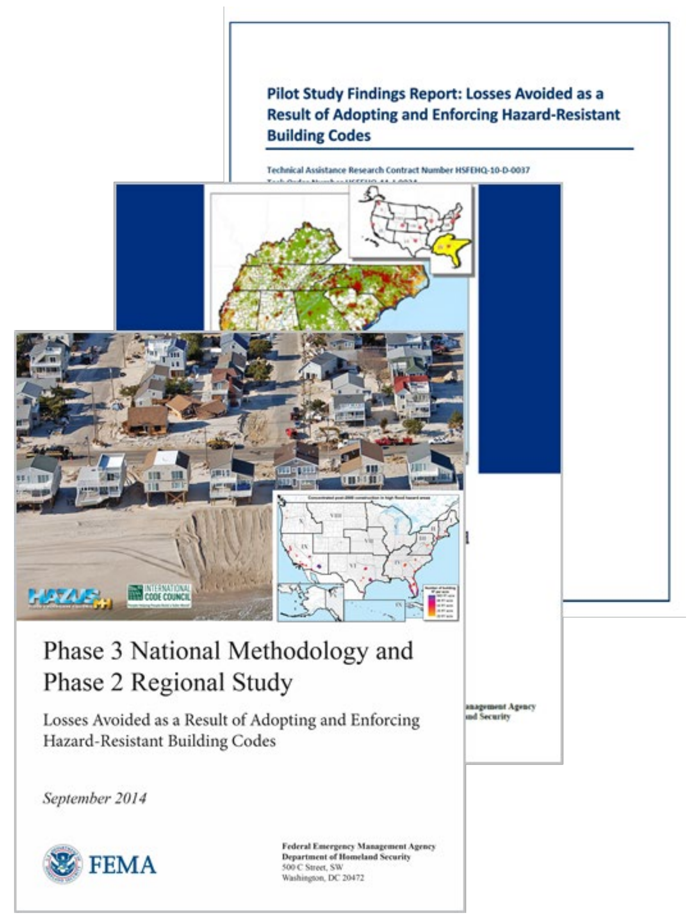
Phase 1: Pilot Study (2012)

- SC and UT
- Issues: Structure and hazard data availability and local building code information, Hazus analysis

Phase 2: Regional Study (2014)

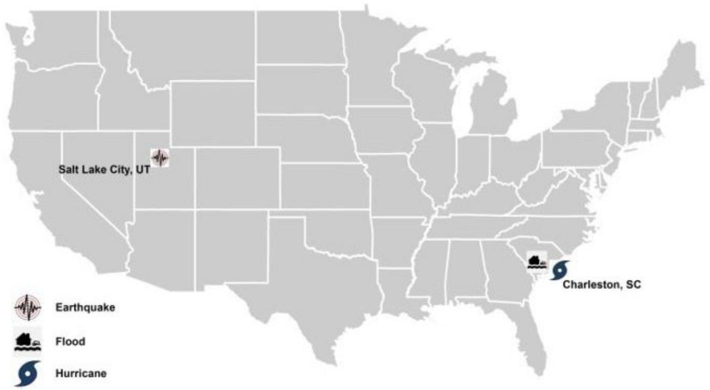
- FEMA Region 4
- CoreLogic data in SFHA only
- Issues: Data processing and gap filling, hazard data, building code assumption, large scale Hazus analysis

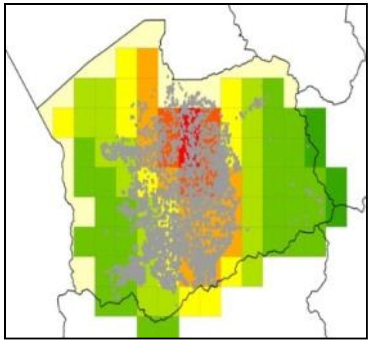
Phase 3: National Methodology (2014)
Phase 4: Nationwide Study (2020)

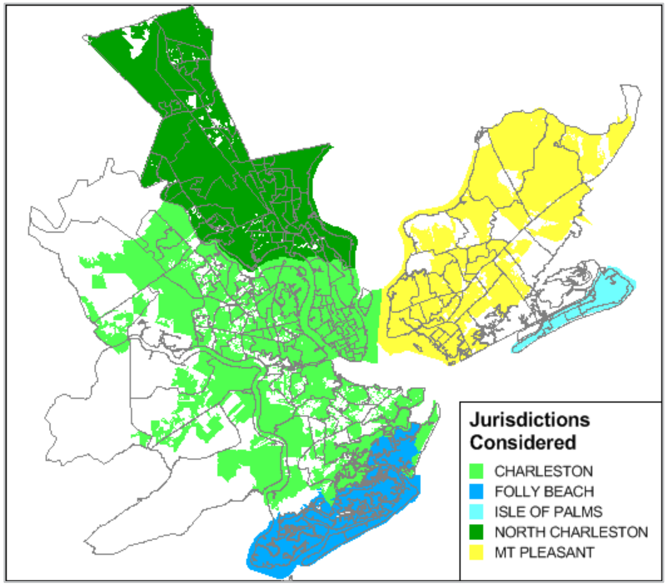


Phase 1 – Pilot Study

- **Purpose**: Test initial concept in city where data is available
- **When**: Conducted in 2011
- **Site selection:** Considered community ratings, hazard exposure, size, data availability and quality
- **Pilot study communities**:
  - Hurricane and flood hazards – Charleston County, SC
  - Seismic hazard – Salt Lake County, UT







Phase 1 – Pilot Study

Flood Summary

Scenario	Lower Bound Depth-Damage Function ($1,000)	Upper Bound Depth-Damage Function ($1,000)
1 foot of freeboard	33,000	66,000
2 feet of freeboard	51,000	103,000

Hurricane Summary

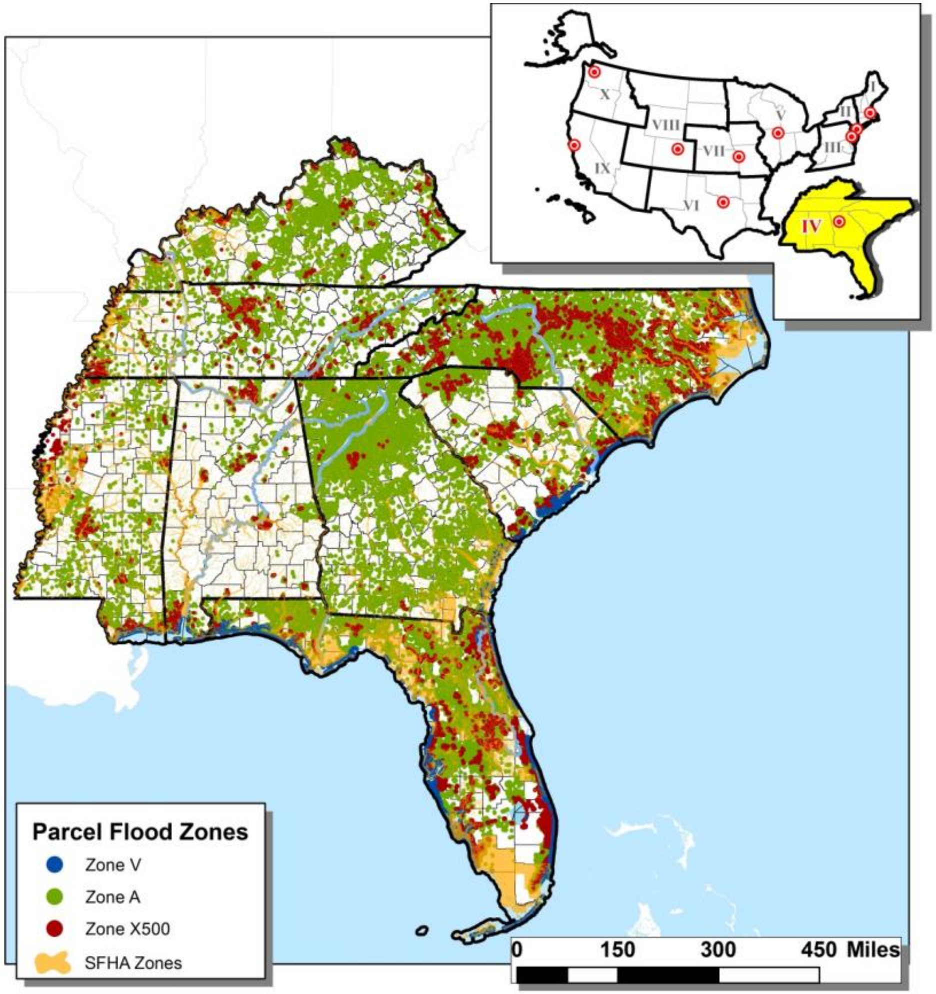
Recurrence Interval	Losses Avoided ($1,000)
20-year (Category 1 Hurricane)	1,500
100-year (Category 2 Hurricane)	132,000
500-year (Category 3 Hurricane)	1,649,000

Earthquake Summary

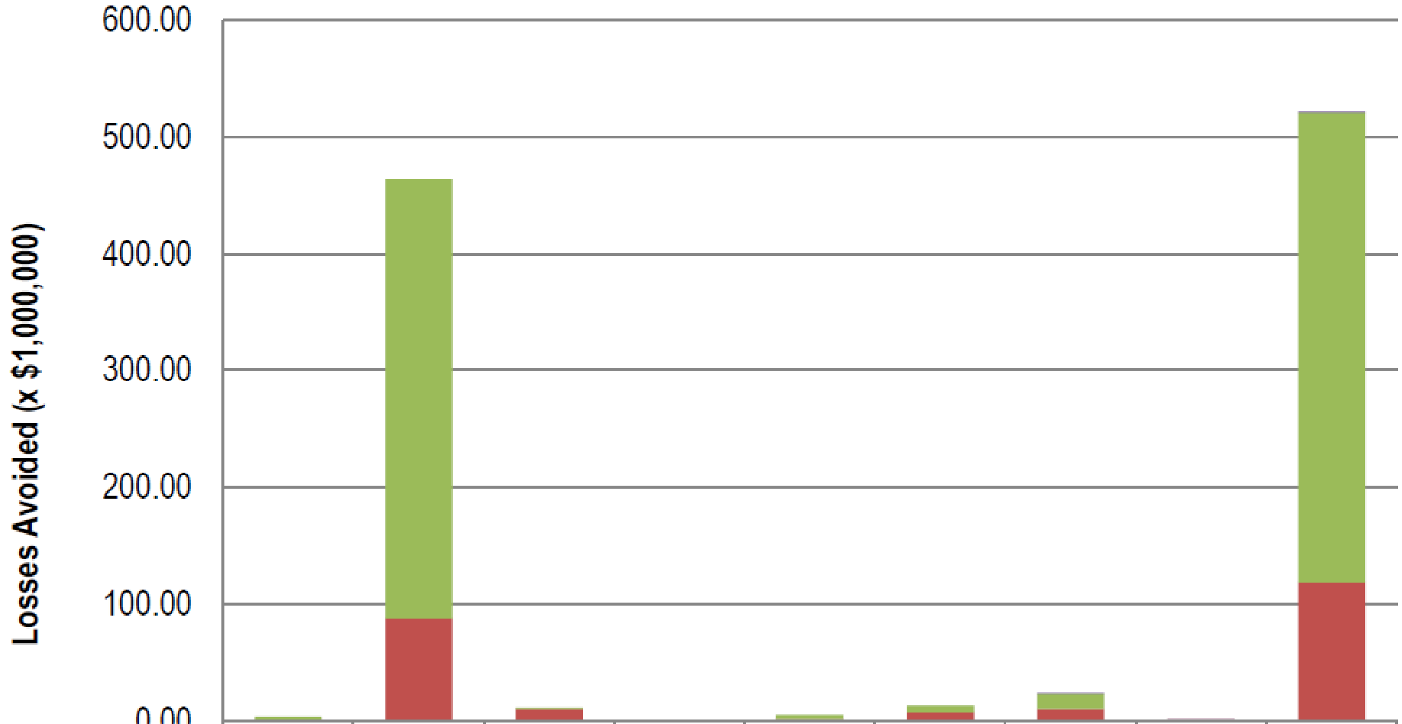
Scenario	Losses Avoided ($1,000)
M7.0 Salt Lake City Segment, Wasatch Fault	493,000
M7.2 Provo Segment, Wasatch Fault	228,000
M6.0 West Valley/ Taylorsville	145,000

Phase 2 – Regional Study

- **Purpose**:
  - Expand and refine Phase 1 method
  - Apply systematically to region as demonstration study
- **Site Selection:**
  - All 10 FEMA Regions were evaluated
  - FEMA Region IV was selected
- **Scope:**
  - Study area: 4.5M parcels
  - Focus on SFHA & 500-year floodplain
  - Flood, wind, seismic hazards



Phase 2 – Regional Study
Results Summary

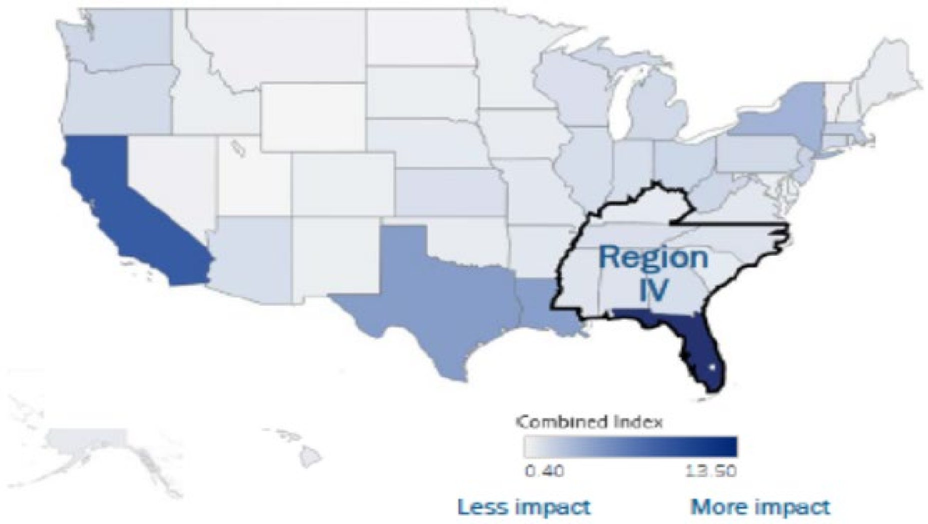


	AL	FL	GA	KY	MS	NC	SC	TN	Total [1]
Seismic Losses Avoided (x $1,000,000)				0.03			0.85	0.06	0.94 [2]
Hurricane Losses Avoided (x $1,000,000)	2.90	376.30	0.96		3.60	5.60	12.80		402.16[3]
Flood Losses Avoided (x $1,000,000)	0.83	87.63	10.10	0.42	1.30	7.30	10.08	0.94	118.60

Phase 2 – Regional Study

Incentivize adoption and enforcement of hazard-resistant building codes nationally

Relative Impact to States for Adopting Model Building Codes[b]



Saves a billion?

Probably - Based on the FIMA-led Losses Avoided Study, **Region IV's** average annual losses avoided from adopting building codes is **$532 M.**[a]

What might it save us nationally?

Combining the states‘

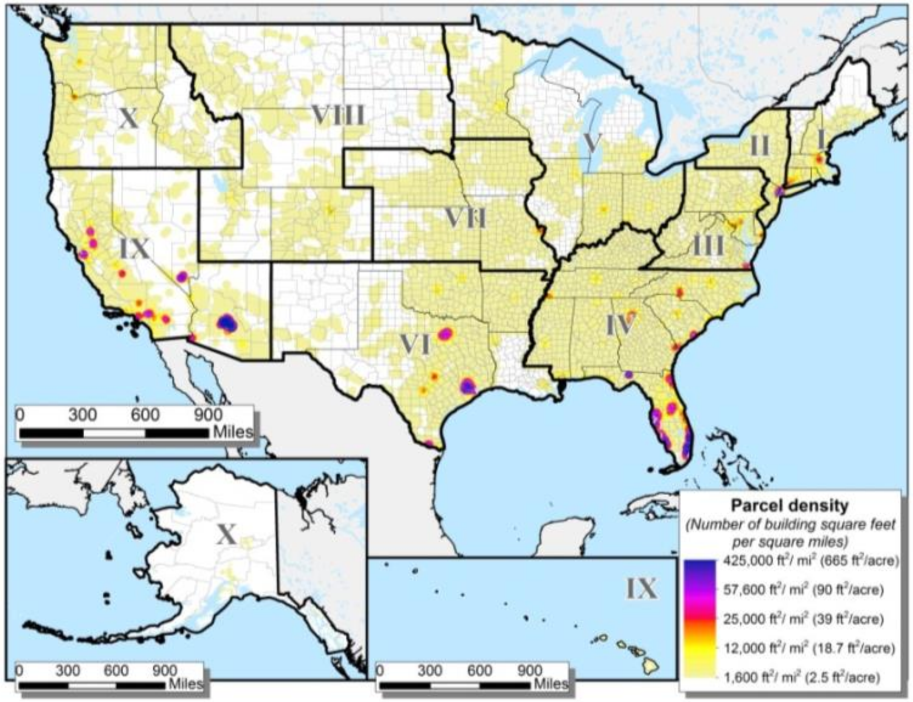
- hazard risk and
- building code adoption and enforcement,

we determine how Region IV compares to the rest Of the country and estimate losses avoided of:
$1.25 B-$2.06 B annually.[c]

[a] Based on FIMA's 2012 Losses Avoided Study, adjusted to 2015 dollars. This estimate does not include lives saved, decreased business interruption or other unaccounted for benefits. The value is expected to increase over time as more of the building stock transitions to model codes and older structures are removed.
[b] State Building Code Enforcement Grading Schedule (BCEGS) scores combined with Average Annual Loss estimates to create a relative impact index. States with low impact values will still benefit from codes.
[c] Average annual losses avoided nationwide. This number is an estimate. A nationwide losses avoided study is needed to get a more precise figure.

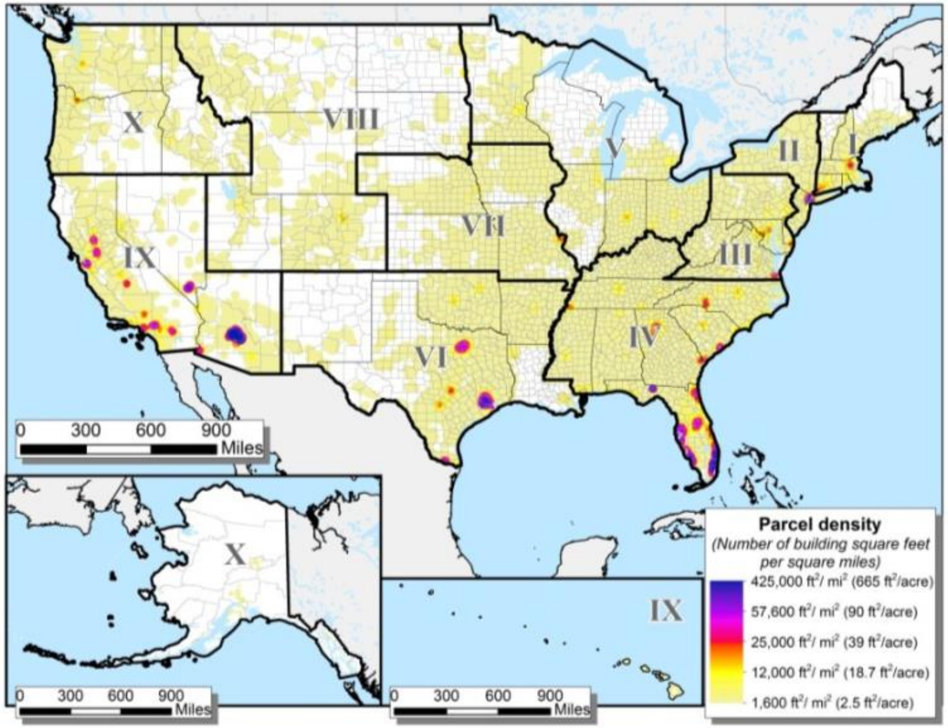
Phase 3 – National Methodology

- **Step 1** – Perform data collection and screening
  - BCEGS, State Fact Sheets, Parcel, CRS, SFHA, NFHL, Bing Footprint, ASCE-7 & USGS Hazard Maps
- **Step 2** – Input data into Hazus (or equivalent analysis)
- **Step 3** – Adapt damage curves
- **Step 4** – Compute and analyze losses avoided
  - Flood within SFHA
  - 22 Hazus Hurricane States
  - 6 western seismic states

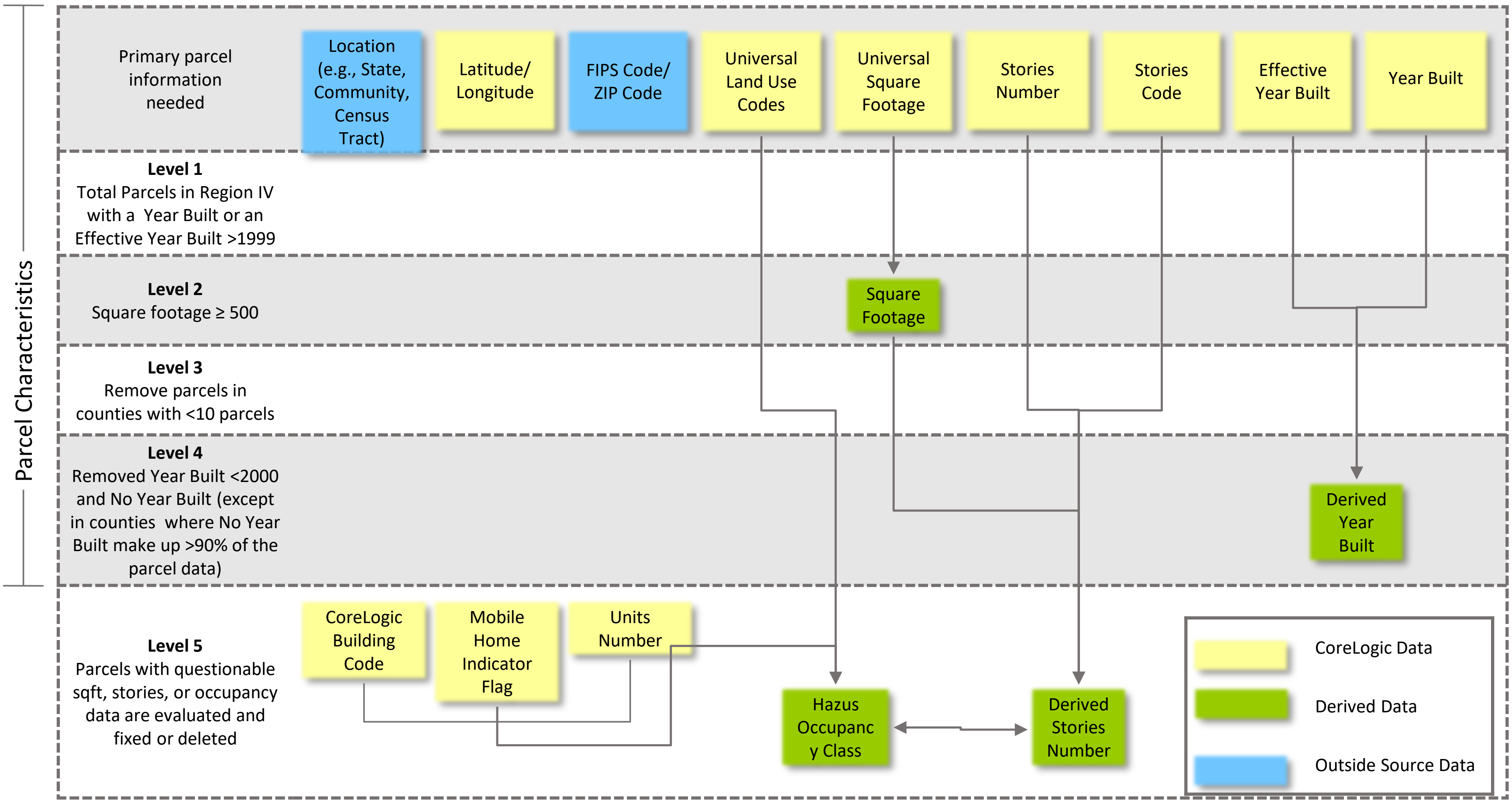


Phase 3 – National Methodology, Cont'd

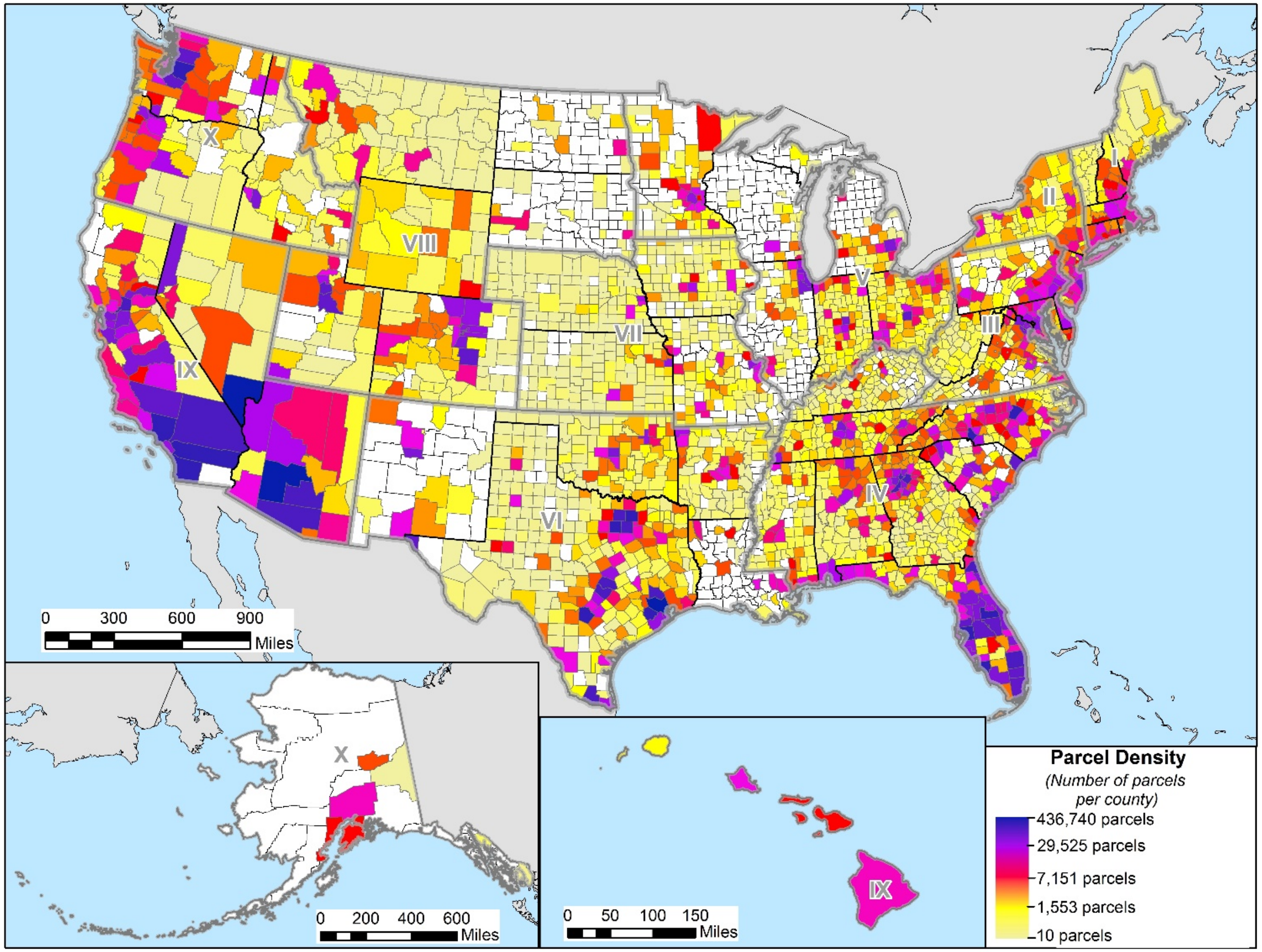
- **Step 5** – Evaluate findings (sensitivity analysis)
- **Step 6** – Perform QA
- **Screening Focus**
  - Areas of growth and exposure
  - Buildings constructed after I-Code adoption



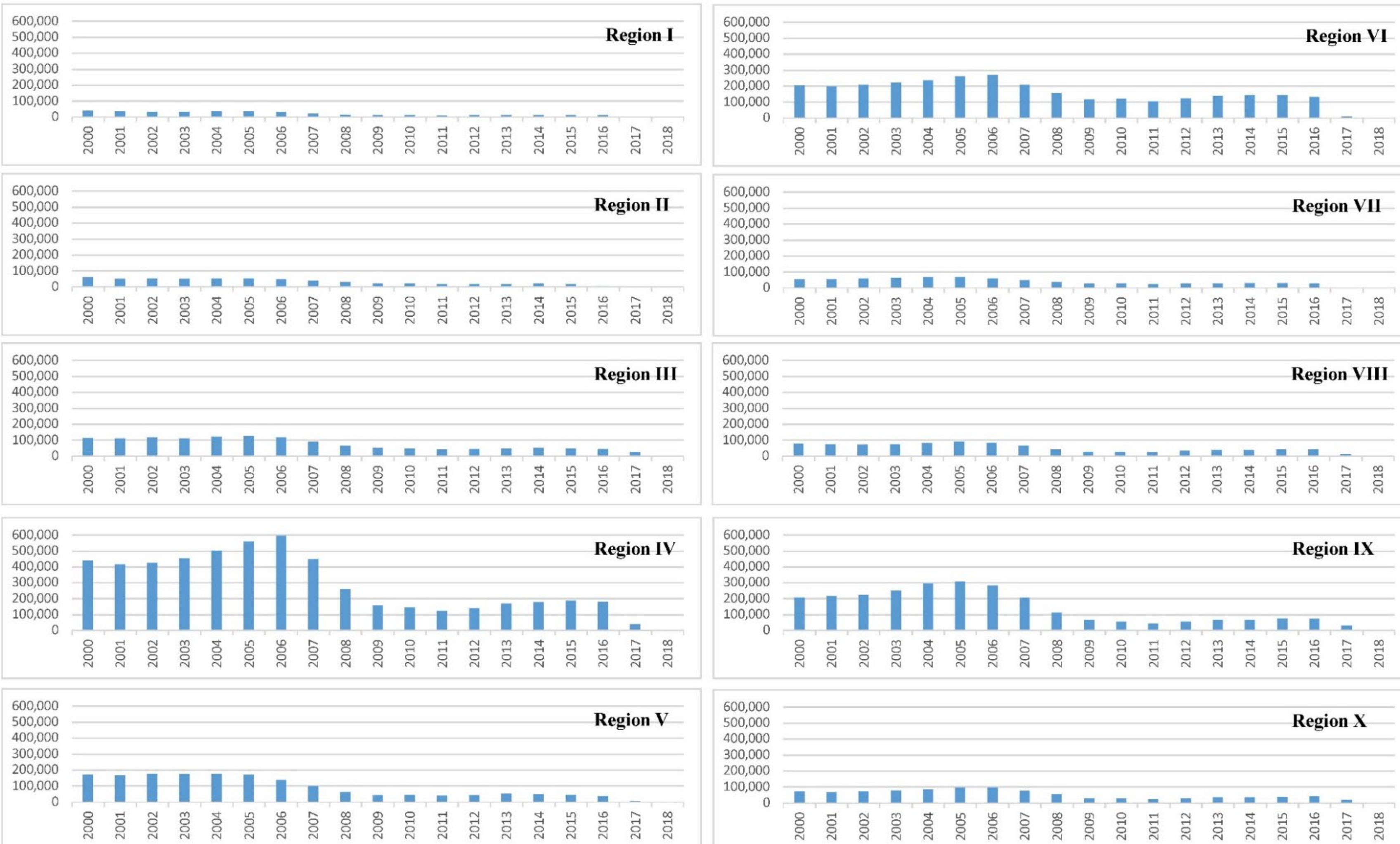
Phase 3 – National Methodology
CoreLogic Parcel Data Filtering



Post-2000 Parcels



Parcels by Year



Calculating Losses

Input Loss Parameters	Hazus Damage Functions
Flood Loss Parameters Foundation type Base flood elevation Freeboard	Compare pre- and post-I-code flood depths
Wind Building Characteristics Roof Opening protection Connections	Compares code-era wind speed and regional practices
Seismic Building Characteristics Model Building Type Design Level	Compare construction quality levels assigned to pre- and post-I-Code conditions

(Pre-I-Code damage) – (Post I–Code adoption damage) = Losses Avoided

Data Development Goals

- To create a nationwide property inventory that accurately aggregates parcel-level data attributes to allow further LAS analysis

What is Our Base Unit?

- 203M parcel point records
- 144M parcel polygon records
- 98% of parcels in over 3k counties
- 88 total attributes

- Key attributes
  - Universal Square Footage
  - Effective Year Built
  - Land Use
  - Structure characteristics (construction type, roof type, frame type, etc.)

06073_parcel_SW

MAIL_STATE	MAIL_ZIP	MAIL_CC	ASSD_VAL	ASSD_LAN	ASSD_IMP	TAX_YR	ASSD_YR	SALE_DT	SALE_PRICE	SALE_TYP_T	SALE_TYP	LAND_ACRES	LAND_SQ_FT	UBLD_SQ_FT	GR_SQ_FT	BSMT_SQ_FT
CA	921542950	C019	546077	189875	356202	2017	2017	20160325	535500	FULL VALUE	F	0.1584	6902	1908	0	0
CA	95963		57800	52000	5800	2017	2017	0	0			154.9523	6749722	0	0	0
CA	921083718	C021	74030	25857	48173	2017	2017	19881200	1337500	FULL VALUE	F	1.8128	78966	1132	0	0
CA	921201539	C030	182053	28284	153769	2017	2017	0	100000	FULL VALUE	F	0.0663	2888	1836	0	0
CA	919453129	C003	44340	21075	23265	2017	2017	20060523	425000	FULL VALUE	F	0.1377	6000	1160	0	0
CA	919773353	C001	210393	90540	119853	2017	2017	20080505	186000	FULL VALUE	F	2.3363	101768	1020	0	0
CA	921062926	C025	1020000	802000	218000	2017	2017	20080414	998000	FULL VALUE	F	0.1939	8446	1884	0	0
CA	941041503	C016	7002868	7002868	0	2017	2017	20120906	60600000	FULL VALUE	F	6.85	298386	0	0	0
CA	919420335	C043	2129116	1130710	998406	2017	2017	19860800	0	FULL VALUE	F	0.5739	24999	12832	0	0
CA	921073757	C014	330000	203000	127000	2017	2017	20040610	400000	FULL VALUE	F	5.5015	239646	1040	0	0
CA	920142118	C011	844139	283541	560598	2017	2017	0	0			0.09	3920	2674	0	0
CA	921273708	R054	855000	435000	420000	2017	2017	20040527	763545.45	FULL VALUE	F	0.1629	7098	2824	0	0
CA	921193331	C008	113232	28050	85182	2017	2017	0	62000	FULL VALUE	F	0.1561	6800	2224	0	0
CA	921202846	C010	349443	84447	264996	2017	2017	20170615	540000	FULL VALUE	F	0.1354	5900	1097	0	0
CA	921732443	C008	237009	166766	70243	2017	2017	20120214	219000	FULL VALUE	F	0.1698	7396	1244	0	0
CA	921544874	R016	548901	169763	379138	2017	2017	20080515	485000	FULL VALUE	F	0.1101	4798	3099	0	0
CA	921062434	C025	1147192	941565	205627	2017	2017	20120221	1060000	FULL VALUE	F	0.1263	5502	2312	0	130
CA	921044941	C010	121211	121211	0	2017	2017	20110909	1100000	FULL VALUE	F	0.1607	7000	0	0	0
CA	919774749	C013	395000	200000	195000	2017	2017	20040122	362500	FULL VALUE	F	0.2066	9000	1562	0	0
CA	920490294	B002	36600	32900	3700	2017	2017	0	0			154.9523	6749722	0	0	0
CA	919022666	C006	442147	148728	293419	2017	2017	0	0	FULL VALUE	F	0.2	8712	2458	0	0
CA	919111534	C014	308441	79518	228923	2017	2017	20110726	285000	FULL VALUE	F	0.163	7100	1550	0	0
CA	921262465	C041	259026	101298	157728	2017	2017	0	179000	FULL VALUE	F	1.4872	64784	1628	0	0

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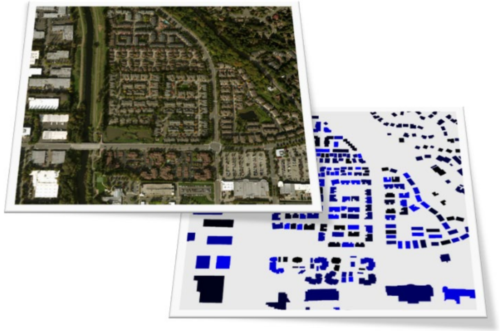
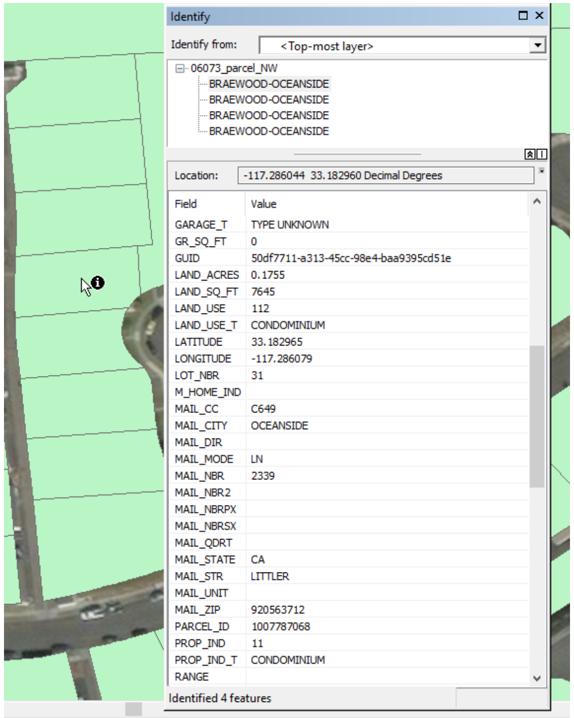
Parcel Strategy



Utilizing Bing Building Footprints



Stacked Parcel Attribution Methodologies

- 1 parcel and 1 building
- 2+ parcels and 1 building
- 1 parcel and 2+ buildings
- 2+ parcels and 2+ parcels

Leveraging Cloud Infrastructure

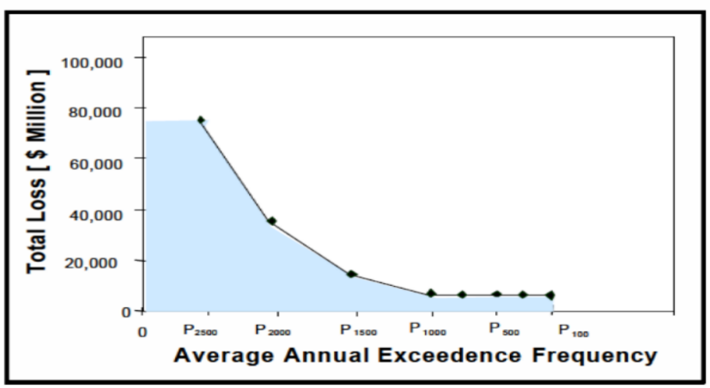
- Use multiple software tools and languages to account for each specific need or tailored solution
- Allows team to focus more on front end
- Provides additional security
  - Physical security of data centers
  - Encryption of data in transit
  - Access/identity control

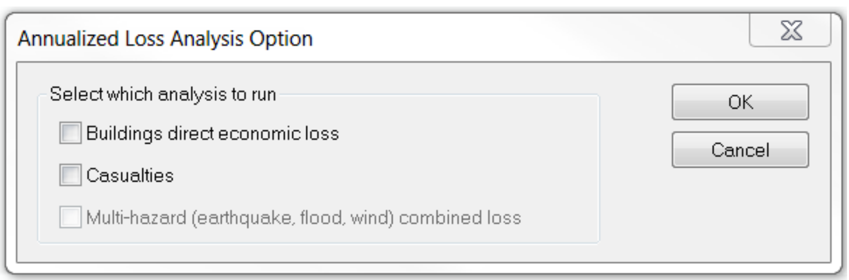
LAS Seismic - General Approach

- Analyze individual “buildings”, derived from CoreLogic parcel data using Hazus Earthquake Advanced Engineering Building Module (AEBM)
  - Additional required data:
    - Model building type (structure type)
    - Hazus design level (~code-required strength)
    - Seismic code adoption history
- Run Average Annualized Loss (AAL) (requires modification to Hazus code) using 2014 National Seismic Hazard Map data built into Hazus

Hazus AAL AEBM Optimization

- Hazus earthquake currently includes AAL calcs for general building stock economic loss and casualties only.
- Automate AAL process for AEBM fields to reduce manual labor-intensive loss calculations
- Planned approach – replicate GBS AAL process
- Radio button will be added to the AAL run menu:





Any resulting code will be shared back with the FEMA Hazus team for review and potential implementation.

Design Level (DL) Determination

- **New DLs were required (Very High and Severe), since Hazus standard DLs were developed from max strength required in UBC94 Zone 4**
- The current "High Code" DL served as the starting point for two new DLs: Very High Code and Severe Code
- AEBM Profiles for the new DLs will be added Hazus and shared with the FEMA Hazus team

Parameter Change	Very High Code	Severe Code
Capacity Curve – Adjust Design Strength & Yield/Ultimate Capacity	Increase by a factor of 1.5	Increase by a factor of 2.0
Structural Fragility Curve – Adjust Median Spectral Displacement Values (beta unchanged)	Increase by a factor of 1.15	Increase by a factor of 1.25
Nonstructural Acceleration-Sensitive Fragility Curve – Adjust Median Spectral Accelerations (beta unchanged)	Increase by a factor of 1.3	Increase by a factor of 1.5
Nonstructural Drift-Sensitive Fragility Curve	No change	No Change

Standalone Hazus Hurricane Tool to Model Losses by Parcel for LAS

- Objective: Estimate hurricane wind losses avoided for all post-1999 buildings from Texas to Maine
  - Approximately 9.4 million buildings
- Approach:
  - Stand-alone application
    - Bare bones, built for bulk processing
    - Follow the Hazus methodology with enhancements
    - Building and contents losses only
  - Excludes
    - ArcGIS user interface
    - SQL database
    - Crystal Reports

Wind Modeling Enhancements

Current Hazus "Design":	Prescriptive		Engineered to ~SBC (100-110 fastest mile) w/o or w/ opening protection, but no small missile above 60'							
Contruction -->	Wood Frame Res	Masonry Res	Engineered	Strip Malls	Ware-houses	Metal Buildings				
Occupancies --> Issues	Single and Multi Family	Single and Multi Family	Commercial and Residential	Retail	Commercial and Industrial	Commercial and Industrial	Modeling Considerations			
Full Load Path	4	1	0	1	0	0	Wall-to-floor and Floor-to-Fdn. are infinitely strong	Racking		
Designed for internal pressure in WBDR	1	1	1	1	1	1	Not considered			
Roof Cover Strength	3		3	3	3	0	Shingles: ASTM G and H Ratings	Tile - does exist for residential	Metal - does exist for residential	BUR/SPM - not code dependent
Gable End Failure	3		0	0	0	0	Unbraced Gables			
Roof Deck	4		2	2	2	0	IRC/FBCR: Ring-shank nails	IRC/FBCR: 4 inch spacing	Non-Res: Not code dependent	
Window Strength	2		4	2	0	0	Not code dependent			
Non-Glazed Entry Doors	1		1	1	1	1	Not code dependent			
Garage Doors	3		0	0	3	3	Weak or Strong			
Masonry Wall Reinforcing	0	1	0	1	1	0	Not code dependent			

4	Highest Priority
3	
2	
1	
0	Lowest Priority or N/A

Hazus Hurricane Damage and Loss Modeling Approach

- Explicit modeling of building performance
  - Component loads
    - Wind pressures
    - Wind-borne debris
  - Resistances
    - Roof-to-wall connection
    - Roof deck attachment
    - Roof covering
    - Opening protection (e.g., engineered shutters)
  - Component failures and wind-driven rain infiltration
  - Building Loss, Contents Loss, Loss of Use as a function of peak gust wind speed in open terrain
- 100,000-year event set
  - Needed to compute regional return period losses

Hazus Hurricane Damage and Loss Modeling Approach

- Start with default Hazus mapping schemes
- Replace unknowns with knowns, where possible
  - Construction
  - Number of stories
  - Roof shape
  - Roof cover type
- Modify remaining building characteristic weights based on year built, location, and building code
  - Window impact resistance and design pressures
  - Roof-to-wall connection and full load path
  - Roof deck attachment
  - Roof cover strength and Secondary Water Resistant

Flood Data Fields

Data Fields	
Foundation Type & Number of Stories	• Using building footprint for gap filling number of stories
Freeboard	• Determined from Community Rating System CRS) and supplemented by BCEGS for adoption data
Flood Zones	• Determined from NFHL with 500 ft buffer.
First Floor Elevation (FFE)	• FFE are assumed based upon code version

Flood-Specific Process Overview

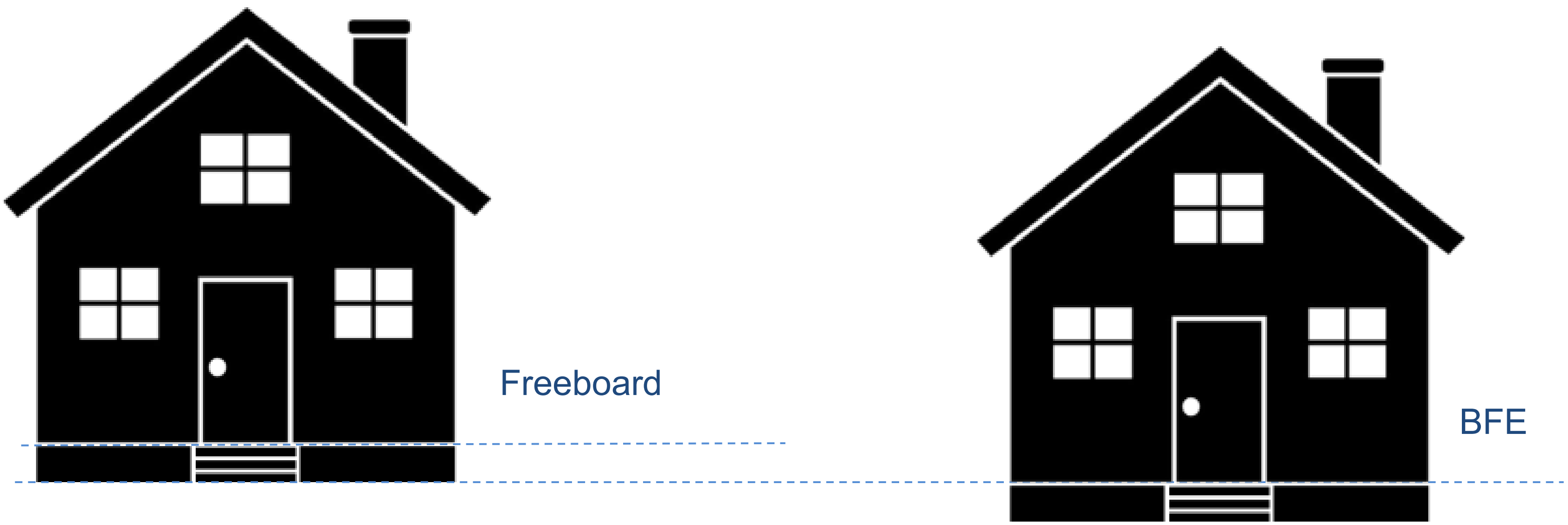
Step 1: Freeboard Lookups (by construction date and flood zone)

a. BCEGS
b. State
c. CRS
d. Community

Step 2: Final freeboard assignment

a. Initial value from BCEGS and State maximum
b. CRS overrides if greater
c. Community overrides all other values

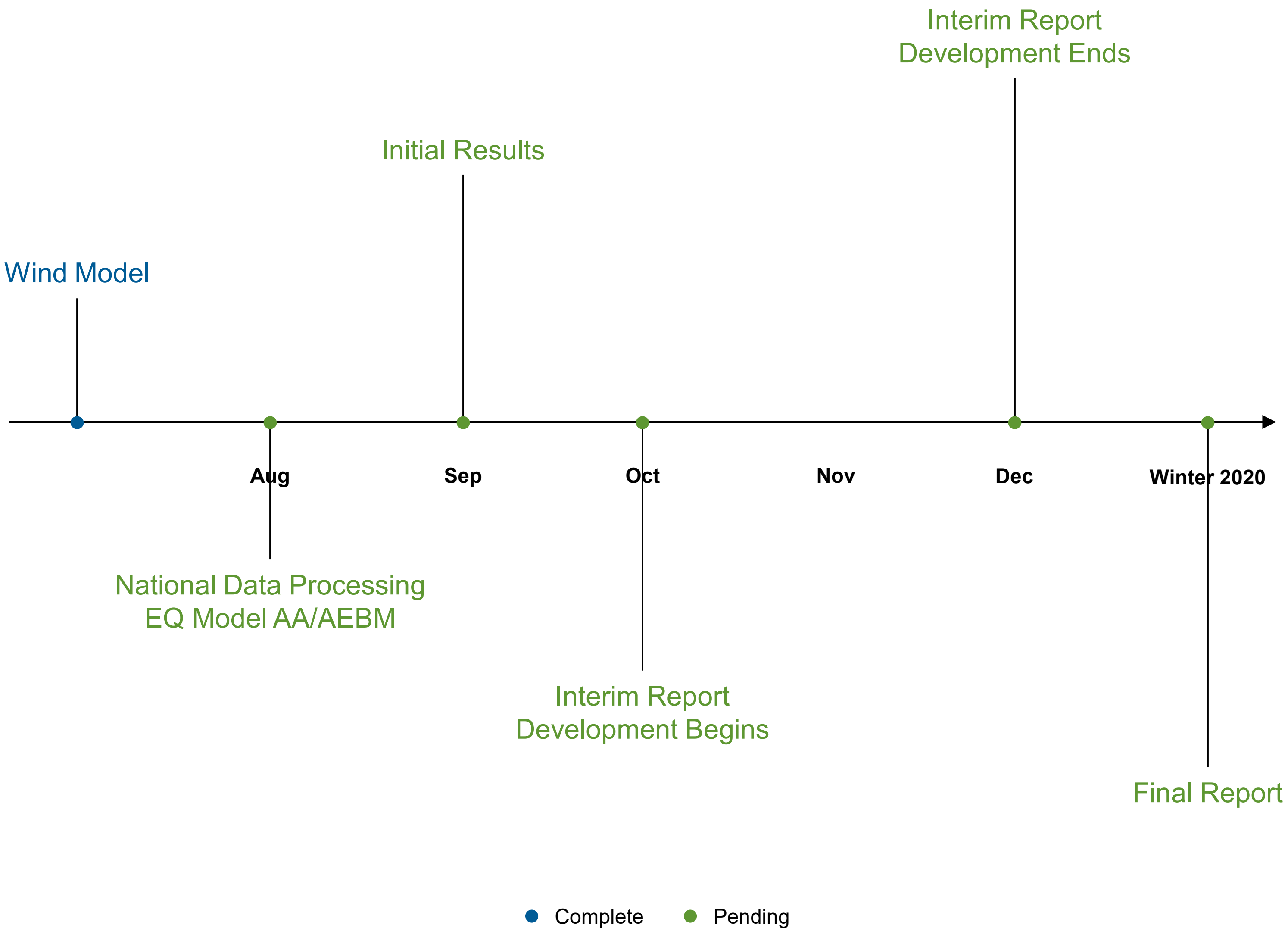
Flood LAS Calculation



With Code = With Freeboard

Without Code = Lowest Floor Elevation (typically FFE) at BFE

Timeline Summary



Questions?

FEMA Building Science Branch

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