Estimating tsunami risk

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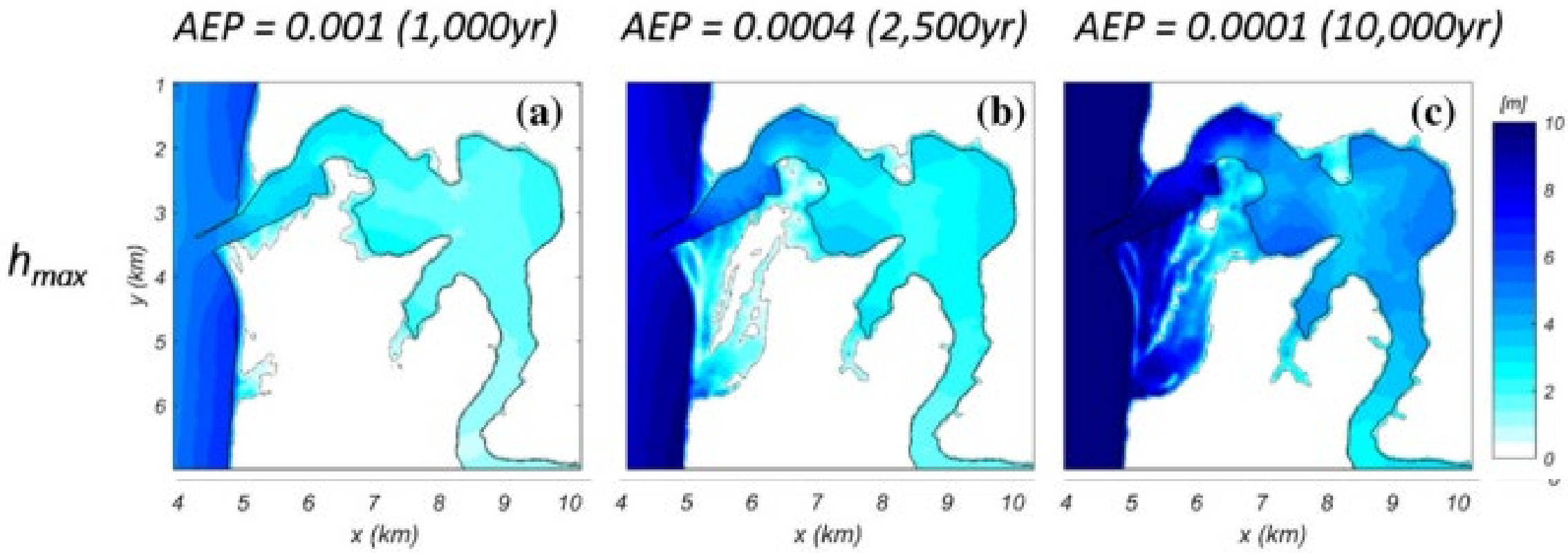
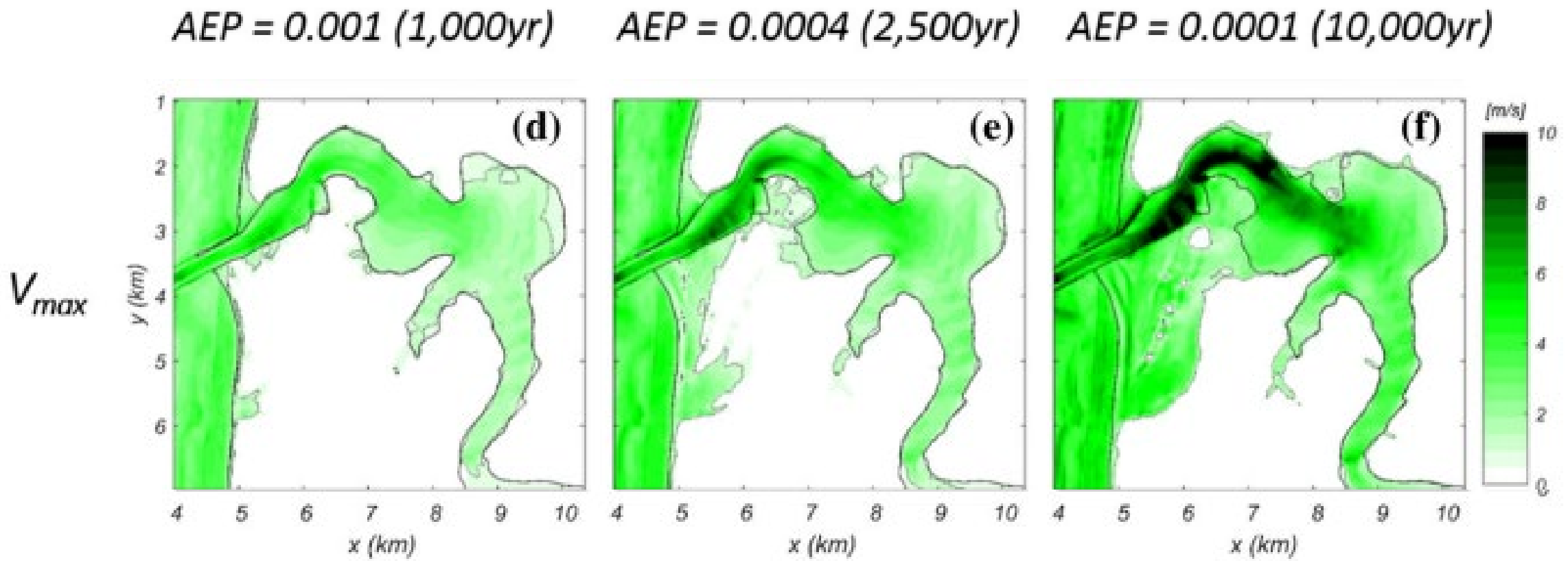


Flow Depth

Park H, DT Cox, AR Barbosa (2018)
"Probabilistic Tsunami Hazard Assessment (PTHA) for Resilience Assessment of a Coastal Community," *Natural Hazards,* https://doi.org/10.1007/s11069-018-3460-3.



Flow Speed

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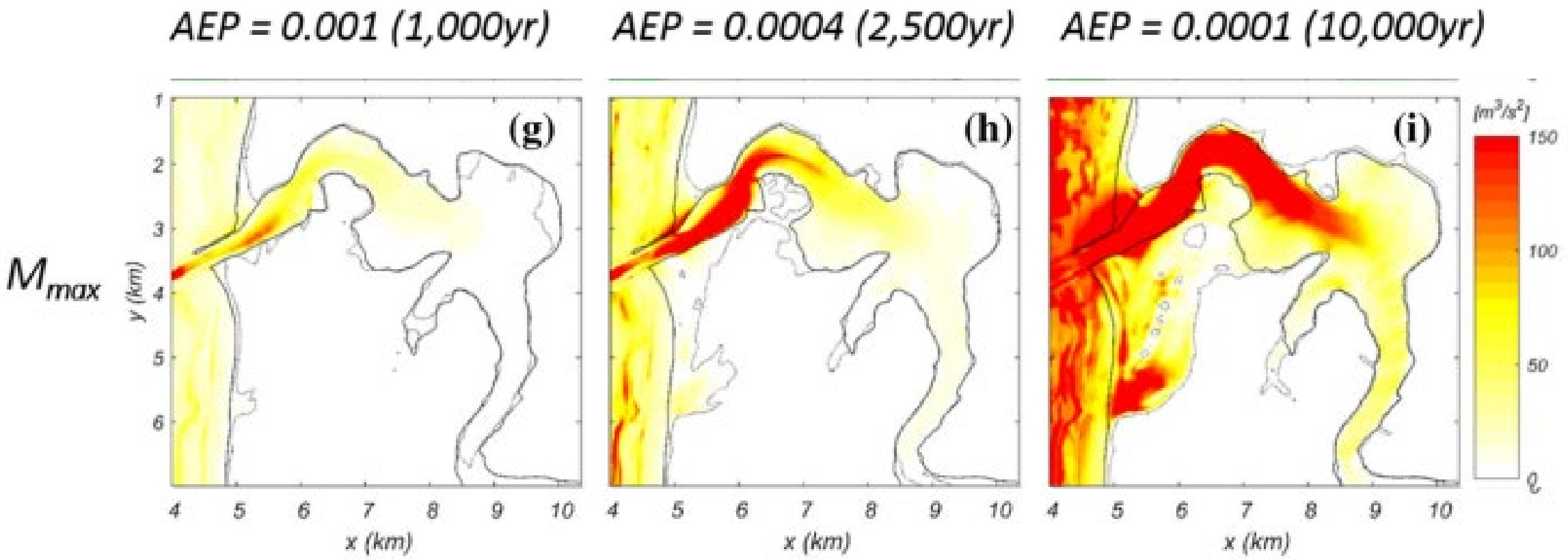
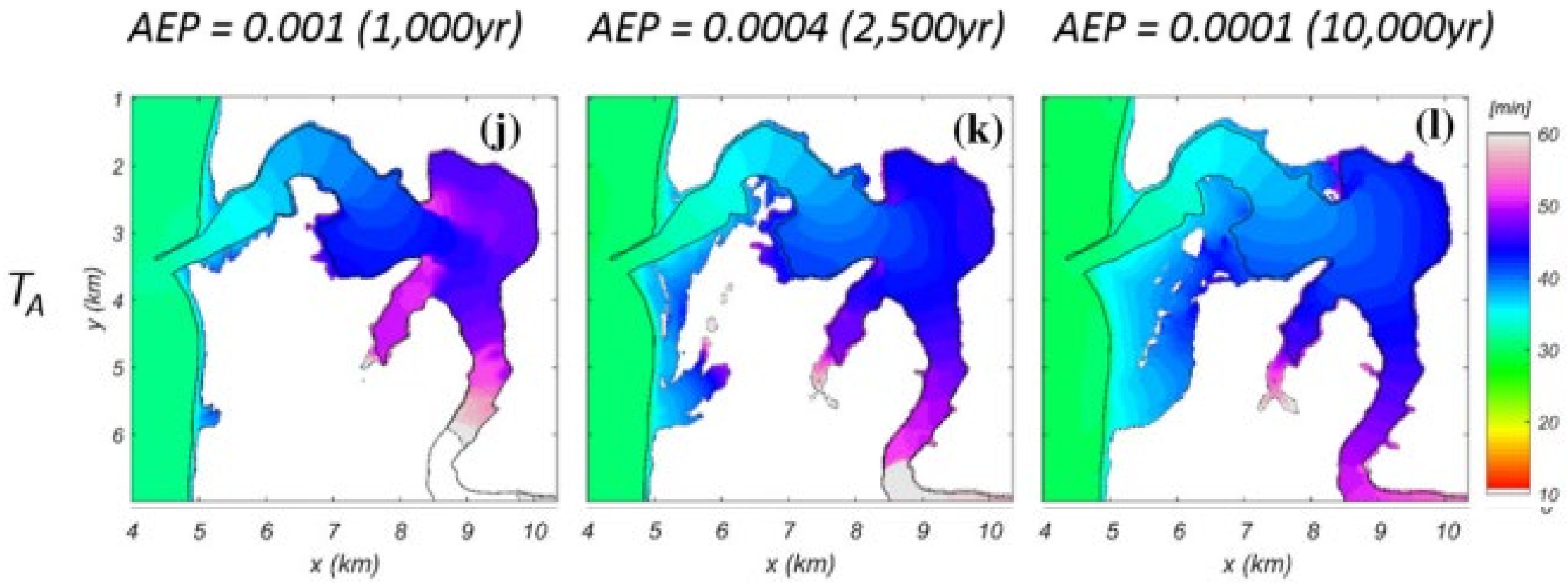


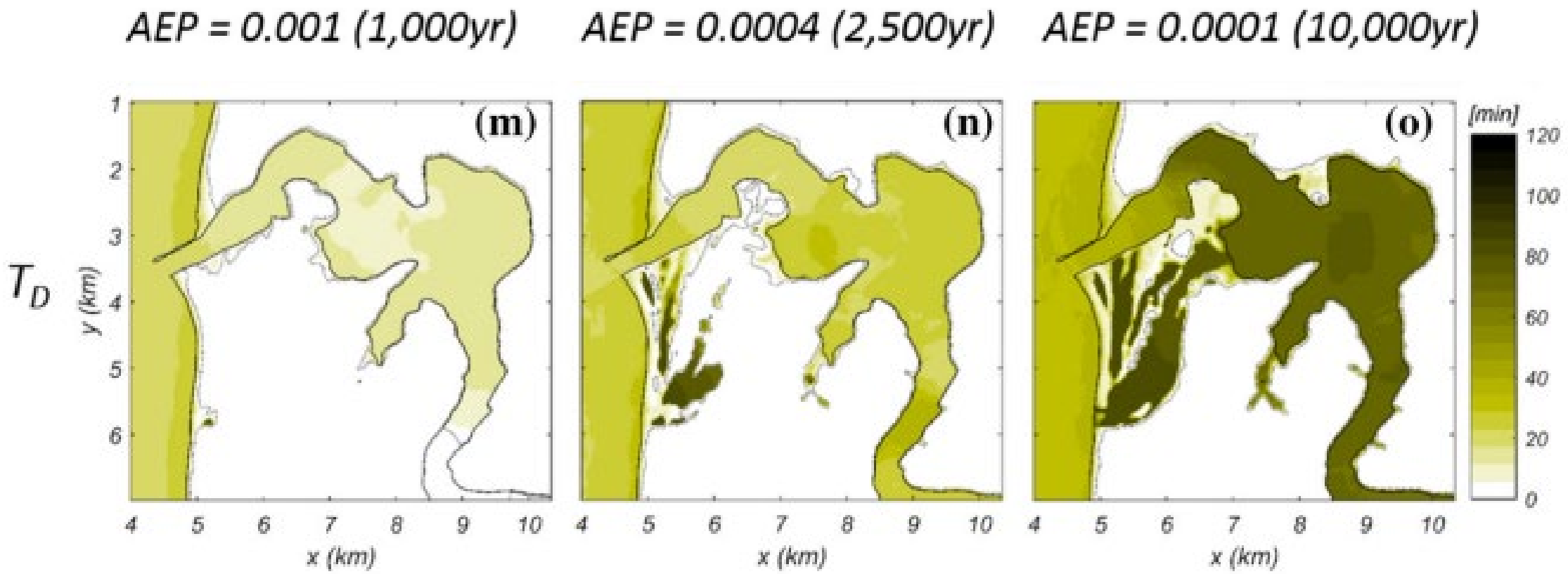
Momentum Flux

Park H, DT Cox, AR Barbosa (2018)
"Probabilistic Tsunami Hazard Assessment (PTHA) for Resilience Assessment of a Coastal Community," *Natural Hazards,* https://doi.org/10.1007/s11069-018-3460-3.



Arrival Time

Park H, DT Cox, AR Barbosa (2018)
"Probabilistic Tsunami Hazard Assessment (PTHA) for Resilience Assessment of a Coastal Community," *Natural Hazards,* https://doi.org/10.1007/s11069-018-3460-3.



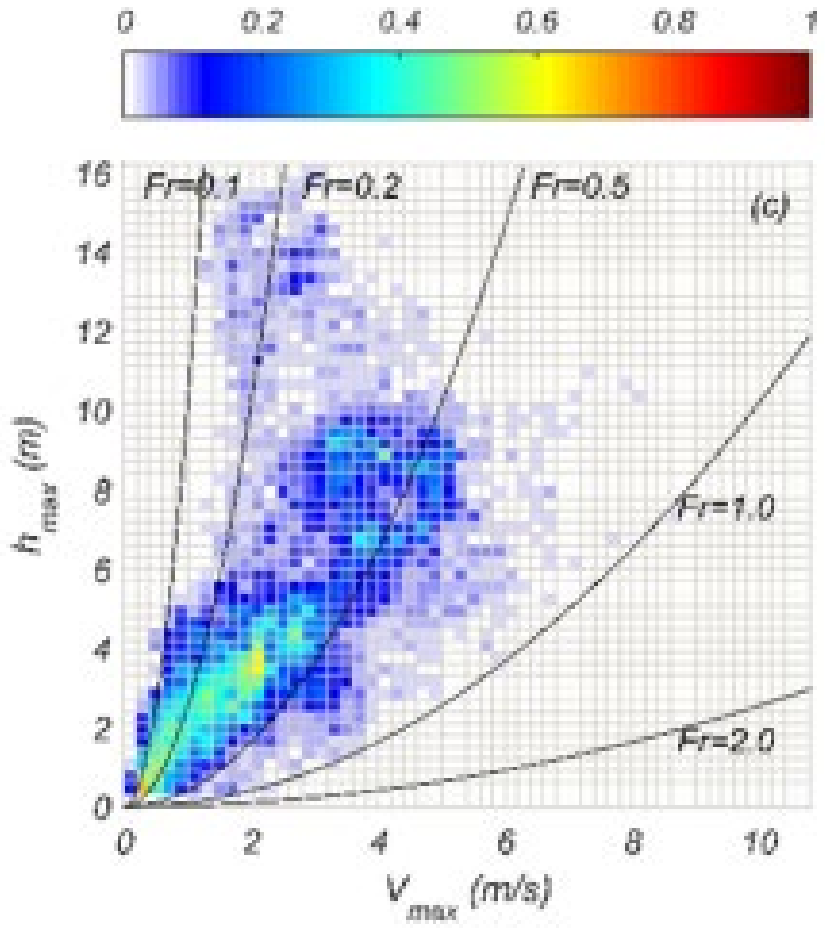
Duration of Flooding

Park H, DT Cox, AR Barbosa (2018)
"Probabilistic Tsunami Hazard Assessment (PTHA) for Resilience Assessment of a Coastal Community," *Natural Hazards,* https://doi.org/10.1007/s11069-018-3460-3.

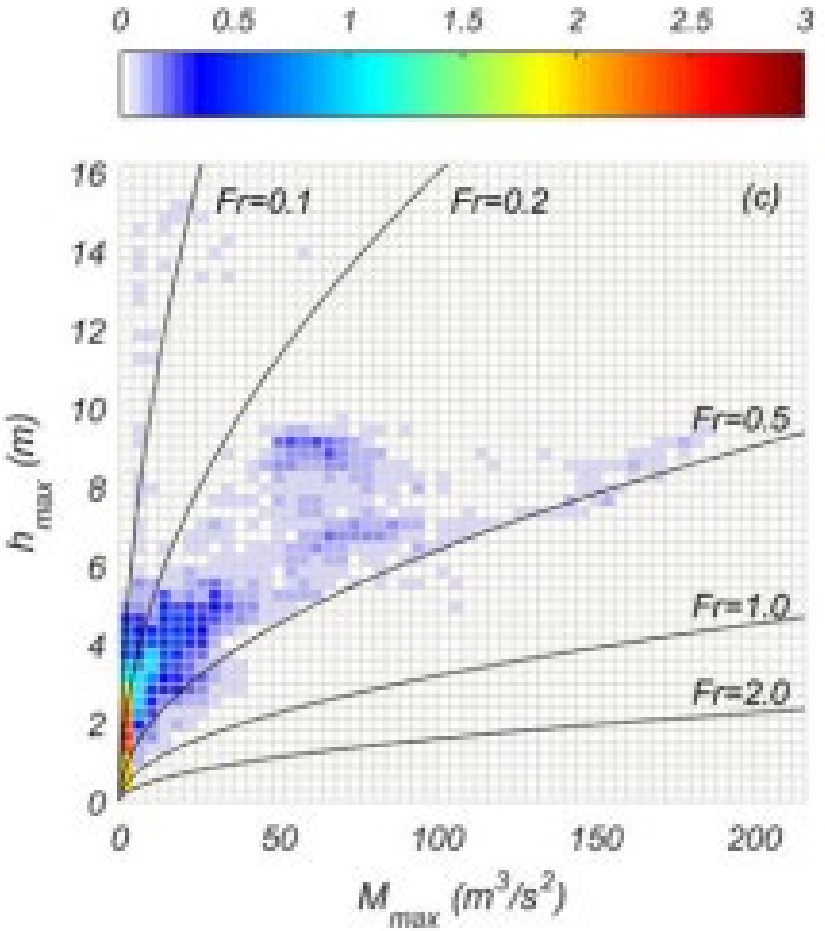
Joint Distributions of IMs

Correlation or relationship among h_{max} and other IMs

h_{max} VS V_{max}



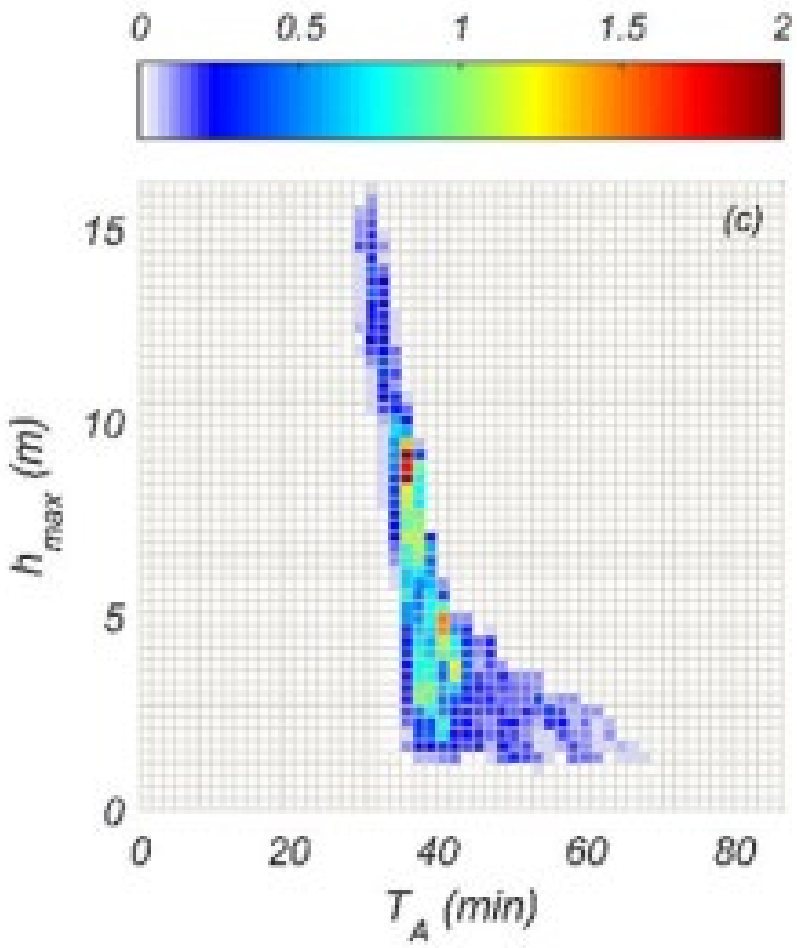
h_{max} VS M_{max}



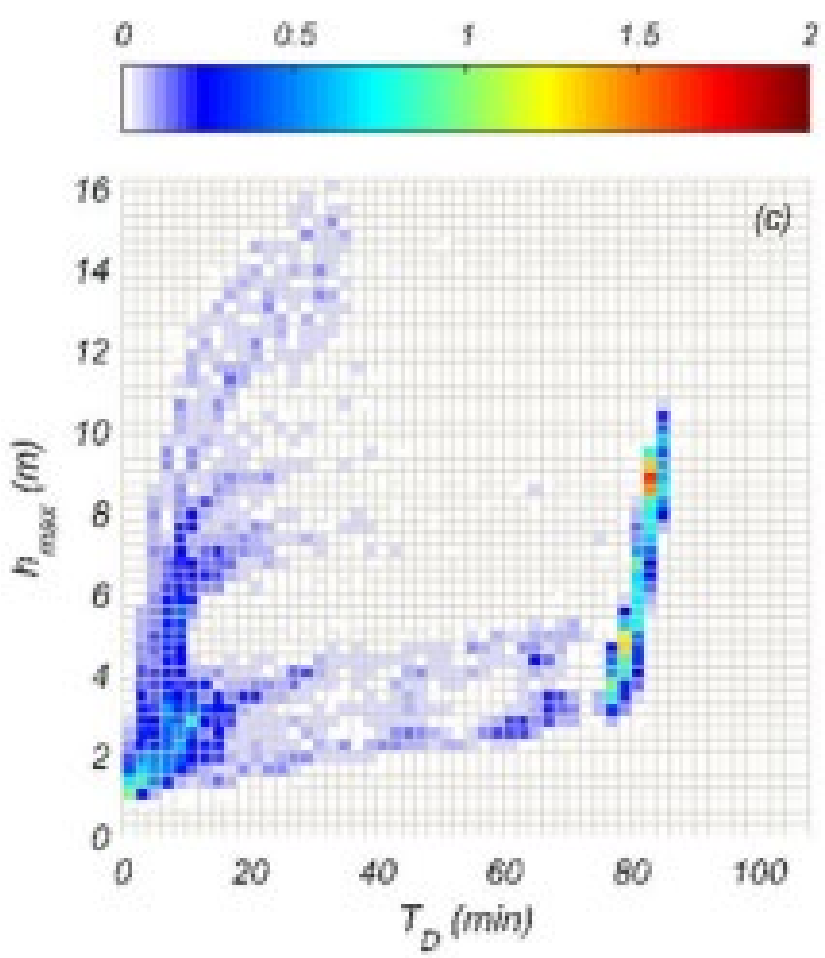
Joint Distributions of IMs

- Correlation or relationship among h_{max} and other IMs

h_{max} VS T_A



h_{max} VS T_D

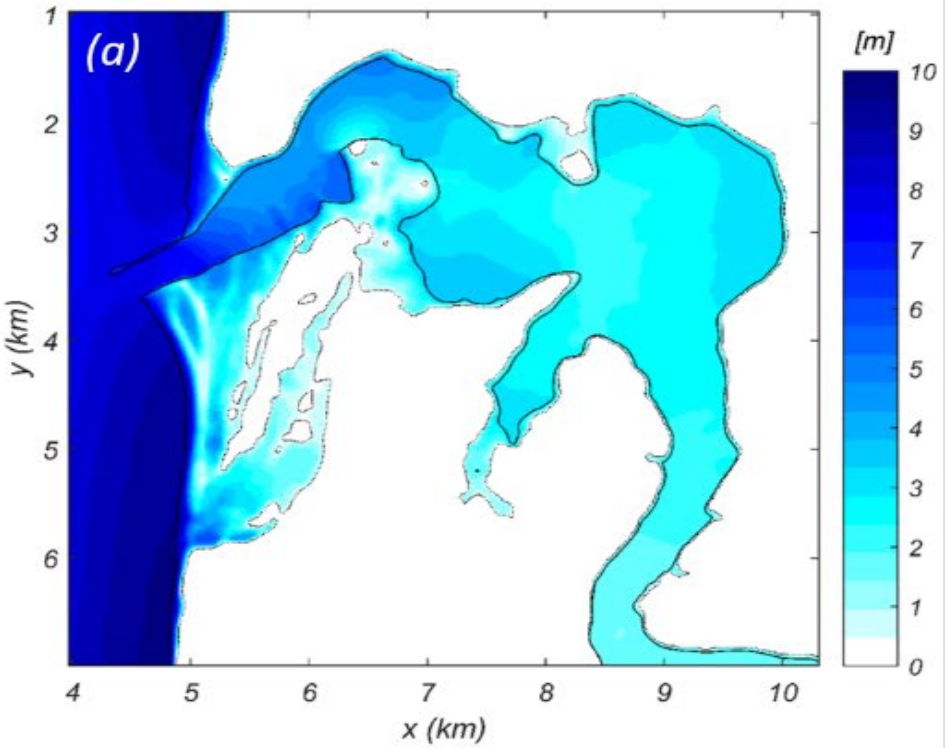


PTHA Comparison for Newport, Oregon

Park et al., 2018

ASCE 7-16

DOGAMI “M”



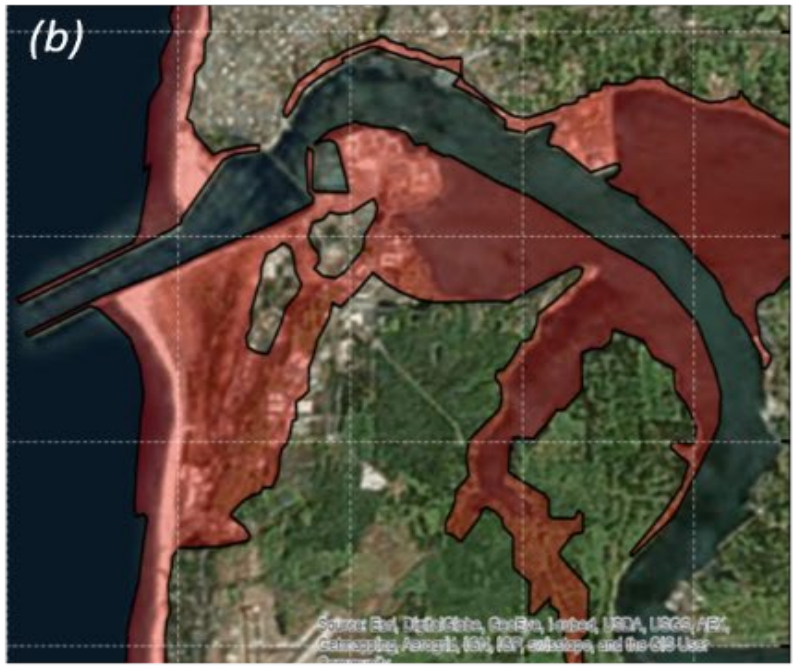


Figure 7: Comparison of maximum extent of tsunami inundation in Newport, Oregon, for (a) present study with AEP = 0.0004, (b) ASCE Tsunami Design Geodatabase (TDG) for AEP = 0.0004, and (c) DOGAMI TIM, ‘M’ scenario (b and c are courtesy of ASCE TDG and Oregon Department of Geology and Mineral Industries).

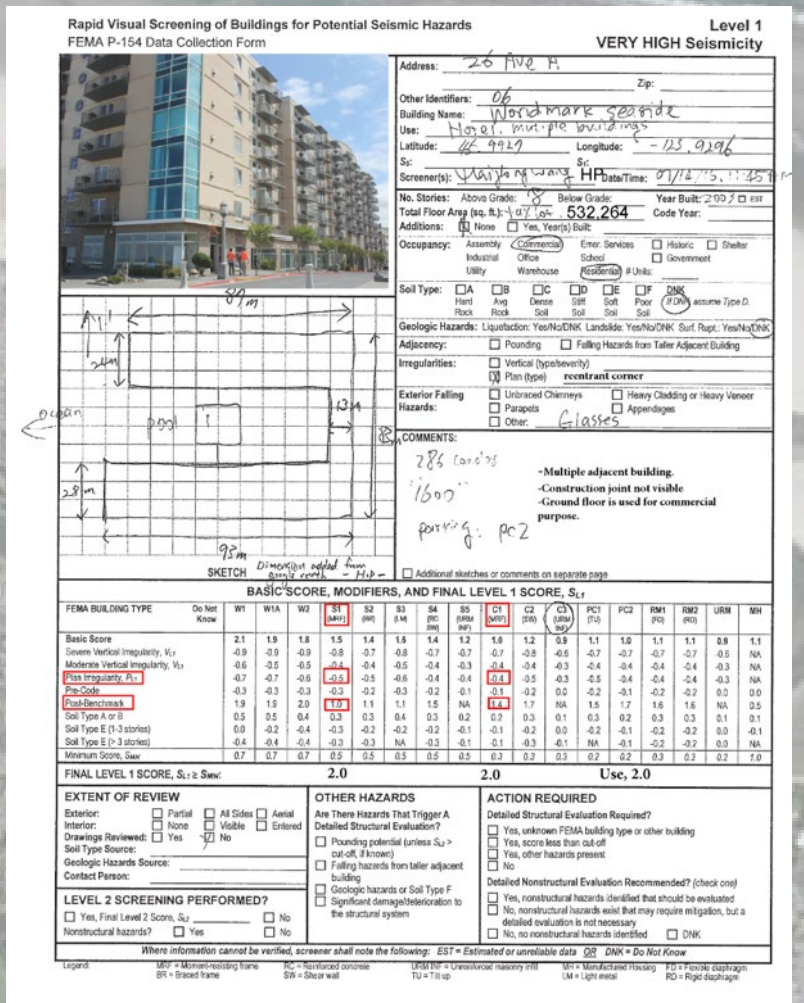
Park H, DT Cox, AR Barbosa (2018) “Probabilistic Tsunami Hazard Assessment (PTHA) for Resilience Assessment of a Coastal Community,” *Natural Hazards,* https://doi.org/10.1007/s11069-018-3460-3.

Three tools for building information at study area

1. Tax lot (Stat_Class, Year)

2. Pictures from Google map street view

3. Fields survey Rapid Visual Screening (RVS)



Rapid Visual Screening of Buildings for Potential Seismic Hazards — Level 1
FEMA P-154 Data Collection Form — VERY HIGH Seismicity

Address: 26 Ave H. Zip:
Other Identifiers: 06
Building Name: Boardmark Seaside
Use: Hotel, multiple buildings
Latitude: 46.9919 Longitude: -123.9296
Screener(s): Yanfang Wang HP Date/Time: 07/12/15, 11:45 PM
No. Stories: Above Grade: 8 Below Grade: Year Built: 2003 EST
Total Floor Area (sq. ft.): 1 of 2: 532,264 Code Year:
Additions: None; Yes, Year(s) Built:
Occupancy: Assembly; Commercial; Emer. Services; Historic; Shelter; Industrial; Office; School; Government; Utility; Warehouse; Residential; # Units:
Soil Type: A Hard Rock; B Avg Rock; C Dense Soil; D Stiff Soil; E Soft Soil; F Poor Soil; DNK (if DNK, assume Type D)
Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: Pounding; Falling Hazards from Taller Adjacent Building
Irregularities: Vertical (type/severity); Plan (type) recentrant corner
Exterior Falling Hazards: Unbraced Chimneys; Heavy Cladding or Heavy Veneer; Parapets; Appendages; Other: Glasses

SKETCH

COMMENTS:
-Multiple adjacent building.
-Construction joint not visible
-Ground floor is used for commercial purpose.

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (PD)	RM2 (RD)	URM	MH
Basic Score		2.1	1.9	1.8	1.5	1.4	1.6	1.4	1.2	1.0	1.2	0.9	1.1	1.0	1.1	1.1	0.8	1.1
Severe Vertical Irregularity, V_{L1}		-0.9	-0.9	-0.9	-0.8	-0.7	-0.8	-0.7	-0.7	-0.7	-0.8	-0.6	-0.7	-0.7	-0.7	-0.7	-0.6	NA
Moderate Vertical Irregularity, V_{L1}		-0.6	-0.5	-0.5	-0.4	-0.4	-0.5	-0.4	-0.3	-0.4	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.3	NA
Plan Irregularity, P_{L1}		-0.7	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.4	-0.4	-0.5	-0.3	-0.5	-0.4	-0.4	-0.4	-0.3	NA
Pre-Code		-0.3	-0.3	-0.3	-0.3	-0.2	-0.3	-0.2	-0.1	-0.1	-0.2	0.0	-0.2	-0.1	-0.2	-0.2	0.0	0.0
Post-Benchmark		1.9	1.9	2.0	1.0	1.1	1.1	1.5	NA	1.4	1.7	NA	1.5	1.7	1.6	1.6	NA	0.5
Soil Type A or B		0.5	0.5	0.4	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.1	0.3	0.2	0.3	0.3	0.1	0.1
Soil Type E (1-3 stories)		0.0	-0.2	-0.4	-0.3	-0.2	-0.2	-0.2	-0.1	-0.1	-0.2	0.0	-0.2	-0.1	-0.2	-0.2	0.0	-0.1
Soil Type E (> 3 stories)		-0.4	-0.4	-0.4	-0.3	-0.3	NA	-0.3	-0.1	-0.1	-0.3	-0.1	NA	-0.1	-0.2	-0.2	0.0	NA
Minimum Score, S_{MIN}		0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 2.0 2.0 Use, 2.0

EXTENT OF REVIEW
Exterior: Partial; All Sides; Aerial
Interior: None; Visible; Entered
Drawings Reviewed: Yes; No
Soil Type Source:
Geologic Hazards Source:
Contact Person:

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
Pounding potential (unless S_{L2} > cut-off, if known)
Falling hazards from taller adjacent building
Geologic hazards or Soil Type F
Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
Yes, unknown FEMA building type or other building
Yes, score less than cut-off
Yes, other hazards present
No
Detailed Nonstructural Evaluation Recommended? (check one)
Yes, nonstructural hazards identified that should be evaluated
No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
No, no nonstructural hazards identified; DNK

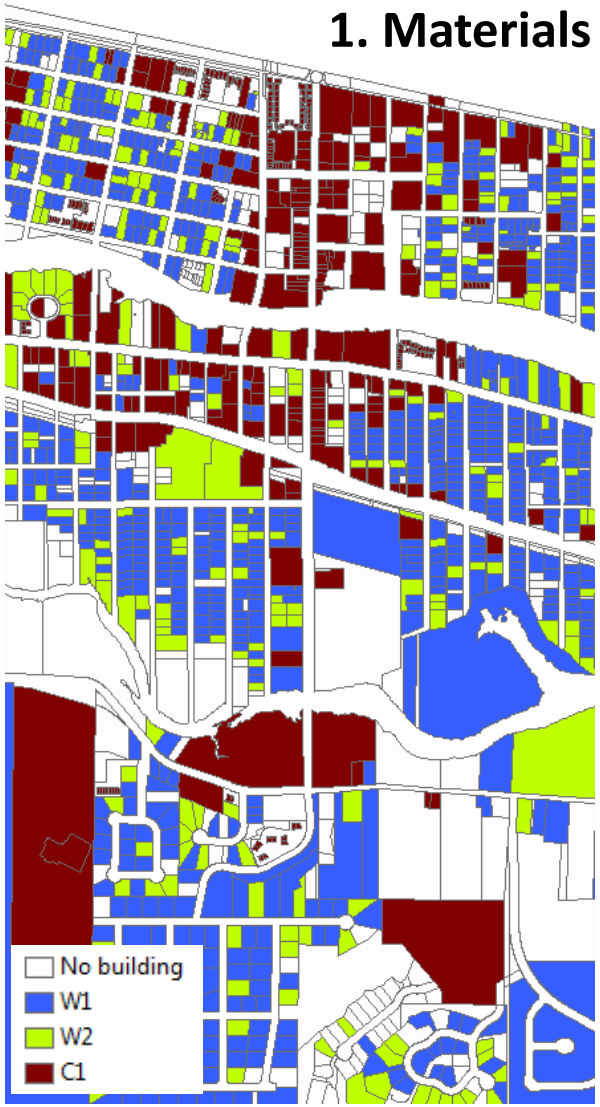
LEVEL 2 SCREENING PERFORMED?
Yes, Final Level 2 Score, S_{L2} ____ No
Nonstructural hazards? Yes No

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

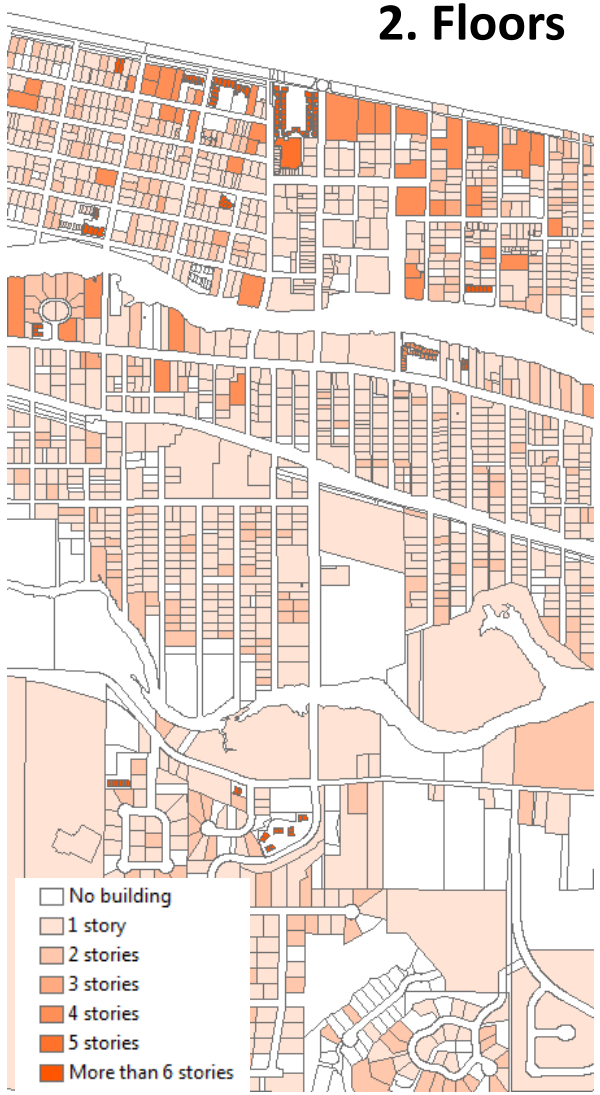
Legend: MRF = Moment-resisting frame; BR = Braced frame; RC = Reinforced concrete; SW = Shear wall; URM INF = Unreinforced masonry infill; TU = Tilt-up; MH = Manufactured Housing; LM = Light metal; PD = Flexible diaphragm; RD = Rigid diaphragm

Building Classification

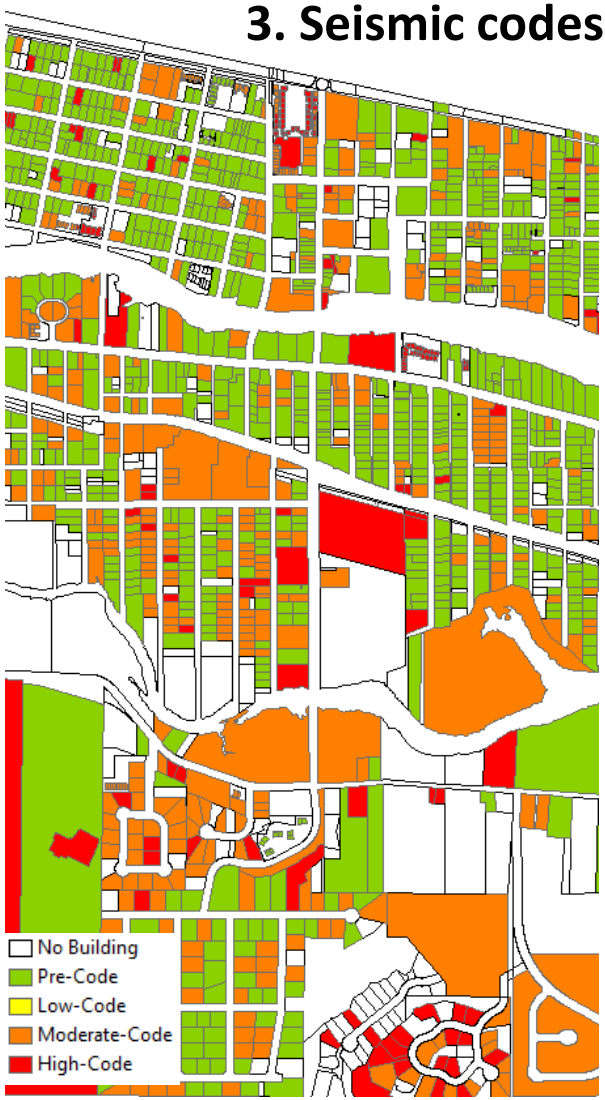
1. Materials



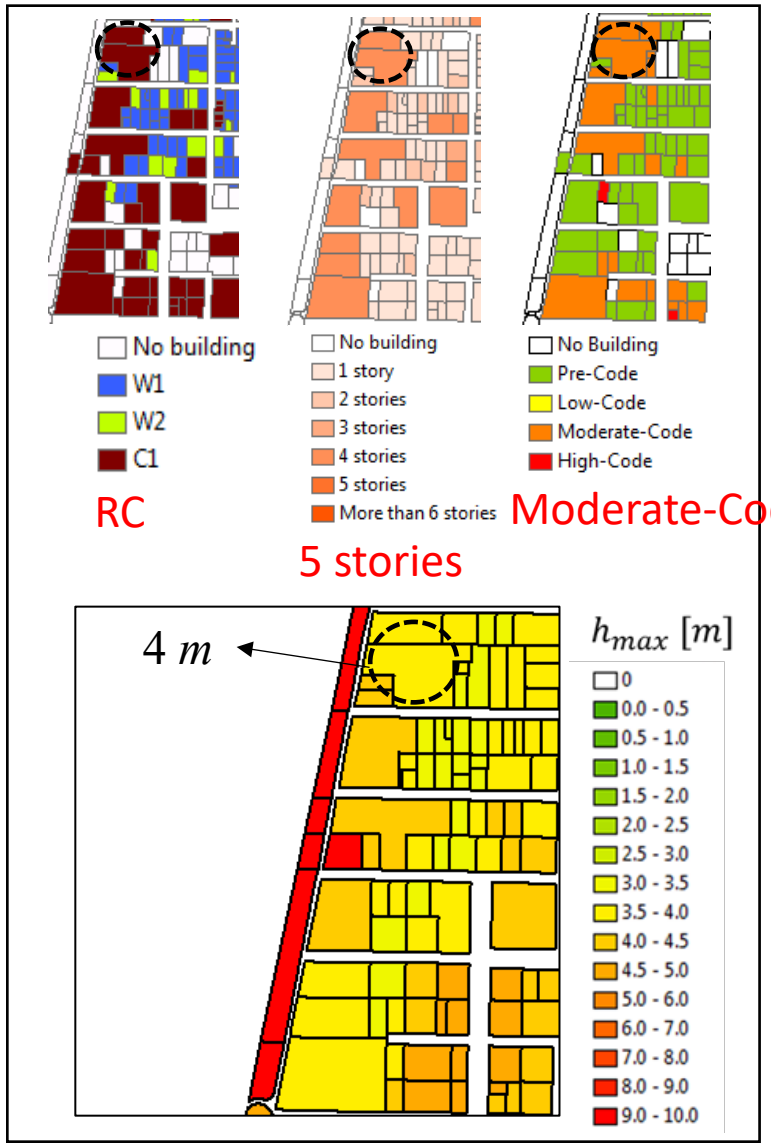
2. Floors



3. Seismic codes



Example of building damage assessment (at AEP = 0.001)



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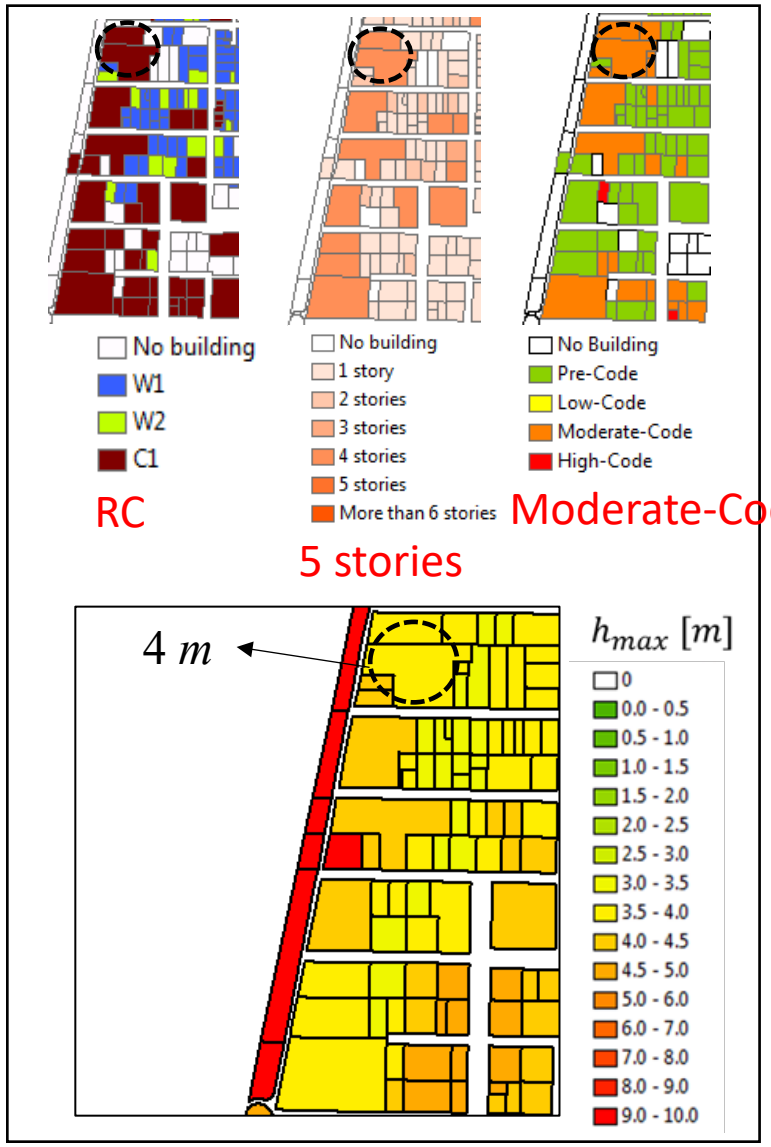

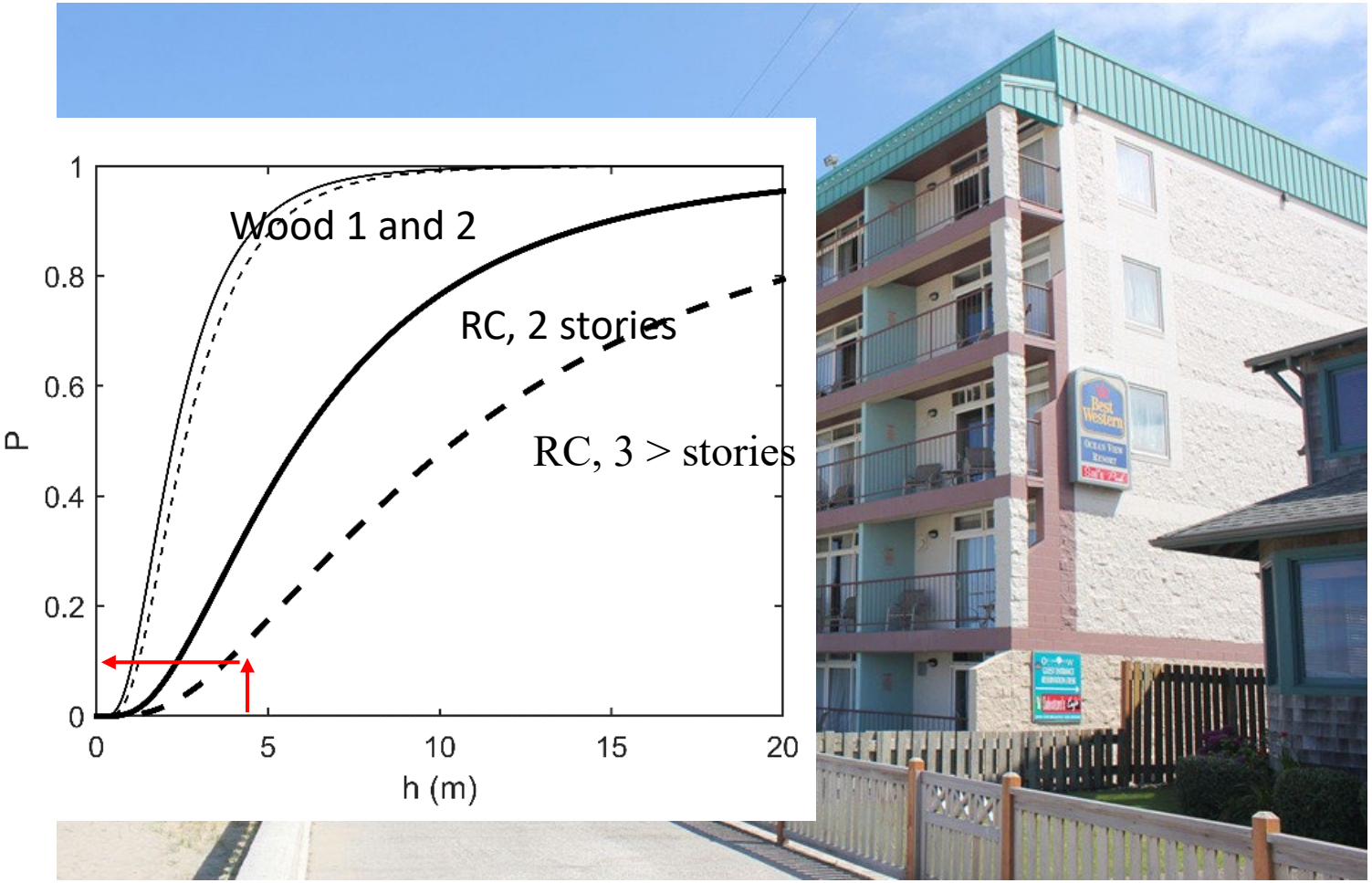

Fragility curves (Suppasri et al., 2013) for collapse damage

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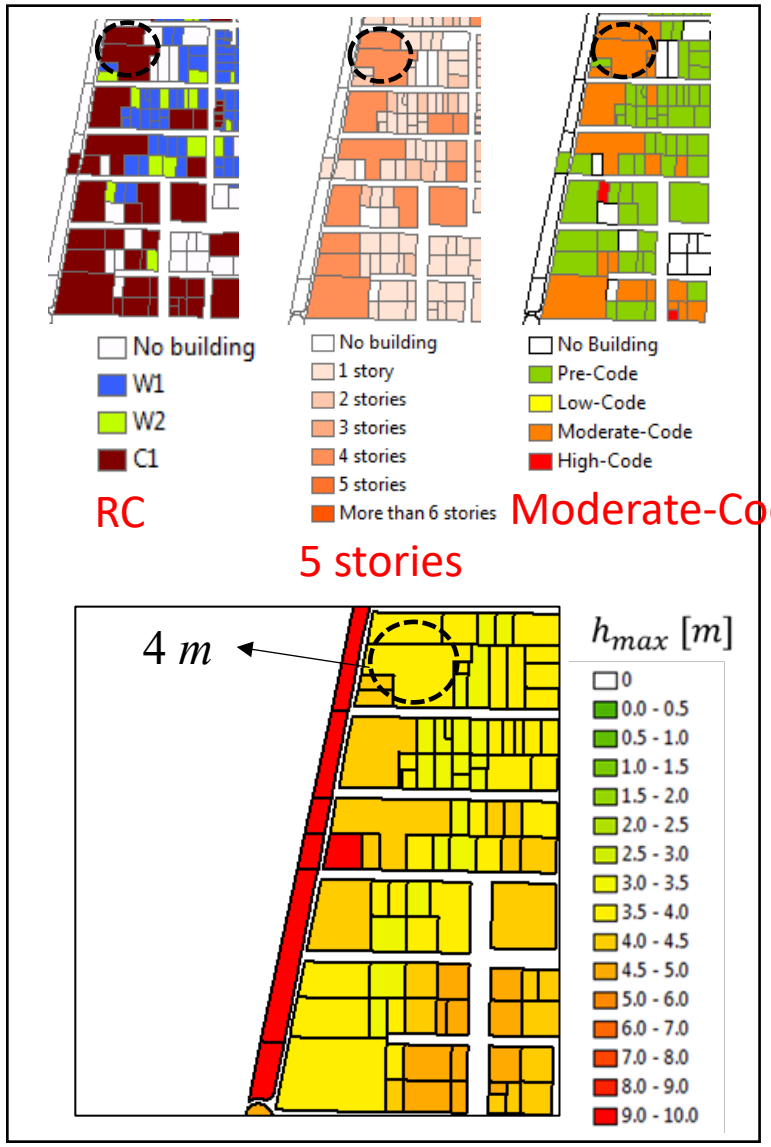

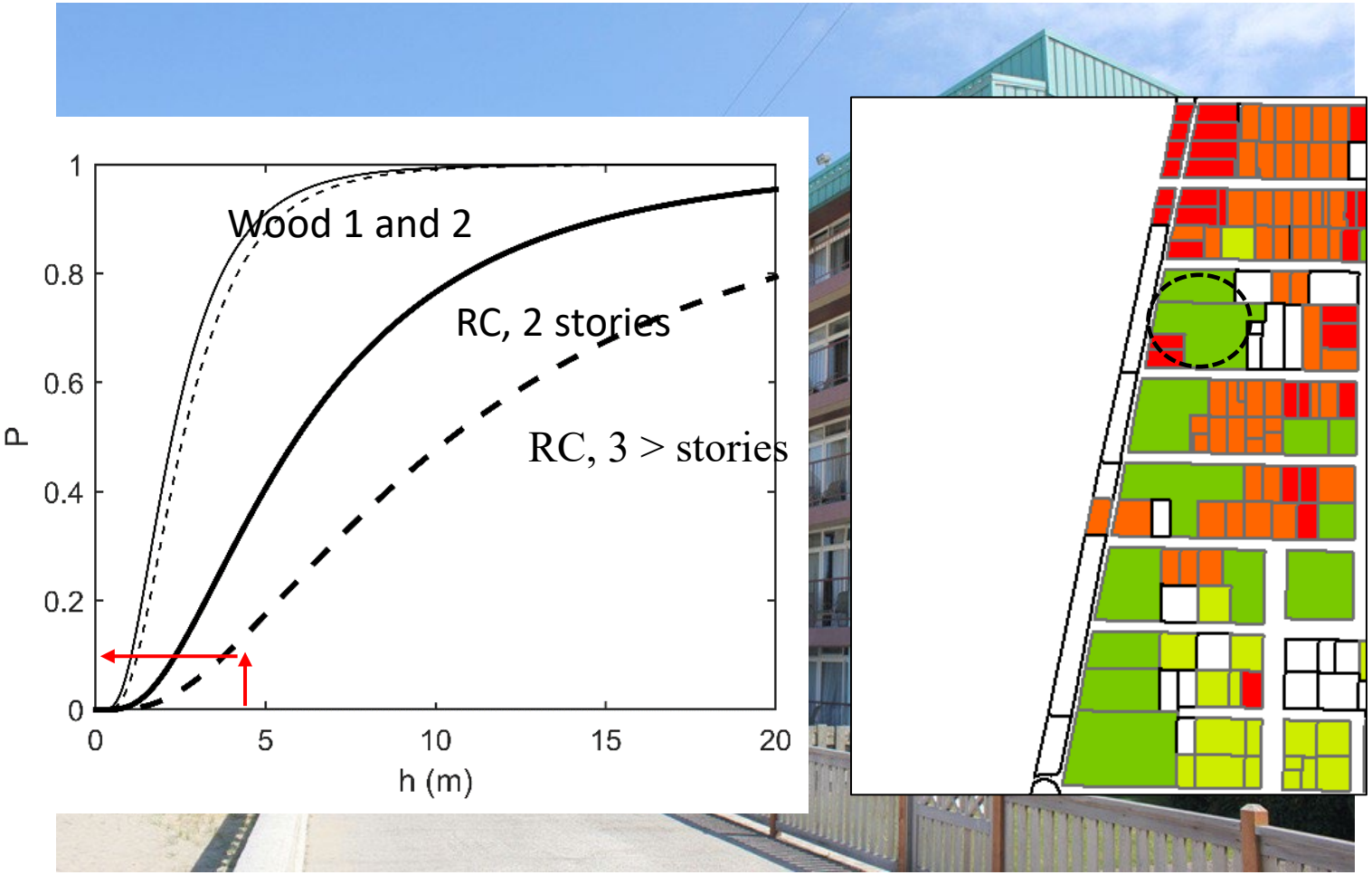

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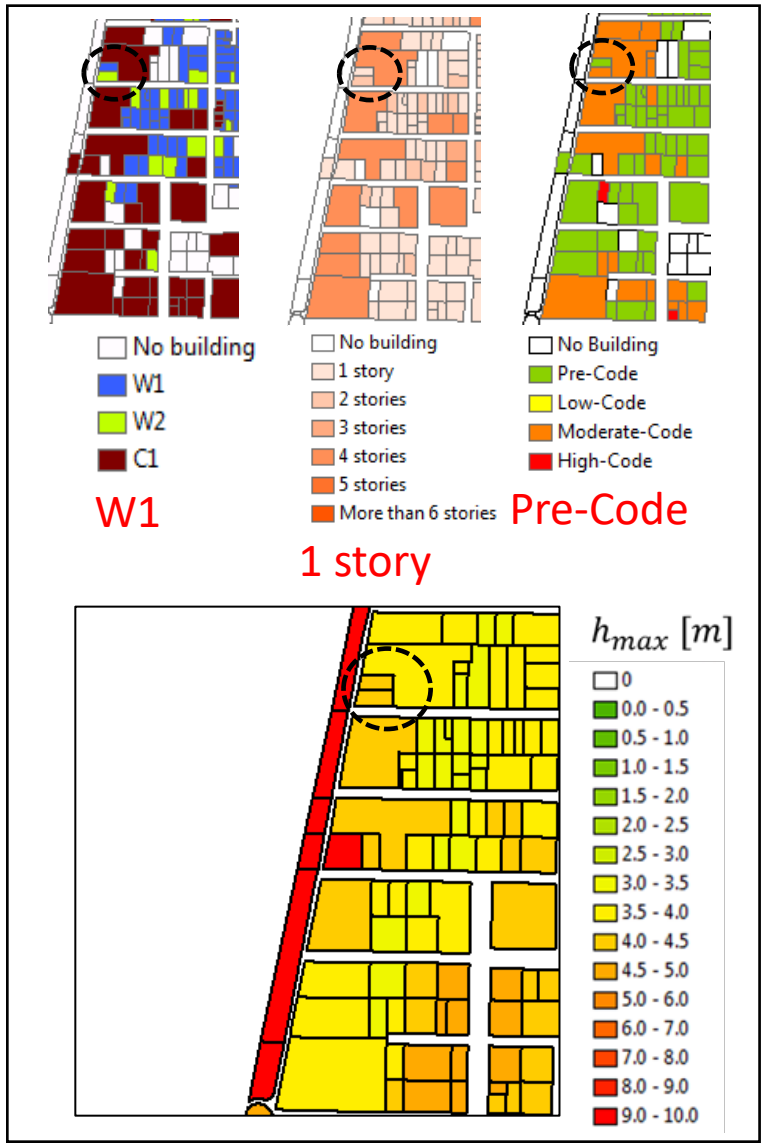
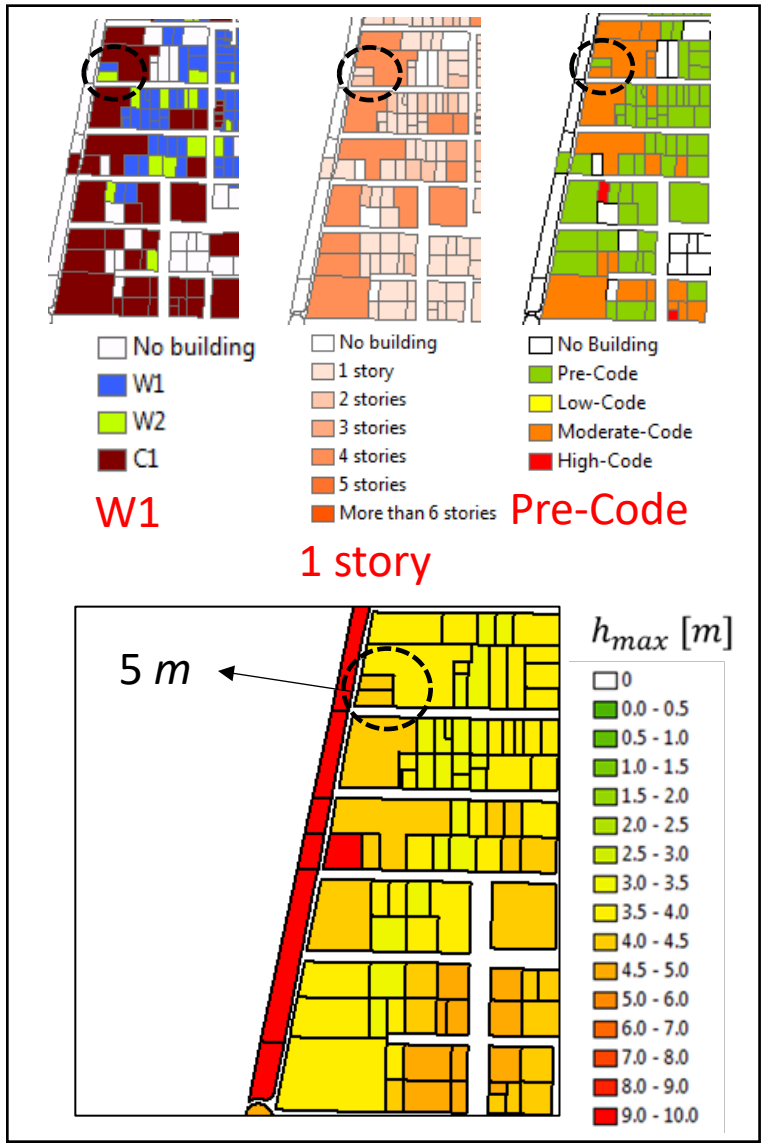
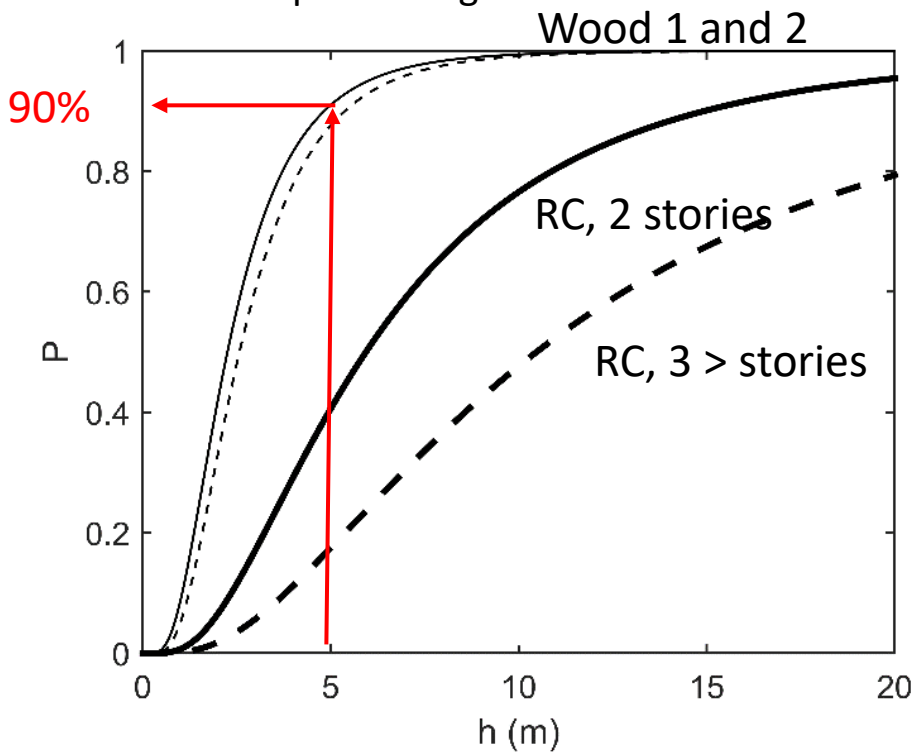


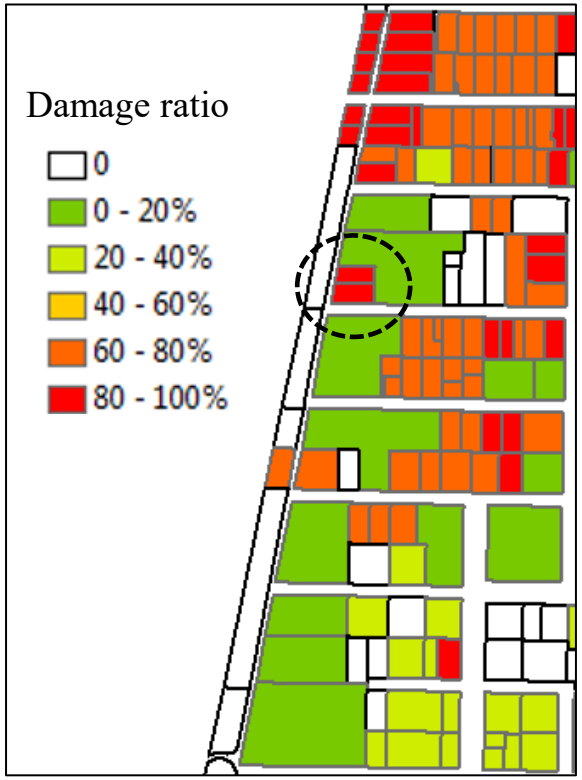
Photo taken by Hyoungsu Park, at Seaside Field trip (July, 14, 2015)

Example of building damage assessment (at AEP = 0.001)

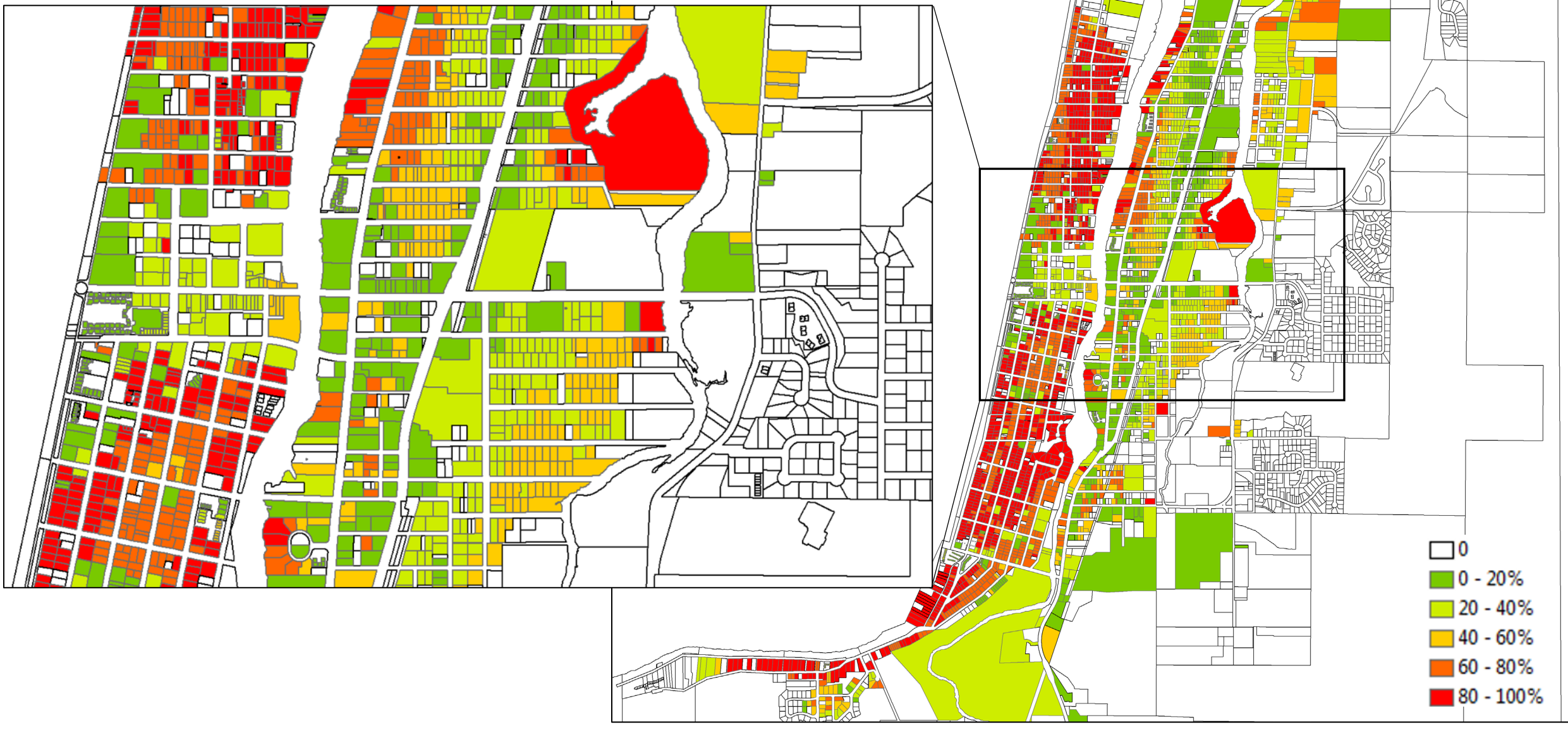


Fragility curves (Suppasri et al., 2013)
for Collapse damage





Probability damage at AEP = 0.001 (~1,000 year event) at CSZ with S2013 model (h_{max} , Collapse DS)

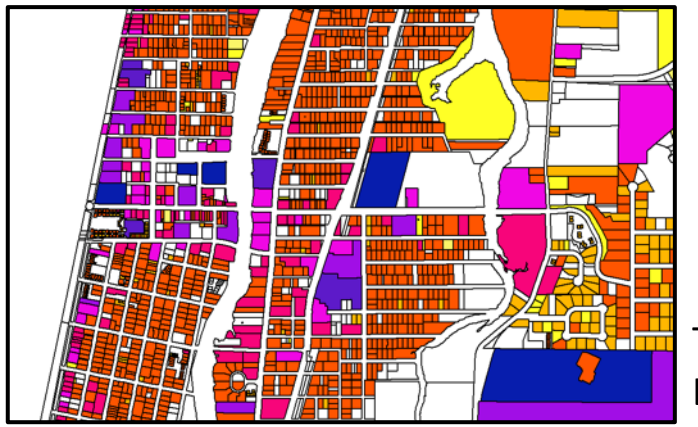


Earthquake Only

Tsunami Only

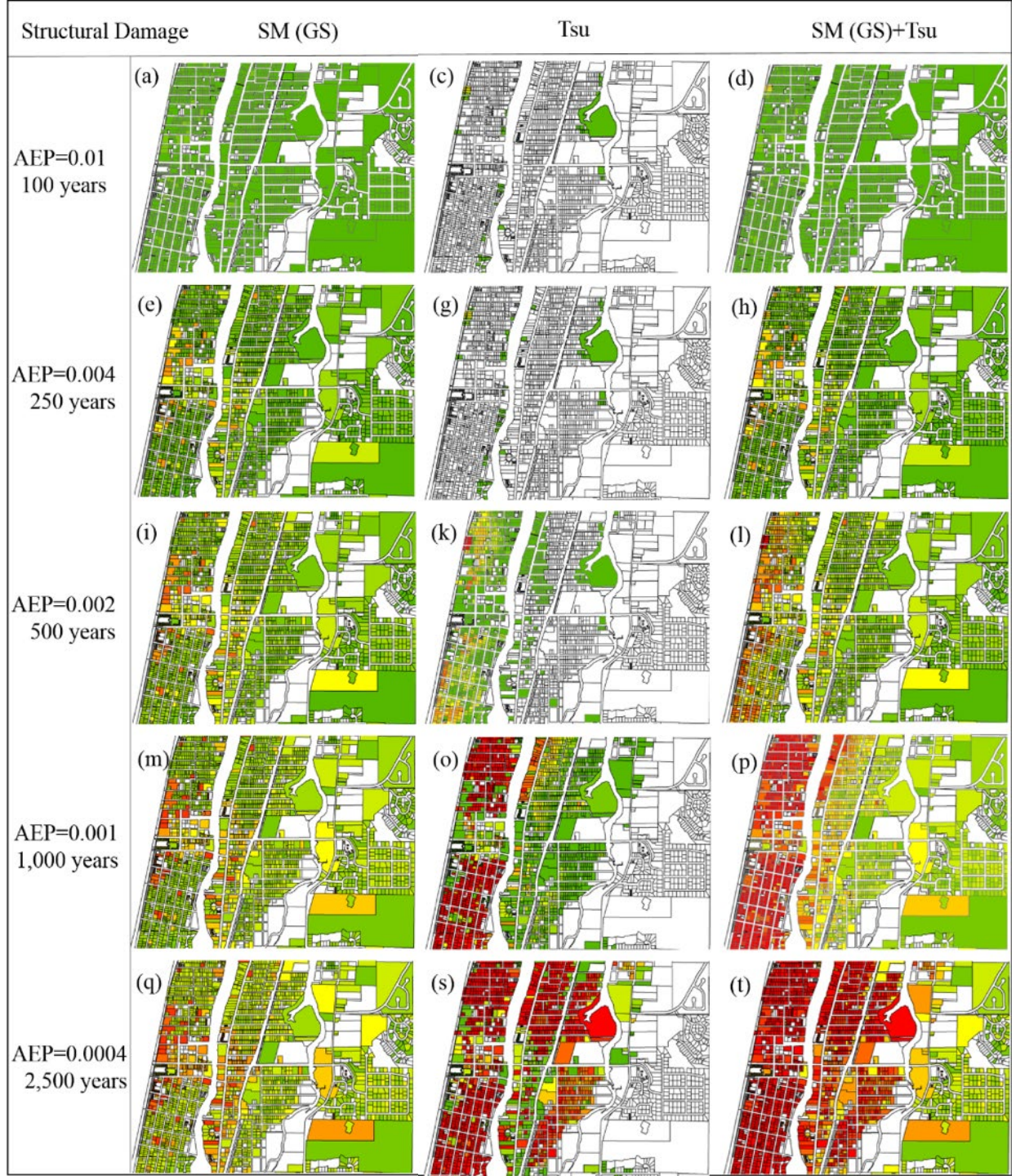
Combined

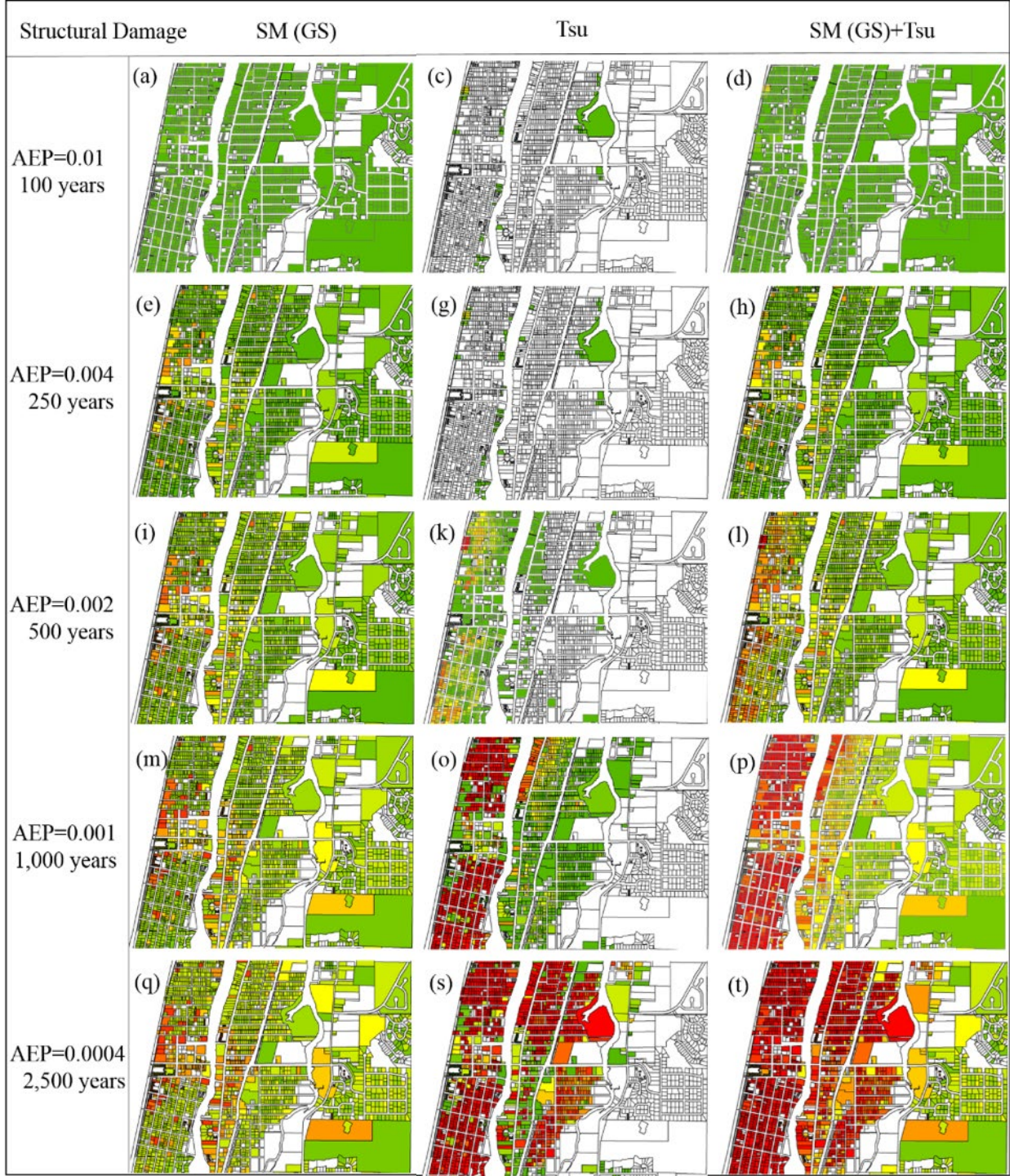
AEP=0.001
1,000 years



TSU + EQ
Loss total: 1,230 M

Park, H, MS Alam, DT Cox, AR Barbosa, JW van de Lindt (2019) “Probabilistic seismic and tsunami damage analysis (PSTDA) for the Cascadia Subduction Zone applied to Seaside, Oregon,” *International Journal of Disaster Risk Reduction*, 35, 101076, https://doi.org/10.1016/j.ijdrr.2019.101076.


Structural Damage
SM (GS)
Tsu
SM (GS)+Tsu
AEP=0.01
100 years
AEP=0.004
250 years
AEP=0.002
500 years
AEP=0.001
1,000 years
AEP=0.0004
2,500 years
(a)
(c)
(d)
(e)
(g)
(h)
(i)
(k)
(l)
(m)
(o)
(p)
(q)
(s)
(t)

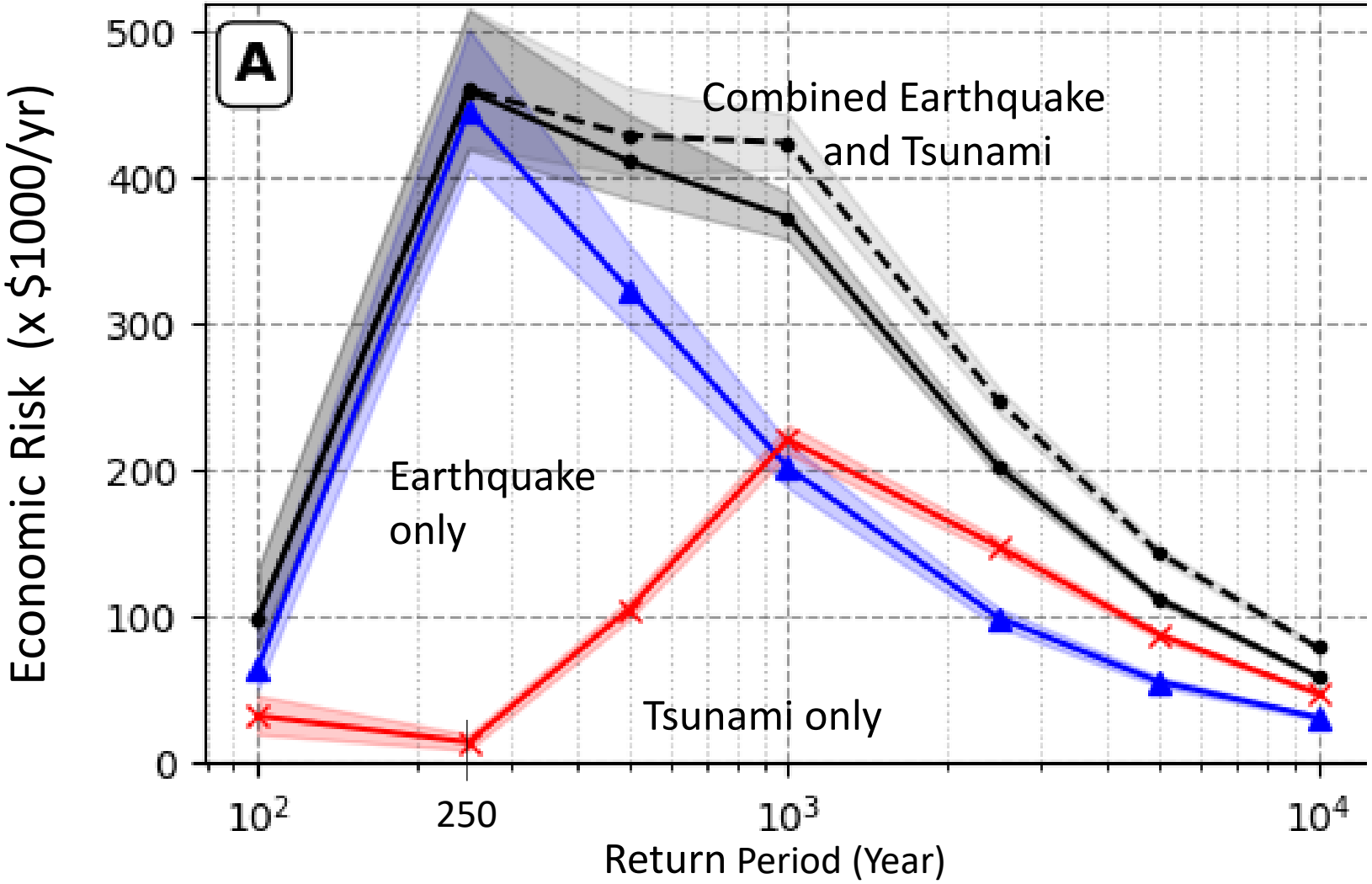


Higher probability
Lower consequences

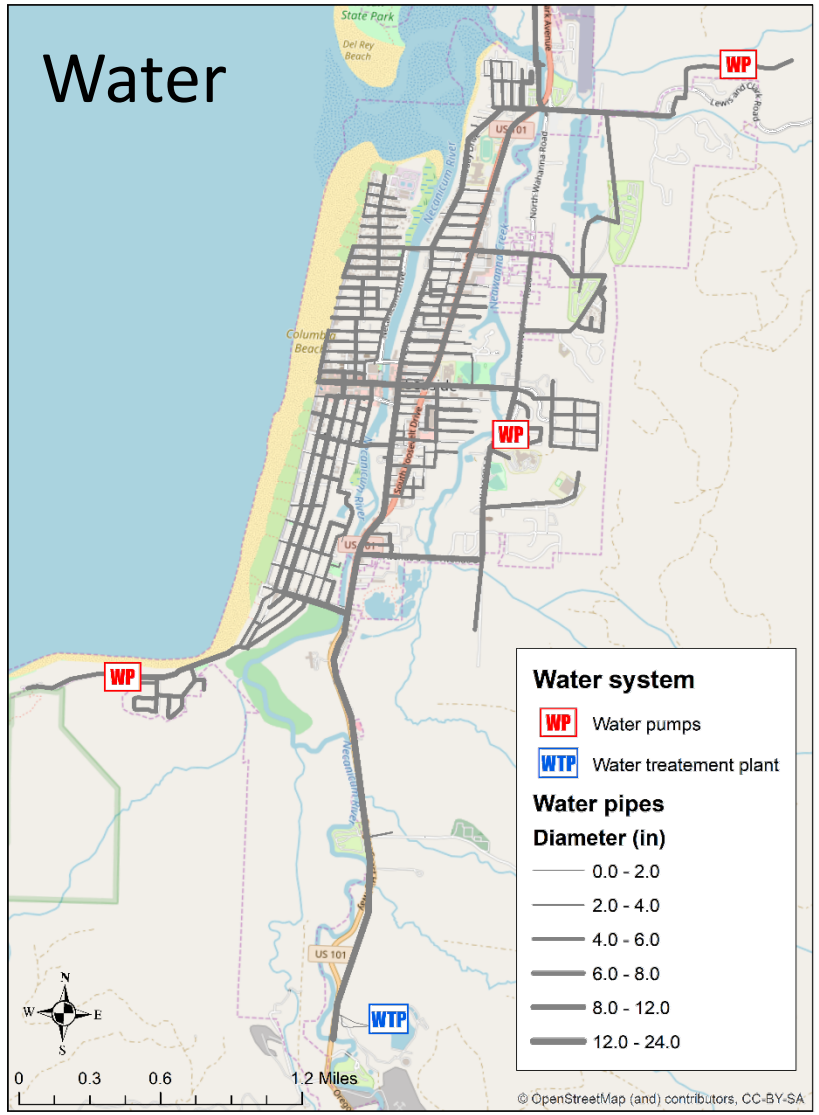
Highest
Risk

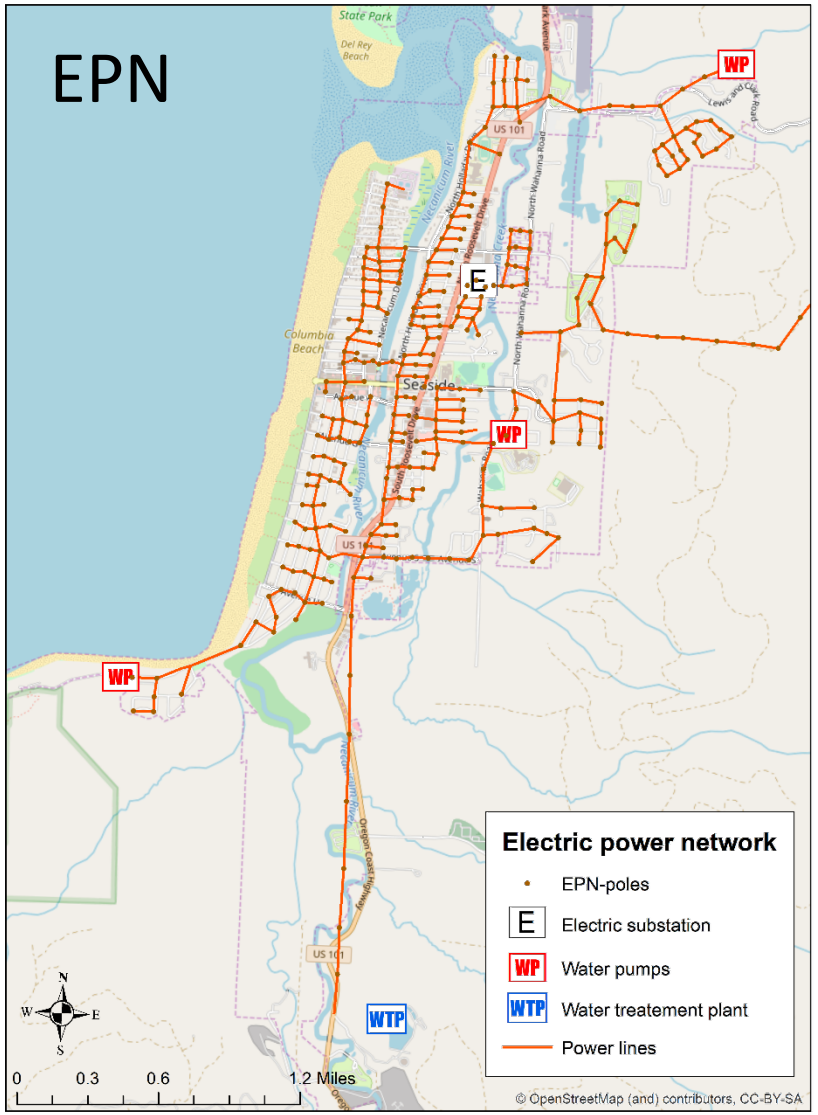
Lower probability
Higher consequences

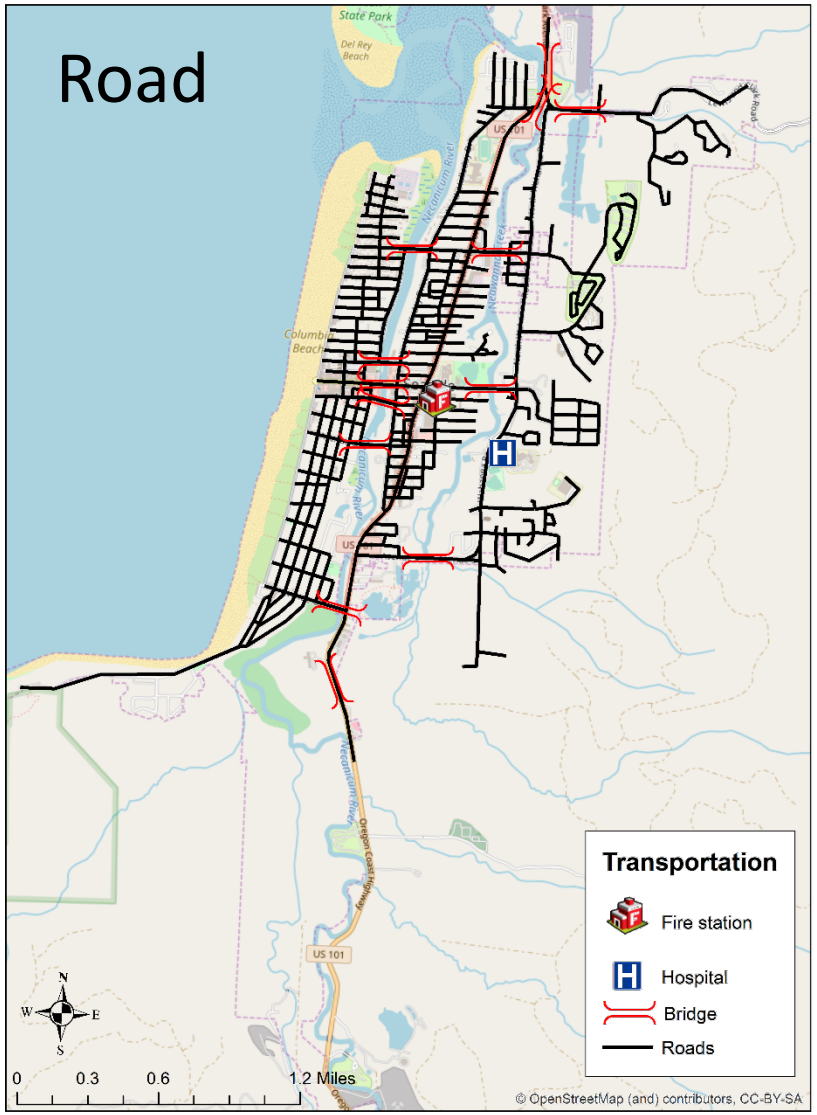
Annualized Risk for Building Damages in Seaside



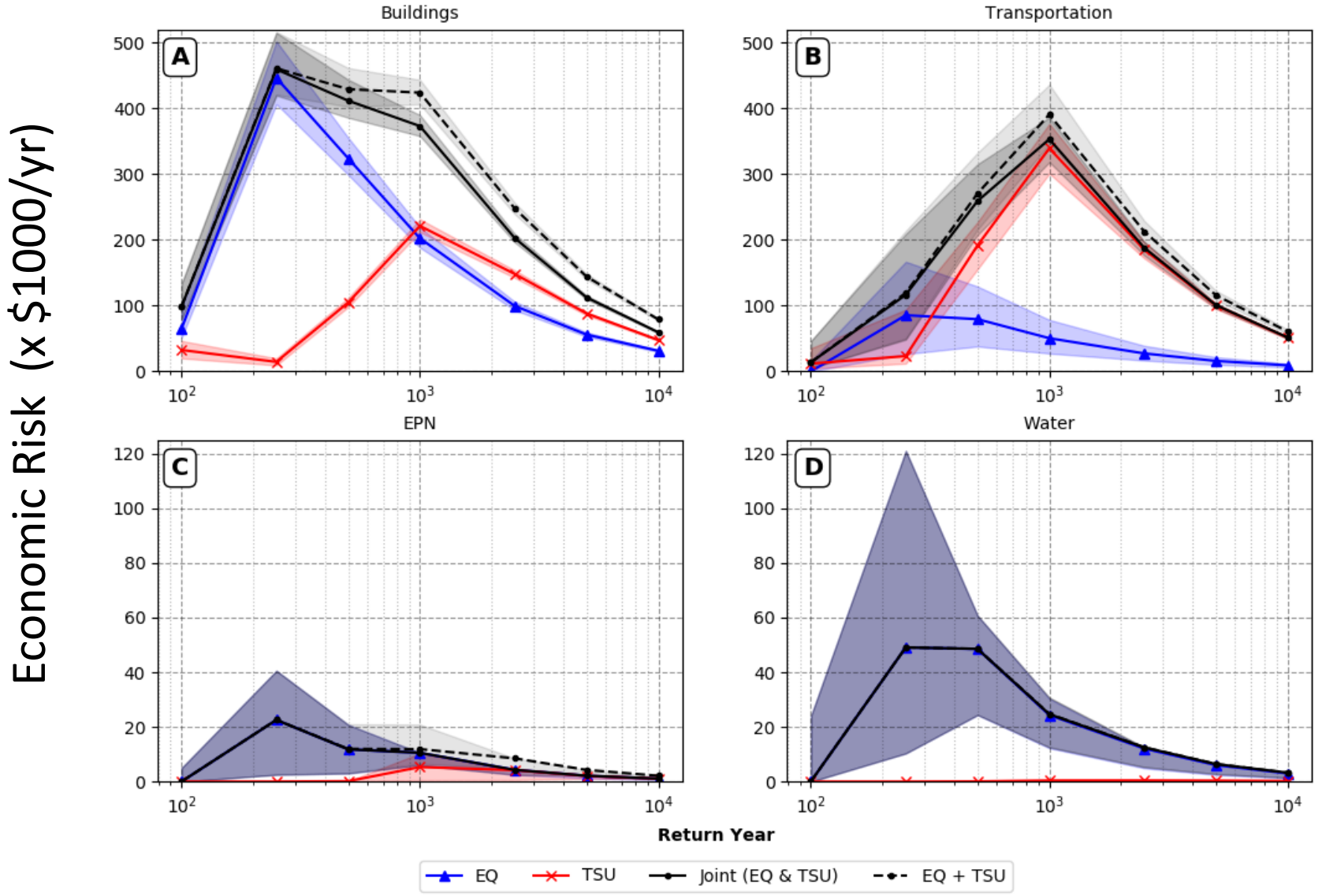
Critical (lifeline) infrastructure networks





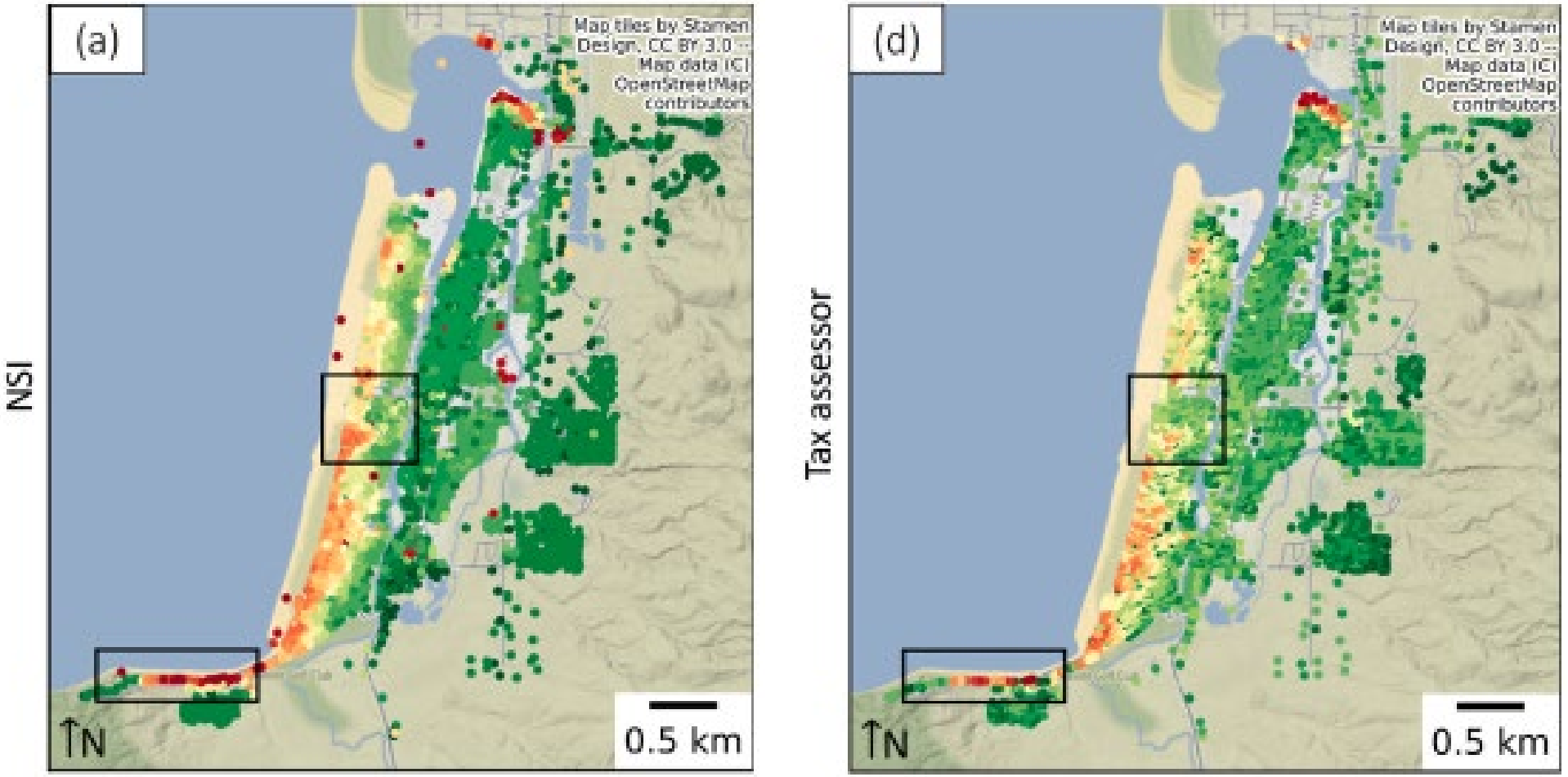


Annualized Risk for Building Damages in Seaside



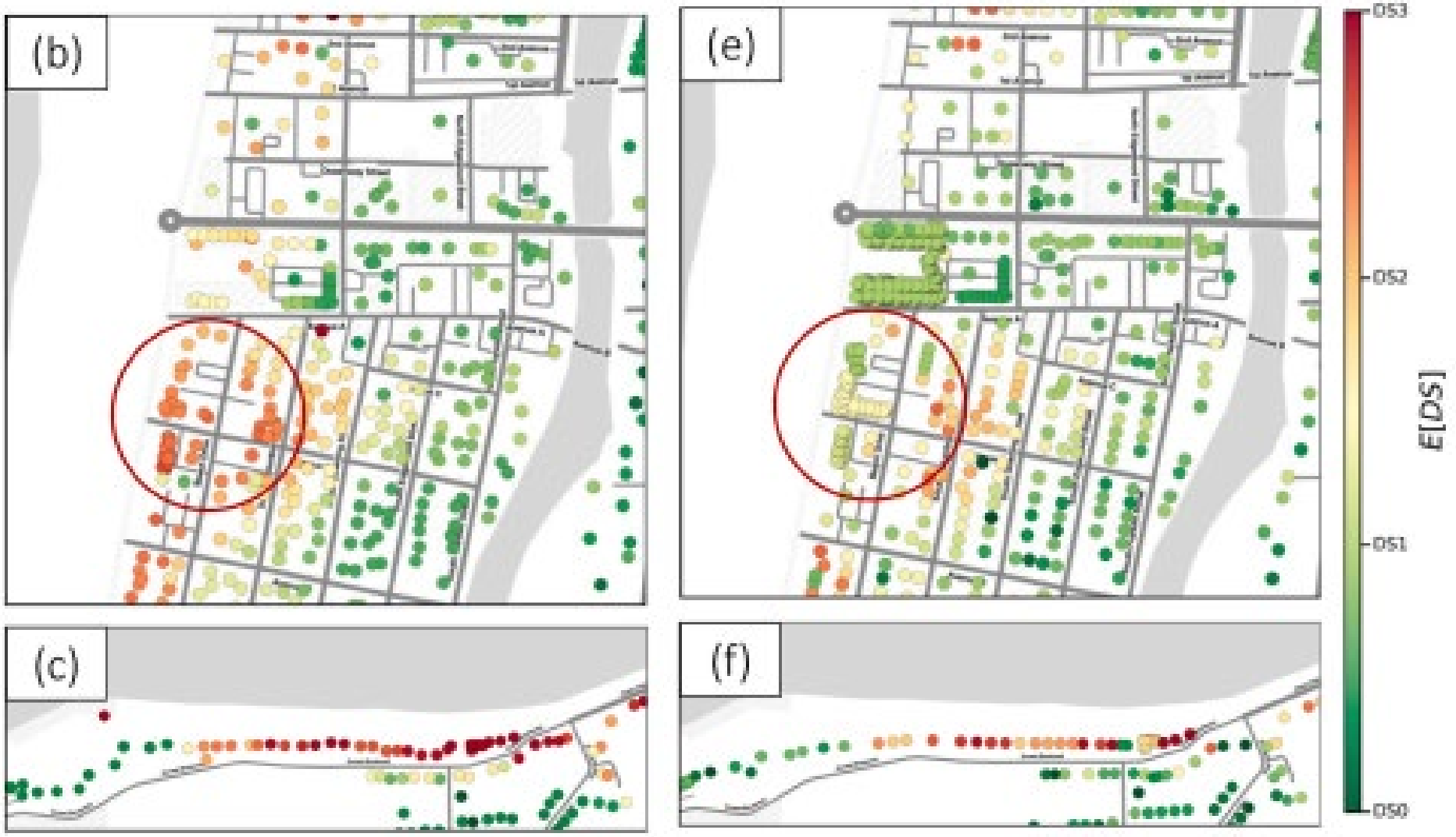
Sanderson D, S Kameshwar, N Rosenheim, DT Cox (2021) "Deaggregation of multi-hazard damages, losses, risks, and connectivity: An application to the joint seismic-tsunami hazard at Seaside, Oregon," *Natural Hazards*, https://doi.org/10.1007/s11069-021-04900-9.

Uncertainty in the building stock



Sanderson D, DT Cox (2023) "Comparison of national and local building inventories for damage and loss modeling of seismic and tsunami hazards: From parcel-to-city-scale" *International Journal of Disaster Risk Reduction*, https://doi.org/10.1016/j.ijdrr.2023.103755

Uncertainty in the building stock



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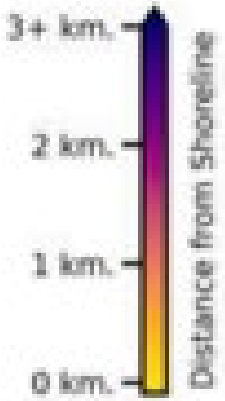
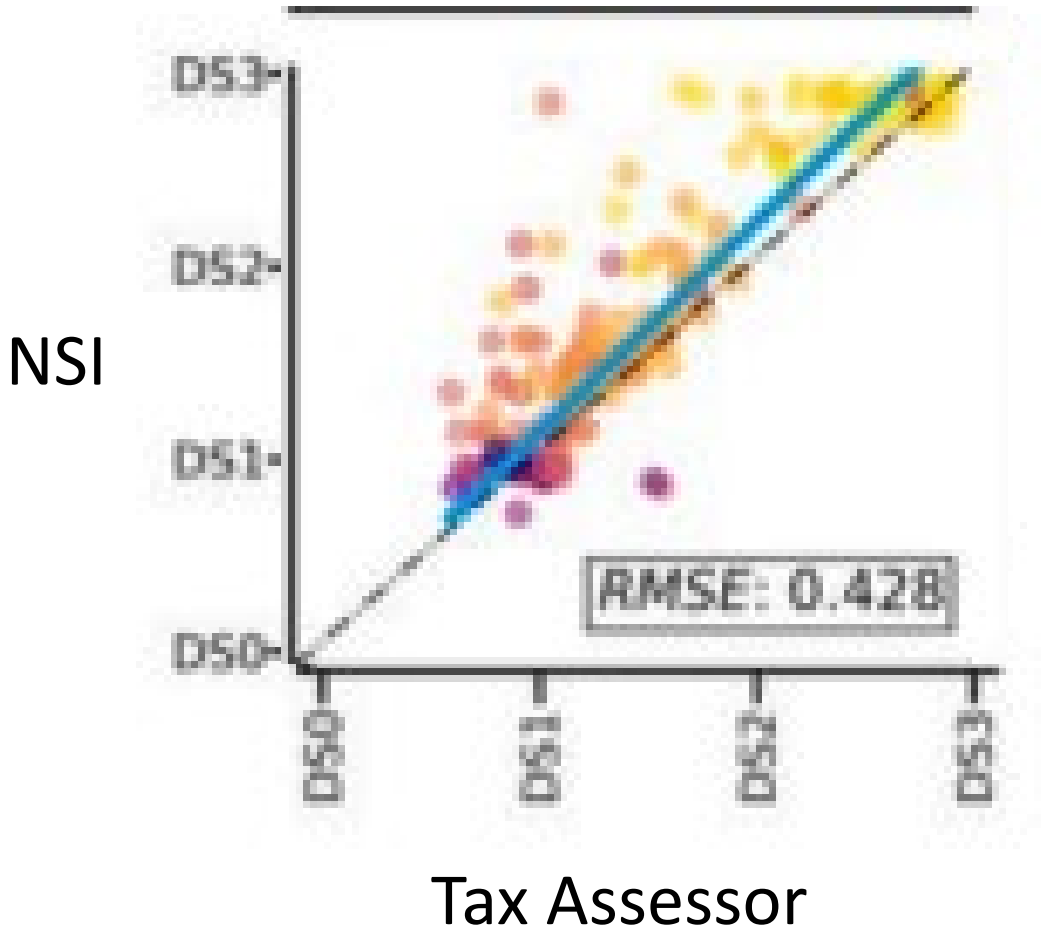
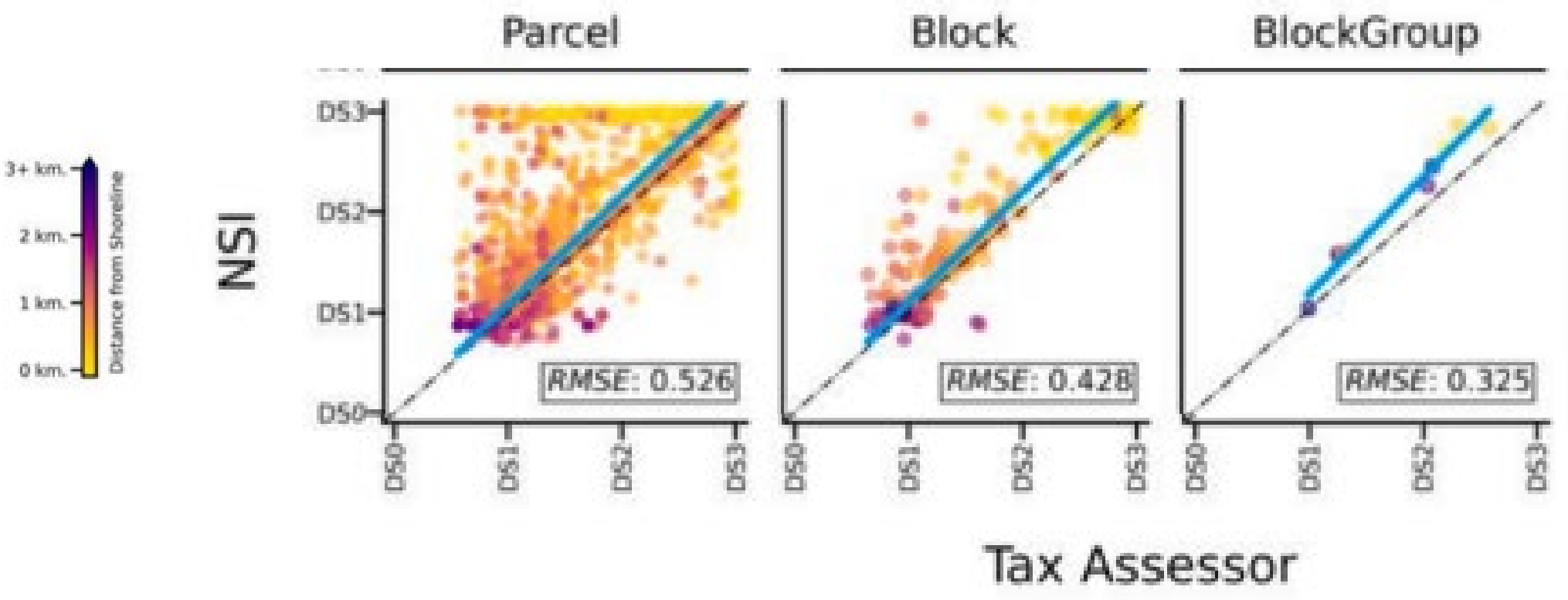
Uncertainty in the building stock

1,000 yr event Block Level

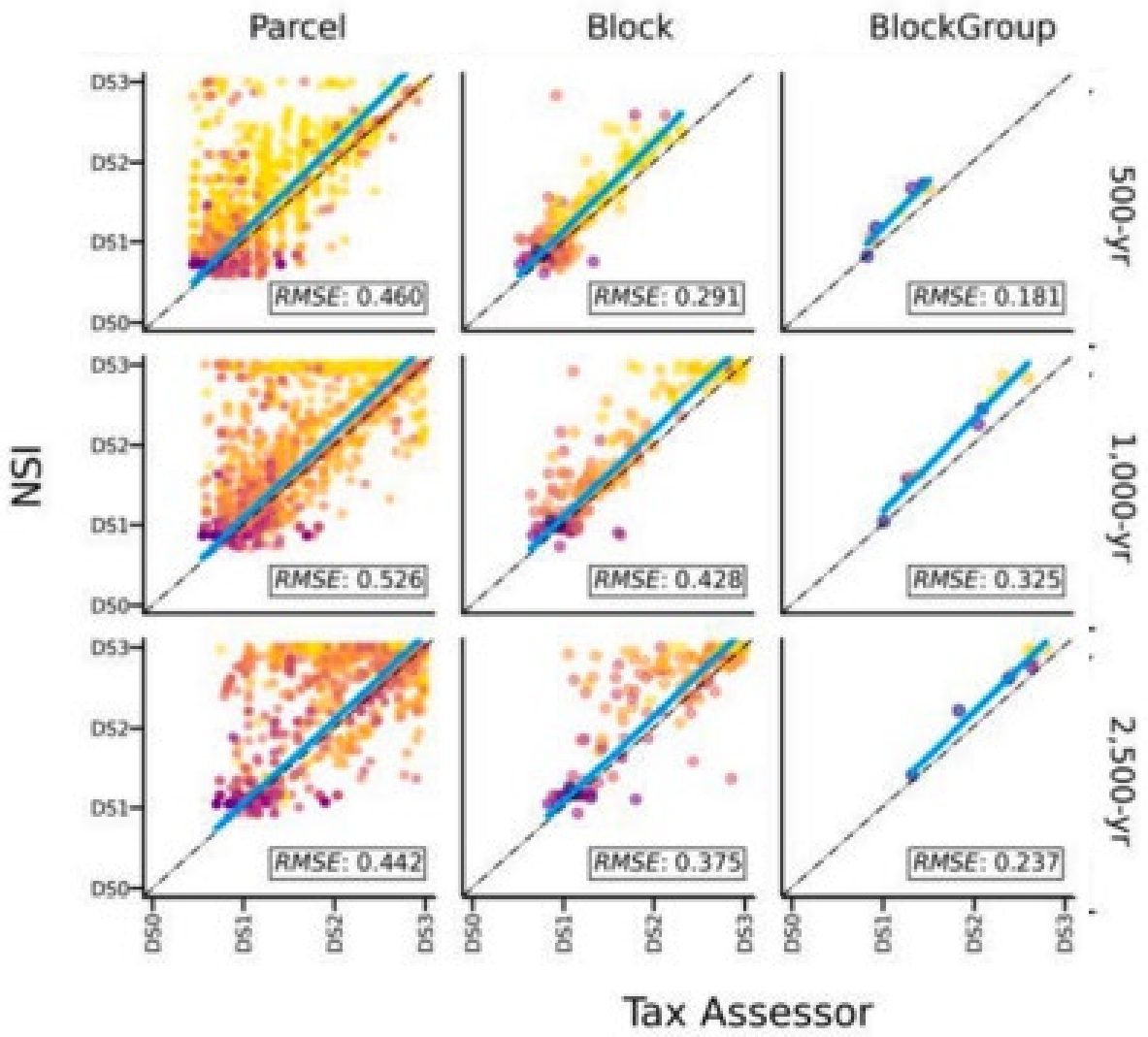


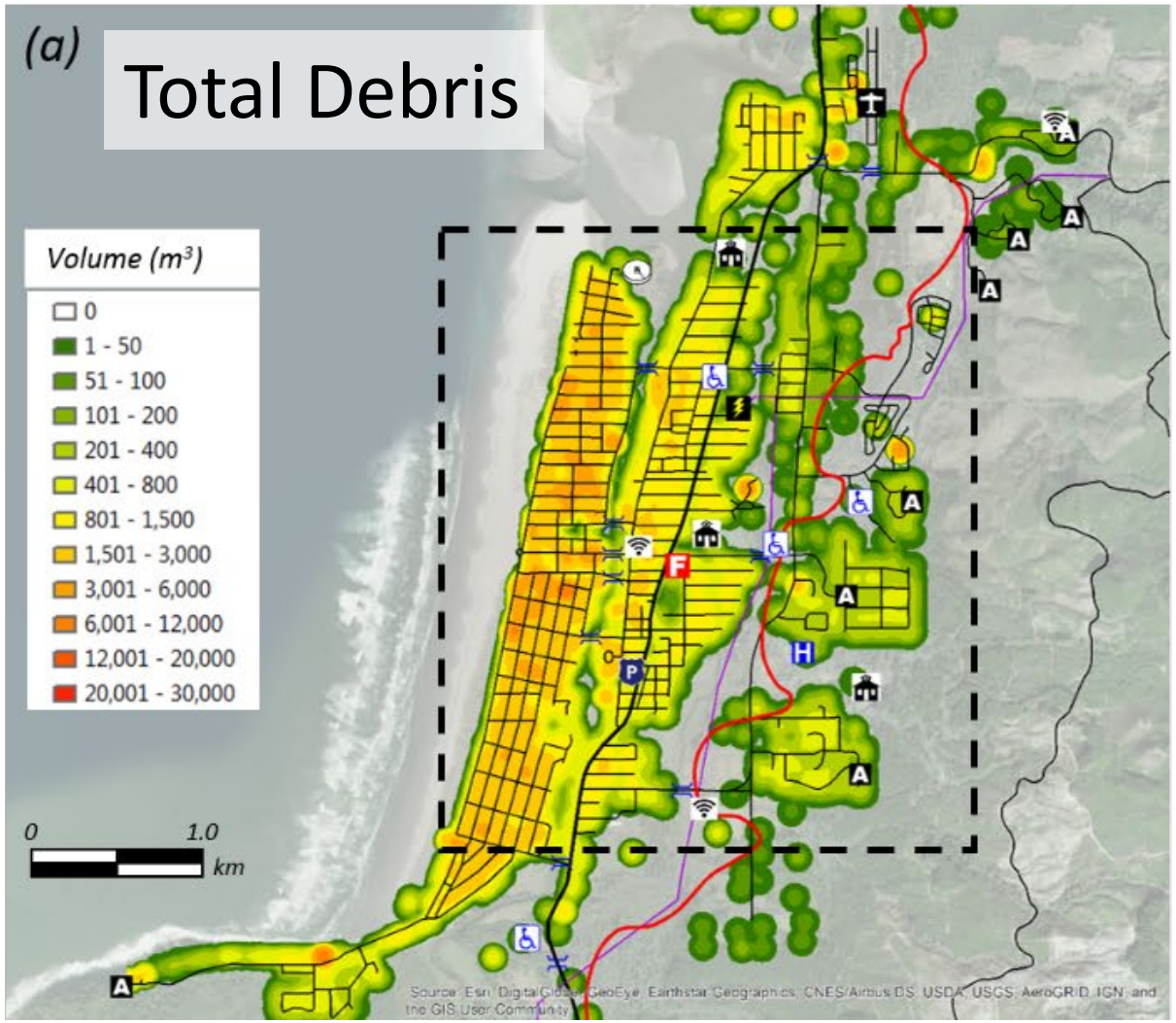


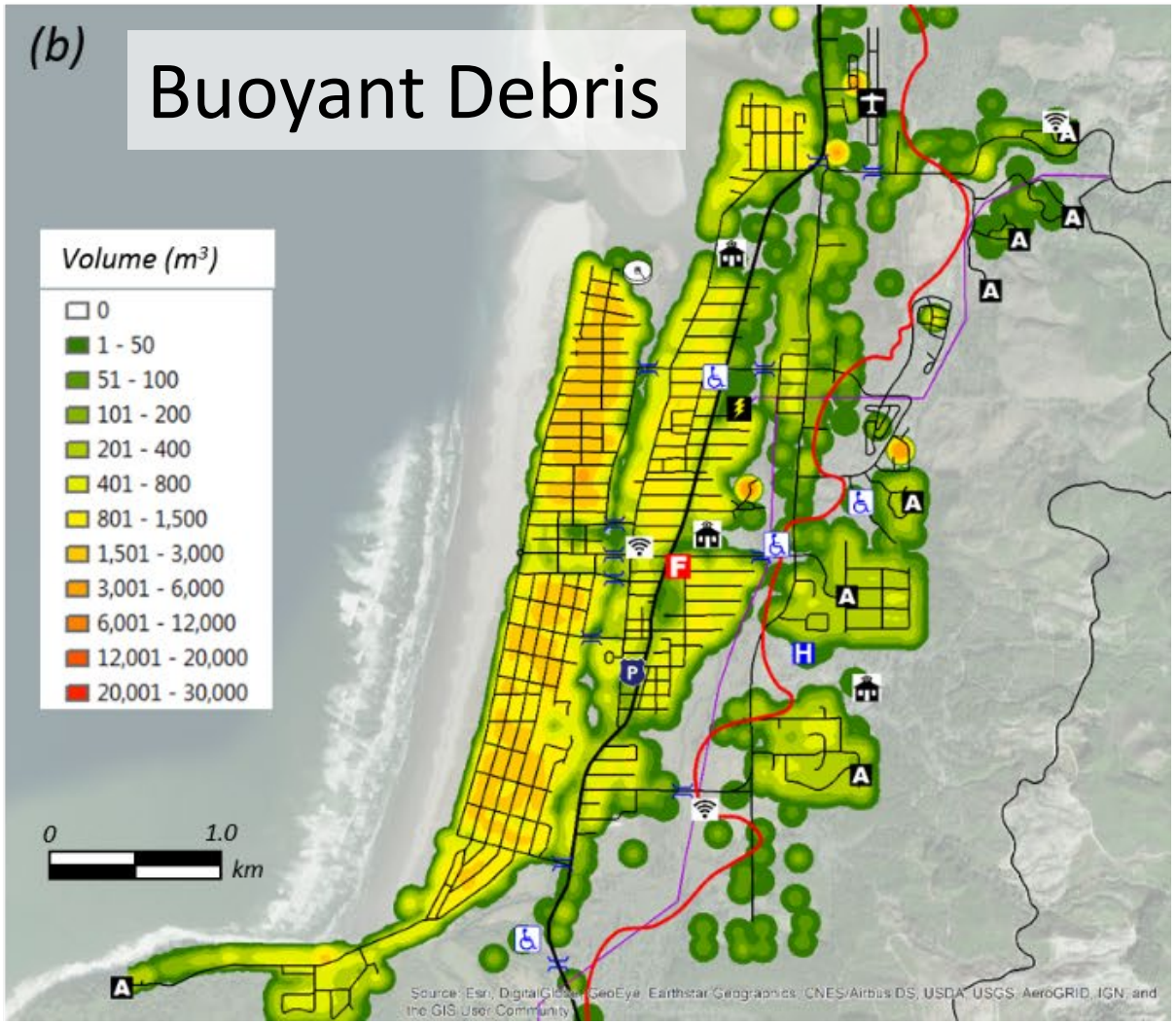
Uncertainty in the building stock



Uncertainty in the building stock

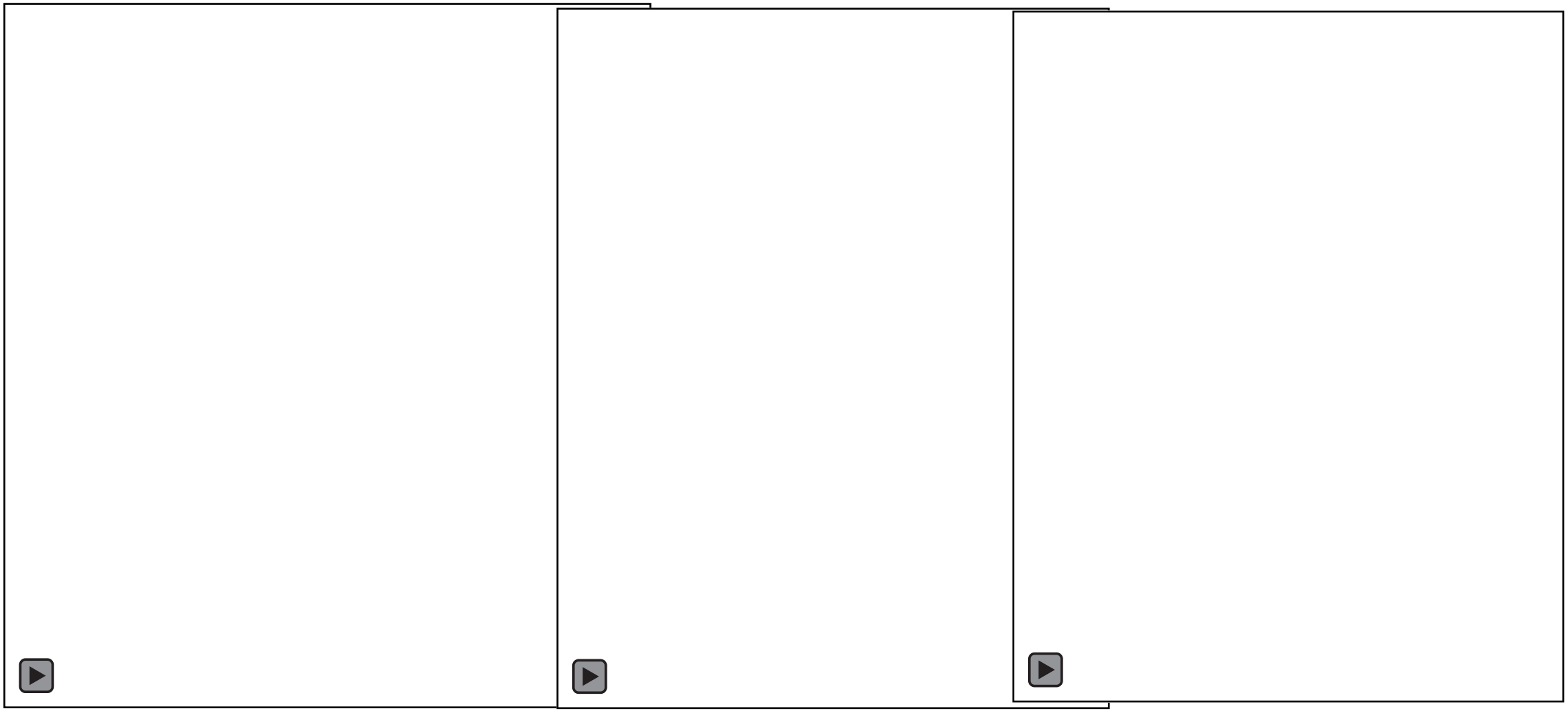




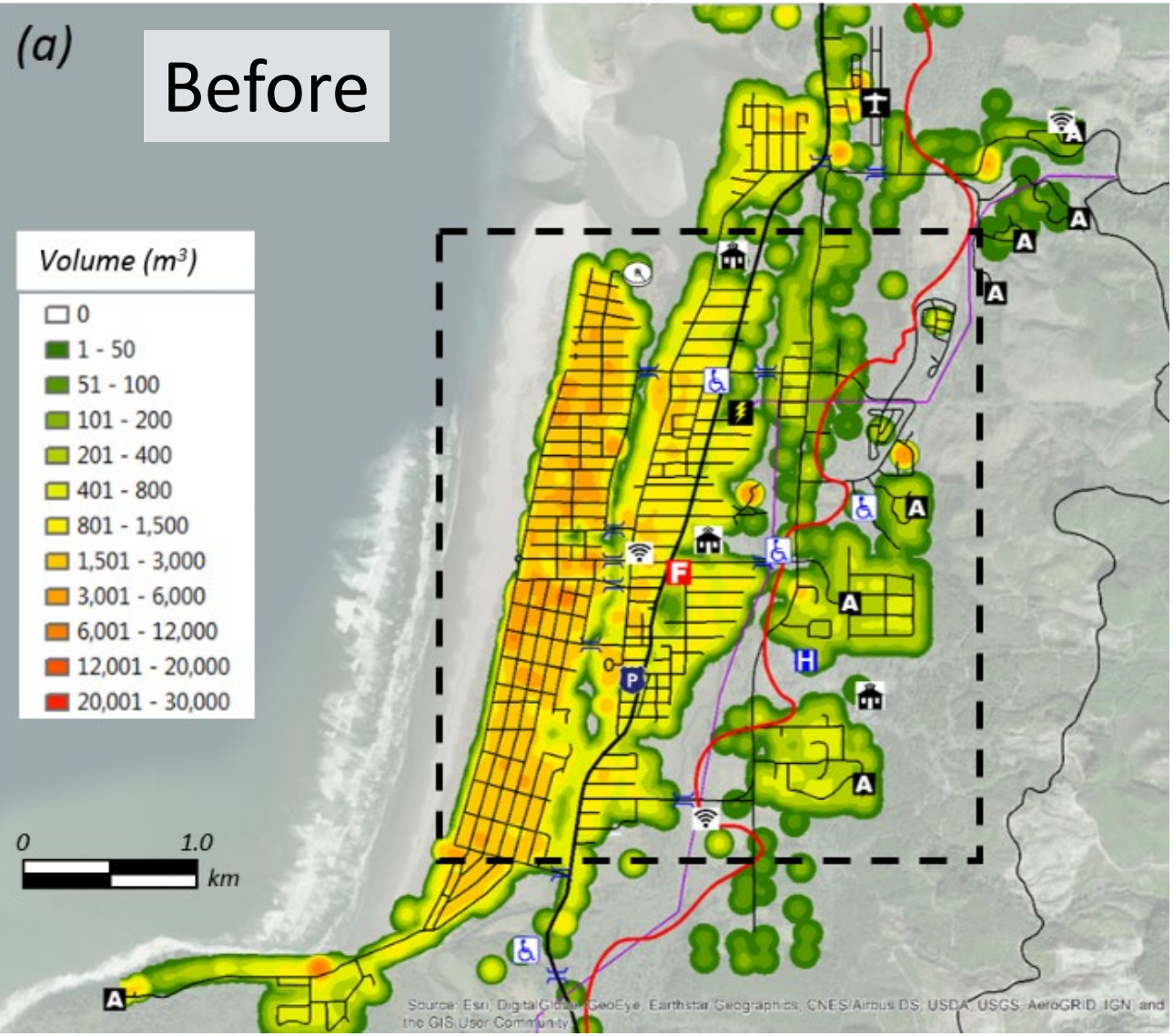


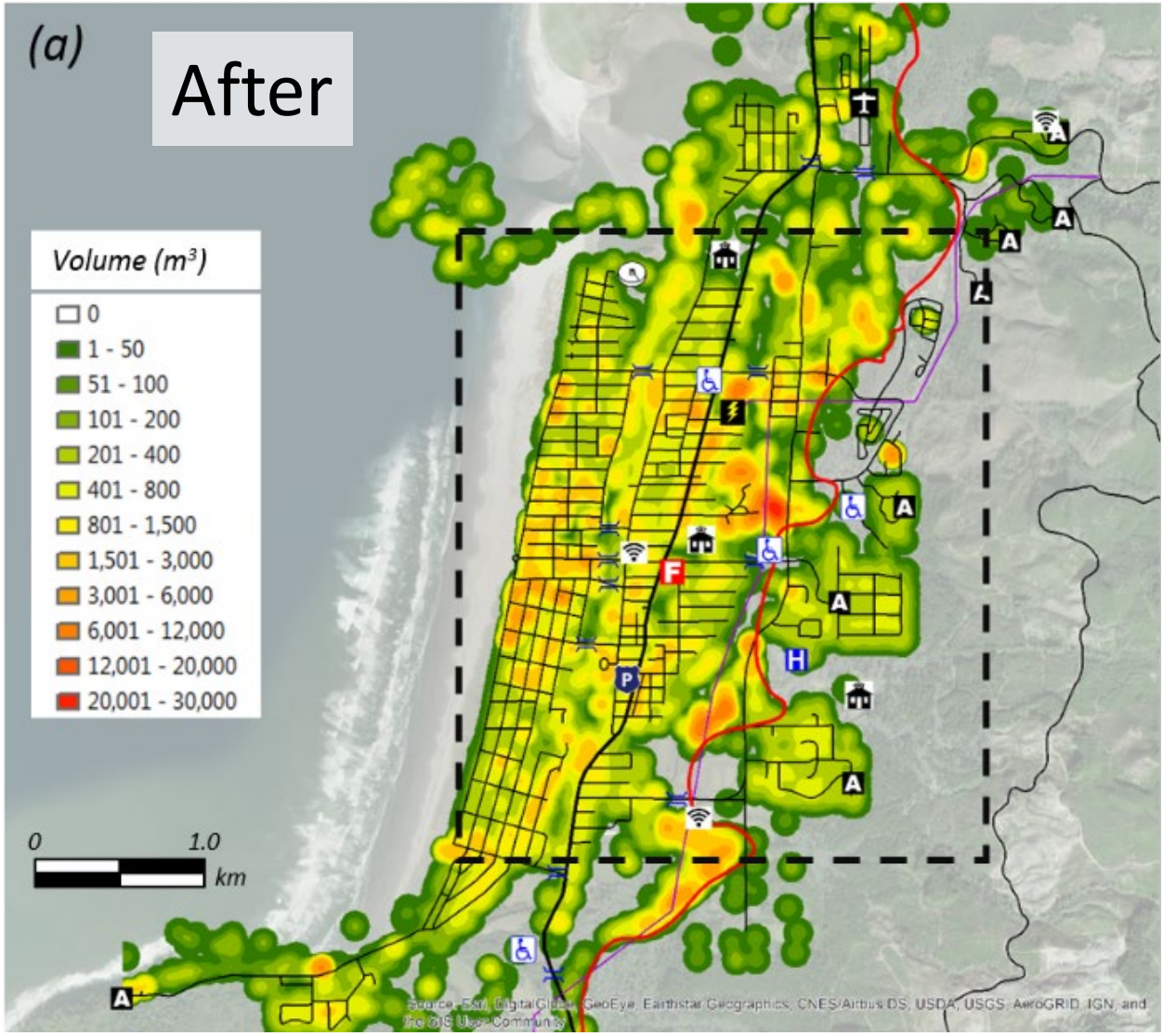
Distribution of expected debris volume (m^3) per unit area (hectare) for 1000 year event without advection. (a) Volume of total debris from EQ+TSU, (b) Volume of buoyant debris only from EQ+TSU.

Advection of buoyant debris from PSTDA at AEP = 0.0004 (2,500 yr)



Thresholds: 3 m, 0.5 m/s 1 m, 0.3 m/s 0.5 m, 0.2 m/s





Park H, DT Cox (2019) "Effects of advection on forecasting construction debris for vulnerability assessment under multi-hazard earthquake and tsunami," *Coastal Engineering* https://doi.org/10.1016/j.coastaleng.2019.103541

Post-event Community Connectivity and Access to Critical Facilities

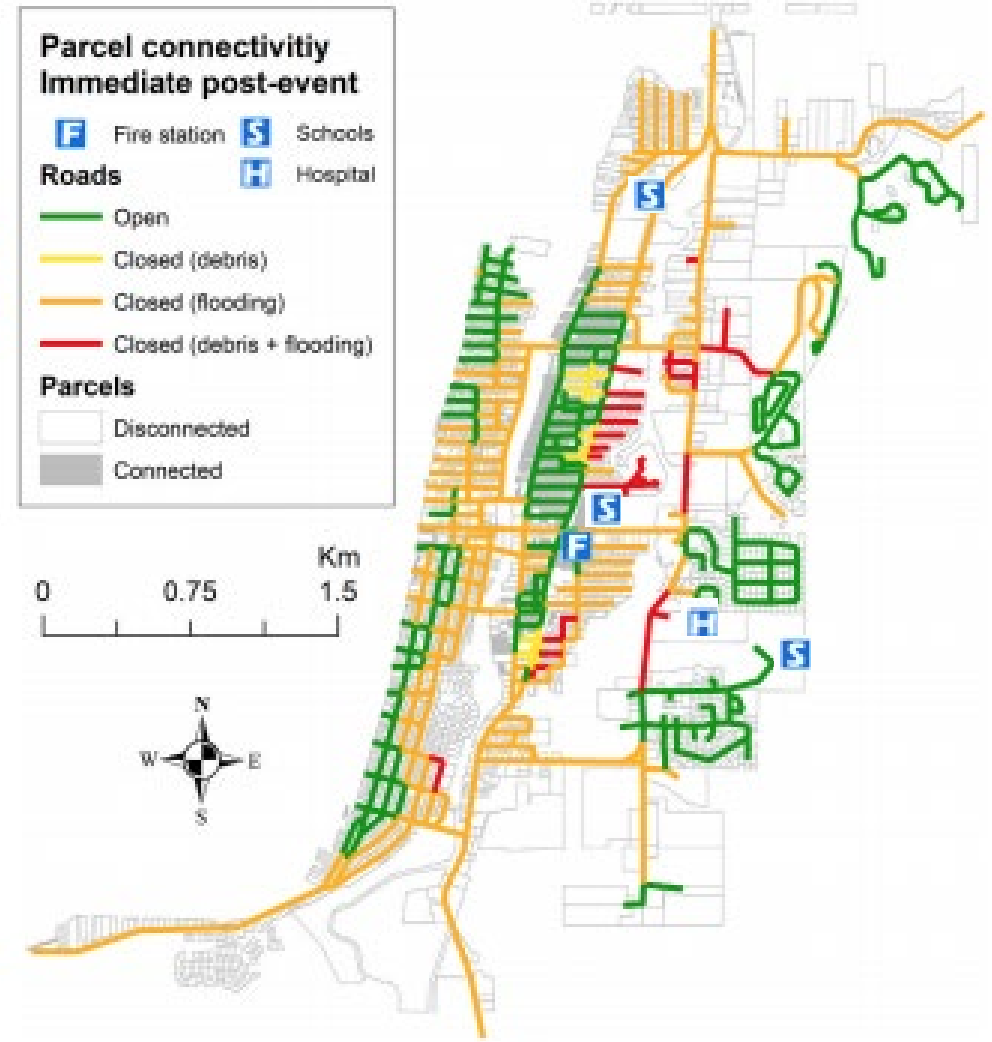


Table 1
Likelihood of accessing hospitals and the high school immediately after tsunami events.

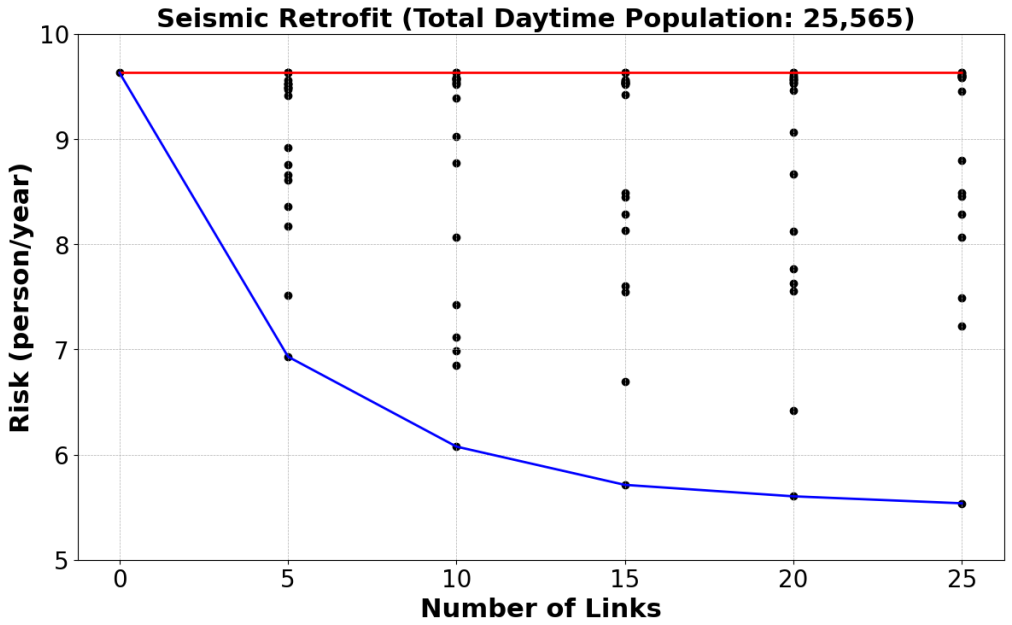
(a) Connectivity to hospital					
Return period	AA #2	AA #5	AA #6	AA #7	AA #8
250	0.84	1.00	1.00	1.00	0.99
500	0.67	1.00	1.00	1.00	0.82
1000	0.00	0.00	0.00	0.00	0.00
2500	0.00	0.00	1.00	0.00	0.00
5000	0.00	0.00	0.00	0.00	0.00
10000	0.00	0.00	0.00	0.00	0.00

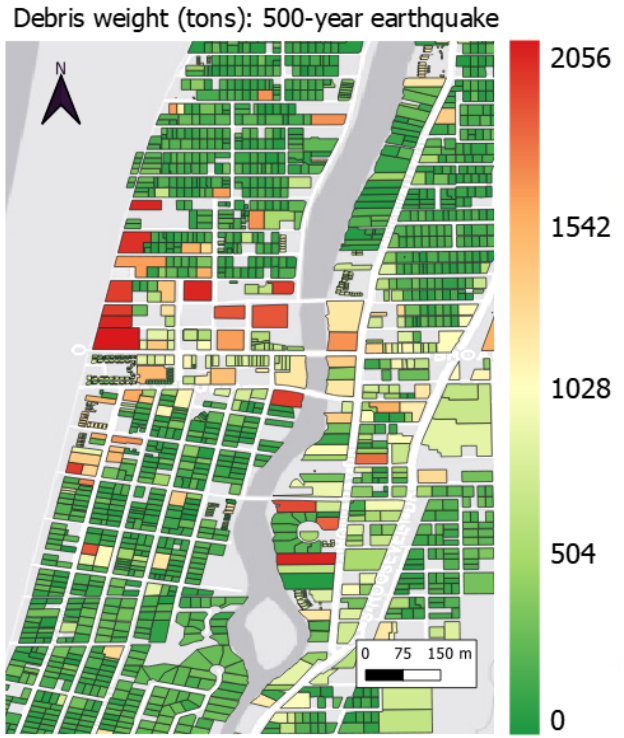
(b) Connectivity to high school					
Return period	AA #2	AA #5	AA #6	AA #7	AA #8
250	0.83	0.99	0.99	0.99	1.00
500	0.63	0.95	0.95	0.95	0.86
1000	0.10	0.00	0.34	0.02	0.32
2500	0.01	0.00	0.05	0.00	0.04
5000	0.00	0.00	0.00	0.00	0.04
10000	0.00	0.00	0.00	0.00	0.02

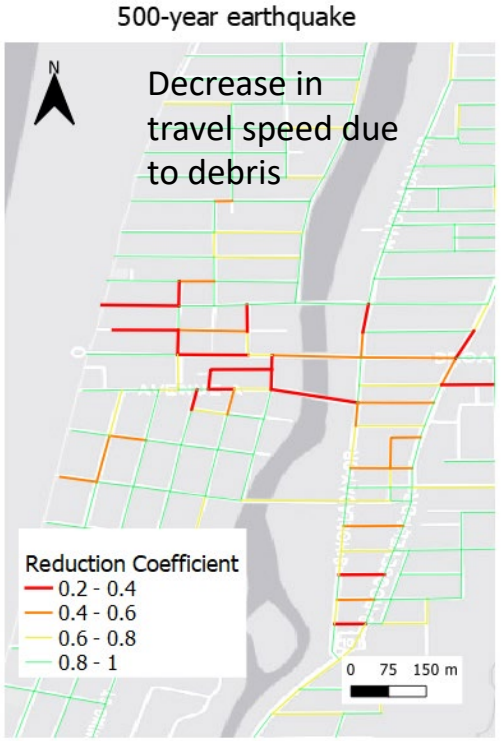
Kameshwar S, H Park, DT Cox, AR Barbosa (2021) “Effect of disaster debris, flood duration, and bridge damage on immediate post-tsunami connectivity,” *Int. J. Disaster Risk Reduction*, https://doi.org/10.1016/j.ijdrr.2021.102119.

Life Safety Modeling

- Effect of earthquake damage on the tsunami casualty:
  - EQ damage increases building evacuation time.
  - EQ debris increases pedestrian evacuation time.
- Work in progress:
  - Risk-based modeling for EQ + Tsu
  - Inclusion of **tourist** in life safety and risk
  - Impact of **structural retrofit** on building egress and road debris







Amini M, DR Sanderson, DT Cox, AR Barbosa (2023) "Evaluating structural retrofit and land use policy options for multi-hazard earthquake and tsunami risk reduction for life safety and damage in a coastal city," *Natural Hazards*, https://doi.org/10.1007/s11069-023-05937-8

Thank you!

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