# CLIMATE RISK AND VULNERABILITY ASSESSMENT


Ephrat Yovel

**Workshop on Climate Change Adaptation**
8 Feb 2021

1

## *TOPICS OF DISCUSSION*

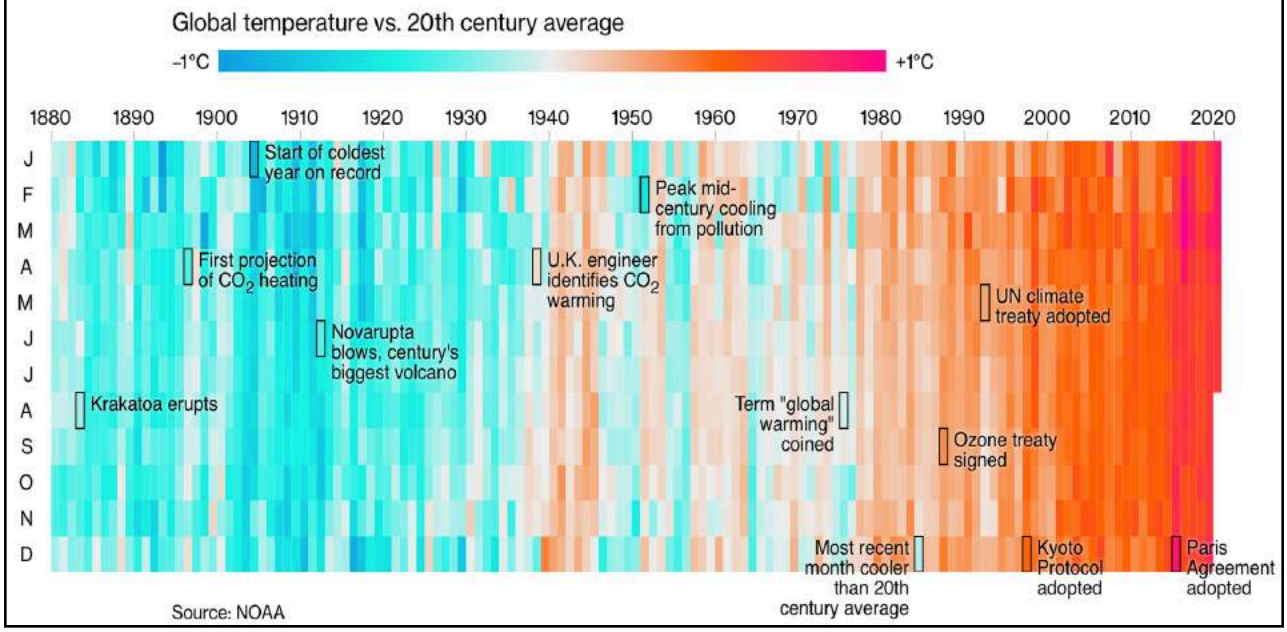
- Shared understanding
- Climate risk and vulnerability assessment
  - Framework
  - Process
  - Approaches and case studies

2

# A SHARED UNDERSTANDING

3

## GLOBAL TEMPERATURES ARE INCREASING




4

## *WE HAVE A GOOD IDEA OF HOW CERTAIN TYPES OF CLIMATE EVENTS ARE BEING AFFECTED*

Stronger and more frequent heat waves

Stronger rainfall and winter storms

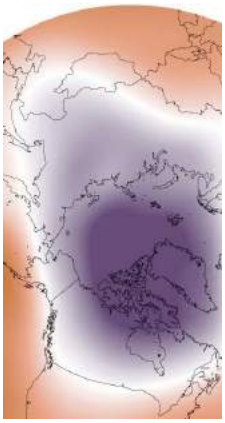
Rising sea level and stronger hurricanes

Larger wildfires in the West

5

## *OTHERS, WE'RE STILL FIGURING OUT*

Droughts: stronger, but more or less frequent?



Polar Vortex: related to Arctic warming?

Derechos: Hard enough to predict, let alone project!

Tornadoes, hail-storms: stronger, but more or less frequent?

6

## *CHANGING CLIMATE IS A RISK MULTIPLIER*

Uncertain impacts on existing systems

Uncertain politics and social reactions

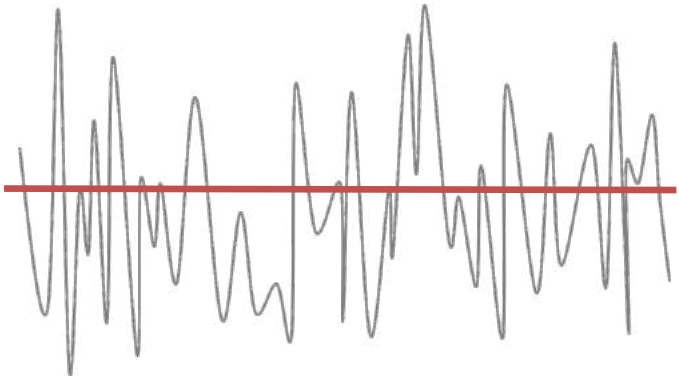
Changing composition of populations

Uncertainty of changing costs and funding flows

7

## *IMPACTS ARE HERE. TIME TO PREPARE*

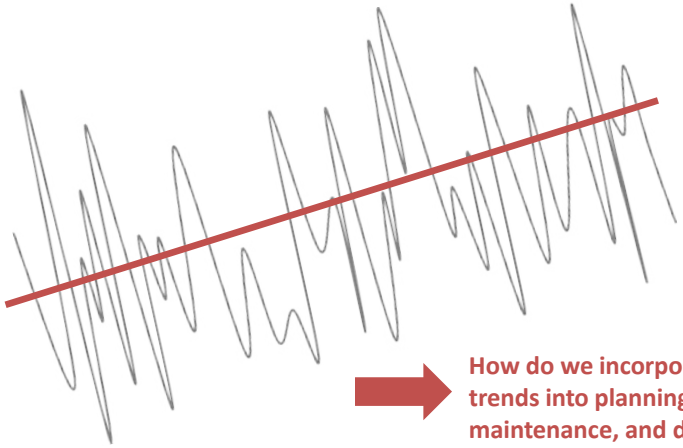
We used to assume that the long-term climate will remain stable and can be predicted based on past climate normals



8

## *IMPACTS ARE HERE. TIME TO PREPARE*

Today, climate is manifestly non-stationary: Past is no longer a reliable indicator of present or future conditions



**How do we incorporate changing climate trends into planning for operations, maintenance, and design?**

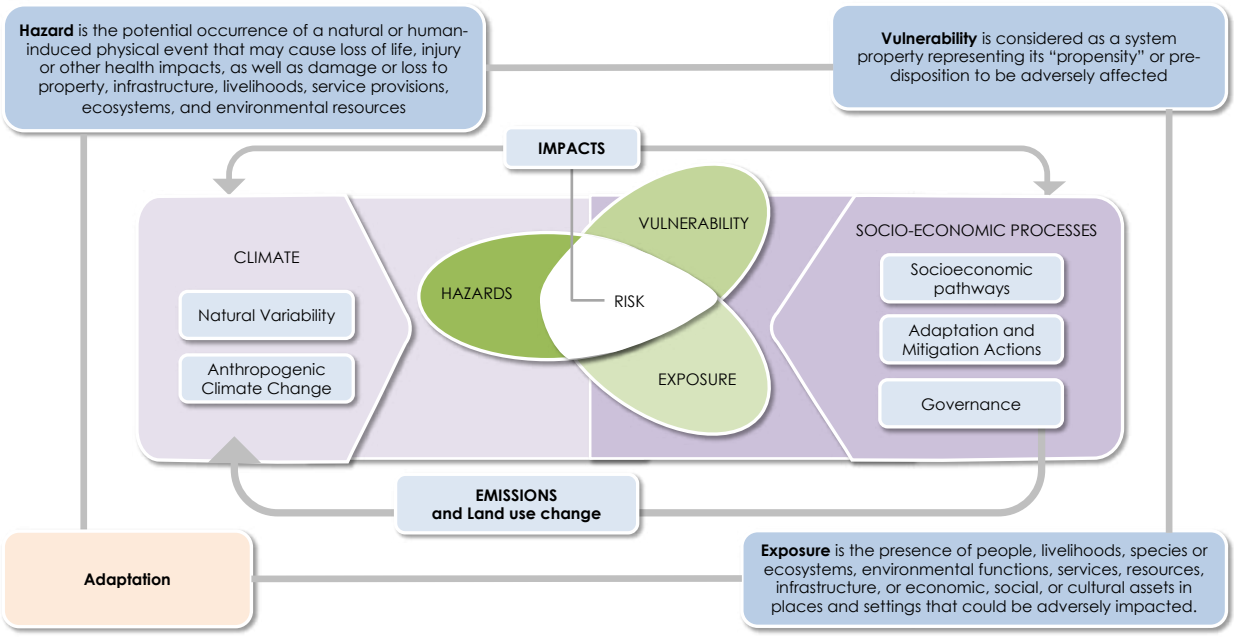
9


10

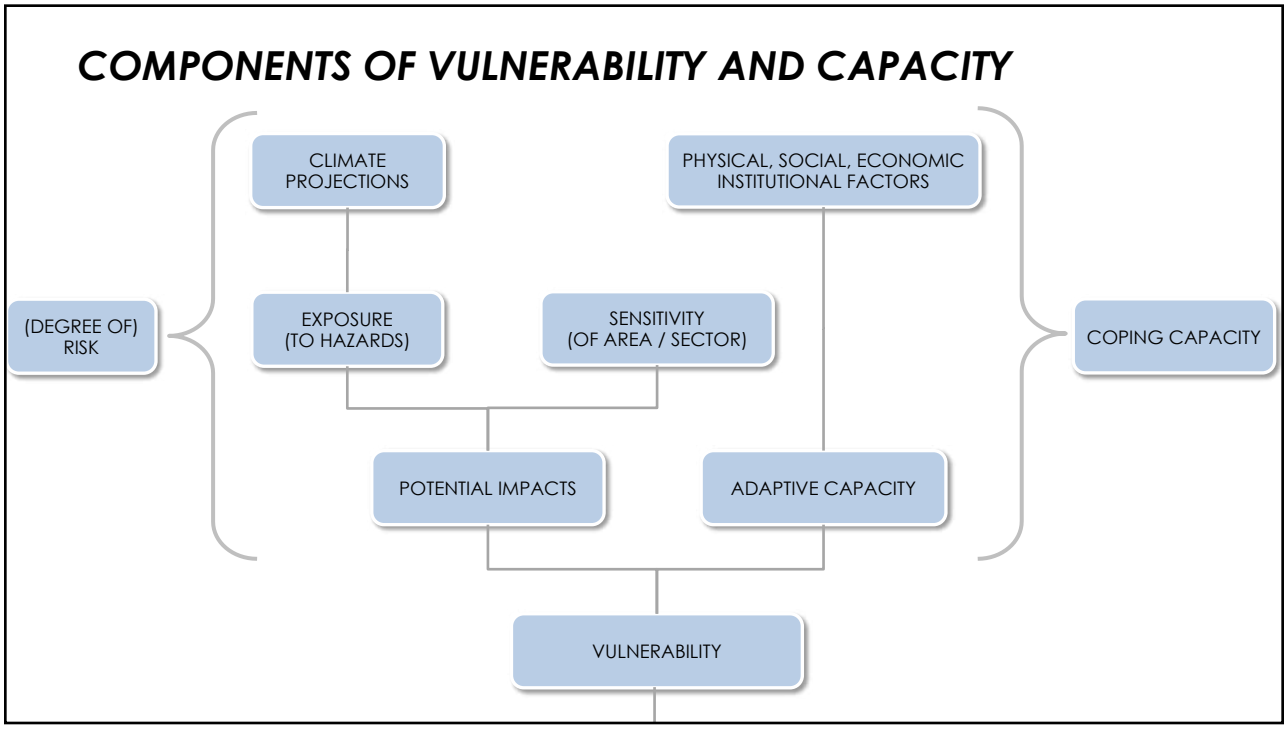
# CONCEPTUAL FRAMEWORK FOR CLIMATE RISK AND VULNERABILITY ASSESSMENT

11

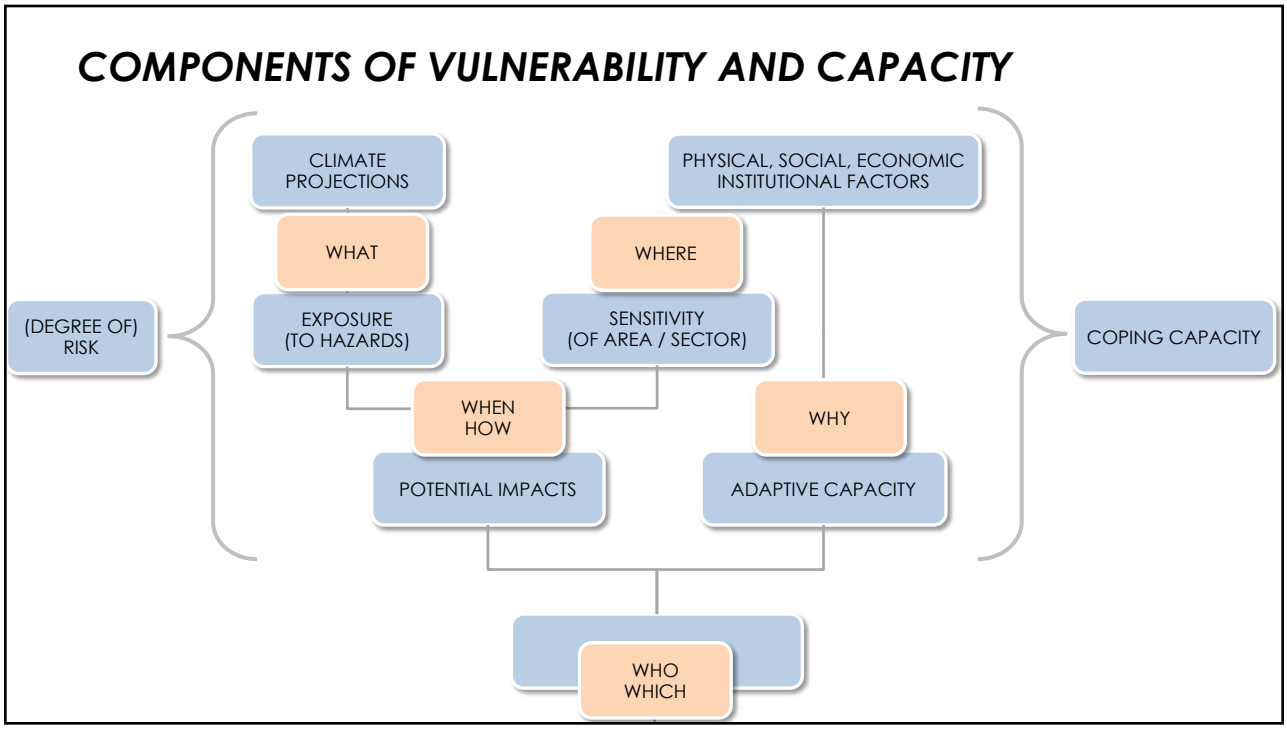
## TRANSITION TO CONTEXTUAL UNDERSTANDING OF VULNERABILITY




12


COMPONENTS OF VULNERABILITY AND CAPACITY
CLIMATE PROJECTIONS
PHYSICAL, SOCIAL, ECONOMIC INSTITUTIONAL FACTORS
(DEGREE OF) RISK
EXPOSURE (TO HAZARDS)
SENSITIVITY (OF AREA / SECTOR)
COPING CAPACITY
POTENTIAL IMPACTS
ADAPTIVE CAPACITY
VULNERABILITY

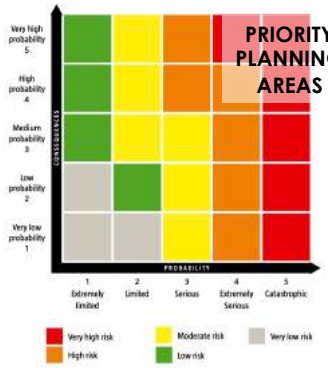
13


COMPONENTS OF VULNERABILITY AND CAPACITY
CLIMATE PROJECTIONS
PHYSICAL, SOCIAL, ECONOMIC INSTITUTIONAL FACTORS
WHAT
WHERE
(DEGREE OF) RISK
EXPOSURE (TO HAZARDS)
SENSITIVITY (OF AREA / SECTOR)
COPING CAPACITY
WHEN HOW
WHY
POTENTIAL IMPACTS
ADAPTIVE CAPACITY
WHO WHICH

14

## *VULNERABILITY & RISK ASSESSMENT*

CLIMATE SCENARIOS & PROJECTIONS




VULNERABILITY & RISK ASSESSMENT


ADAPTATION PLANS

15

# *PROCESS OVERVIEW*

16

## *WHY ASSESS VULNERABILITY AND ADAPTATION?*

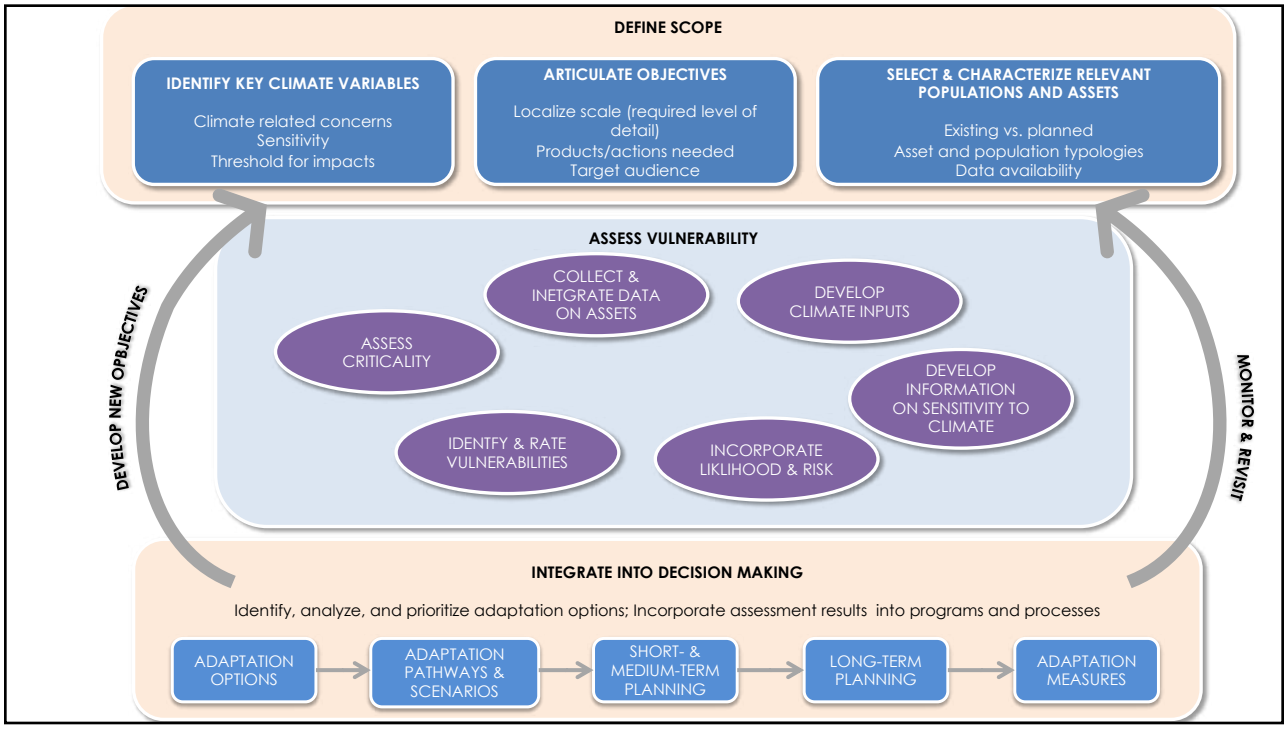
- To identify the extent and location of short-term and long-term threats from natural disasters and climate change
- To understand the underlying vulnerability of populations and assets and their adaptive capacity
- To assist in the identification and prioritization of current and future adaptation needs
- To support preemptive action and provide a baseline for planning and undertaking adaptation and mitigation efforts

17

## *KEY CHALLENGES*

- Absence of international and national guidelines
  - Absence of standardized sectoral assessment frameworks
- Inconsistent application of IPCC definitions
- Transition from high science modeling to practical, technical and participatory processes
  - Technical knowledge and analysis capacity
- Accounting for multi-sectoral considerations

18




19

# *1 – IDENTIFY KEY CLIMATE VARIABLES*

- Identify climate or weather-related concerns
  - Quantify the type of the information required
  - Determine which of these risks have changed historically or are likely to change in the future, and the extent to which climate science can provide robust information on these risks to be used in future planning
    - **Current climate hazards (historical and observed data)**
    - **Detecting changes (should be available from hydromet)**
    - **Future climate hazards (GCMs, RCMs, downscaled, projections & likely scenarios, uncertainty envelopes)**
- Threshold for impacts

20

## *2 – ARTICULATE OBJECTIVES*

- Asymmetry between the needs and concerns of scientists and decision-makers
  - Localize scale (what is the required level of detail)
  - What type of products or actions are needed
  - Who is the target audience

What are **current objectives** for the population, asset or locality?

What **strategies & tools** accomplish revised objectives?

How are they **failing**?
Where, when & why?

21

## *ASYMMETRY BETWEEN THE NEEDS AND CONCERNS OF SCIENTISTS AND DECISION-MAKERS*

**Technical and scientific community**

- Problems = Global warming / GHG emission levels
- Focus = Climate science
- Methods = GCM scenarios, etc.
- Perspective = Top-down
- Vulnerability = Climate impacts
- Adaptation = Future
- Goal = Adaptation measures
- Assessment = Global, regional

**Decision-makers**

- Problems = Budget, poverty
- Focus = Prioritization of issues
- Methods = Development aid strategies
- Perspective = Bottom-up
- Vulnerability = Current and future
- Adaptation = Current
- Goal = Policies and actions
- Assessment = National, local, projects

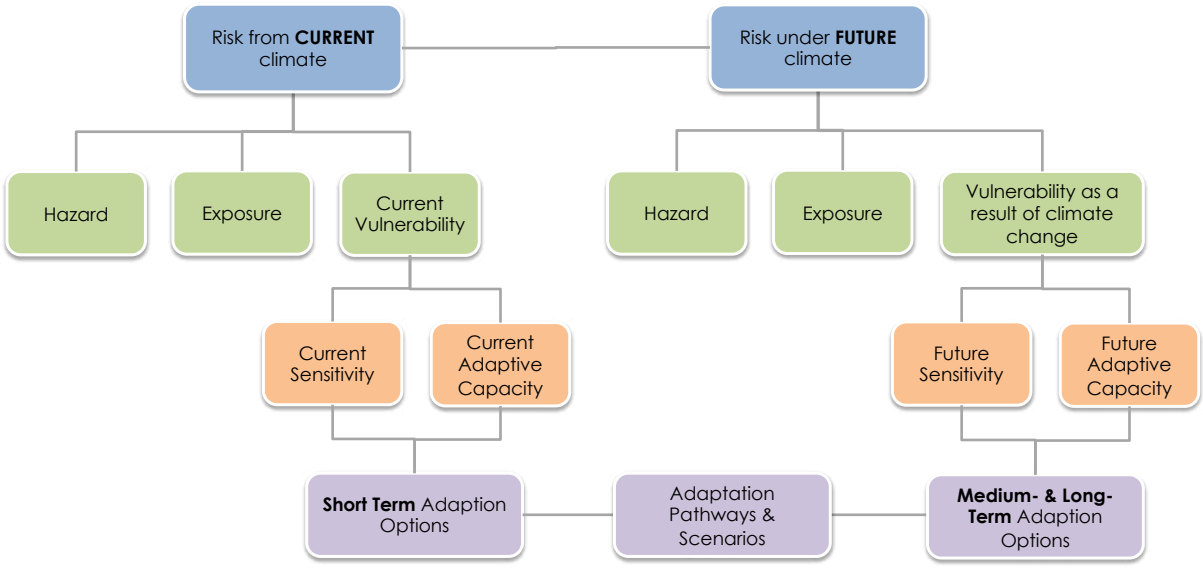
22

## *2 – ARTICULATE OBJECTIVES*

- Technical knowledge needs to be translated into a language that decision-makers understand, and converted to timescales appropriate for the decision-making process
  - Ensure that realities in the field (institutional limitations, technical capacities, stakeholders' and partners' needs) are coherent with the selected methods and tools
  - The information produced must be politically relevant and technically reliable

23

## *4 – ASSESS VULNERABILITY*




24

***KEY QUESTIONS***

- How are the key concepts of risk, vulnerability (and/or resilience) relevant in your work?
- How might you develop a framework for risk/vulnerability assessment in the context of your institution/project/programme?
- How would you frame/scope a vulnerability/risk assessment (e.g., that you were commissioning for a specific intervention)
  - What questions need to be asked?
  - Who should do the assessment?
  - What type of assessment is appropriate?
  - What data sources & types of analysis are needed?

2

25

# *APPROACHES*

26

***DIFFERENT APPROACHES TO ASSESSMENT***

| | |
|---|---|
| **Quantitative**<br>Numeric indicators (continuous, binary, categorical), mapping | **Qualitative**<br>Expert judgment/review, narrative |
| **Impacts-based**<br>Model climate hazards & impacts | **Vulnerability-based**<br>Assess societal underlying sensitivity |
| **Current risks/vulnerabilities**<br>Existing risks & near-term benefits | **Future risks/vulnerabilities**<br>Identify & plan for future risks |
| **Top down**<br>Mapping risks, identify priority areas | **Bottom up**<br>Stakeholders identify risks/needs |
| **Prediction/projection based**<br>Climate model outputs, downscaling | **Hypothetical/plausibility based**<br>What would happen if....? |

27

## *HOW TO CHOOSE THE APPROPRIATE TOOLS?*

Tools selection must be a function of the desired level of analysis:

| **"Resources" Scale** | **"Decision" Scale** |
|---|---|
| Global | International Agreements |
| Ecosystem | Regional Agreements |
| Watershed | Governments |
| Landscape | Communities |
| Farm | Household |

28

## *CLIMATE RISK & VULNERABILITY ASSESSMENT*

- It's not a plug-and-play process
- Before you start:
  - What tool to use
  - What inputs are you selecting
  - What do you want to get out of it?
- Common flow, but different emphases:
  - Assessing criticality
  - Assessing vulnerability
  - Assessing interdependencies
  - Assessing social and /or engineering resilience

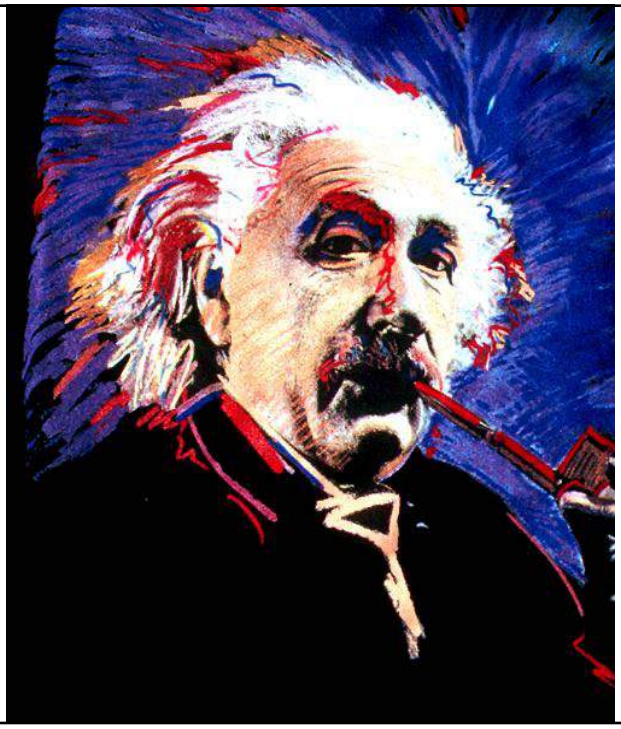
29

## *KEY POINTS*

- The choice of terms, concepts, methods and tools is not the most crucial aspect. **The important thing is to use those selected in a way that produces information that will be relevant for the clients, users, partners and stakeholders**
- Vulnerability and adaptation assessments are multi-scale and multi-level processes
  - Impacts are a function of the different spatial and temporal scales
  - The recommended strategies/policies/measures should be a function of the scale of the assessment
    - Spatial entities (landscapes, watersheds) should be linked to social entities (families, communities, individuals)

30

You can't solve a problem at the same level of consciousness that created it.…



31

***CASE STUDY 1 –***
***LEVEL OF RISK (EXPOSURE TO CLIMATE HAZARDS) FACING COASTAL INFRASTRUCTURE ASSETS IN SOUTHEAST USA***

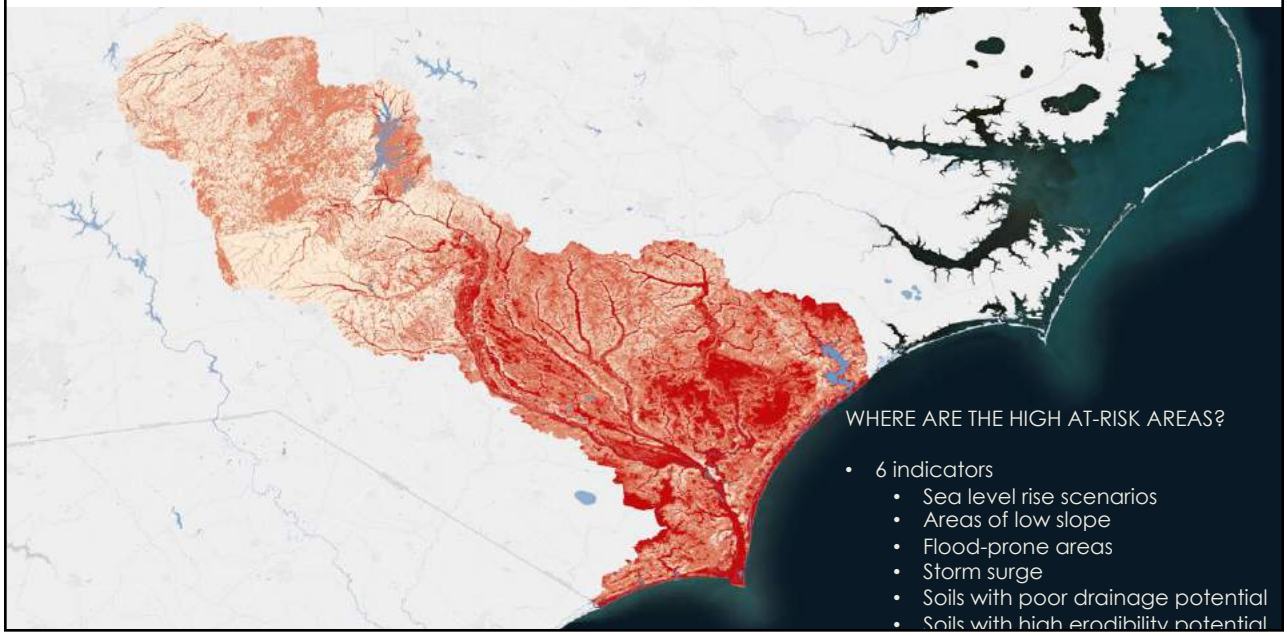
32

## *LEVEL OF RISK (EXPOSURE TO CLIMATE HAZARDS) FACING COASTAL INFRASTRUCTURE ASSETS IN SOUTHEAST USA*

- Objective
  - Identify areas on the landscape where implementation of conservation actions will have maximum benefit for human community resilience AND fish and wildlife habitat
  - Account for coastal and inland storm events
  - Use regional assessments create a contiguous and standardized dataset for all U.S. coastlines
- Vulnerability assessment conducted at watershed level
  - The Cape Fear Watershed Assessment focused on identifying areas of open space where the implementation of restoration or conservation actions could build human community resilience and improve fish and wildlife habitat in the face of increasing storms and flooding impacts.

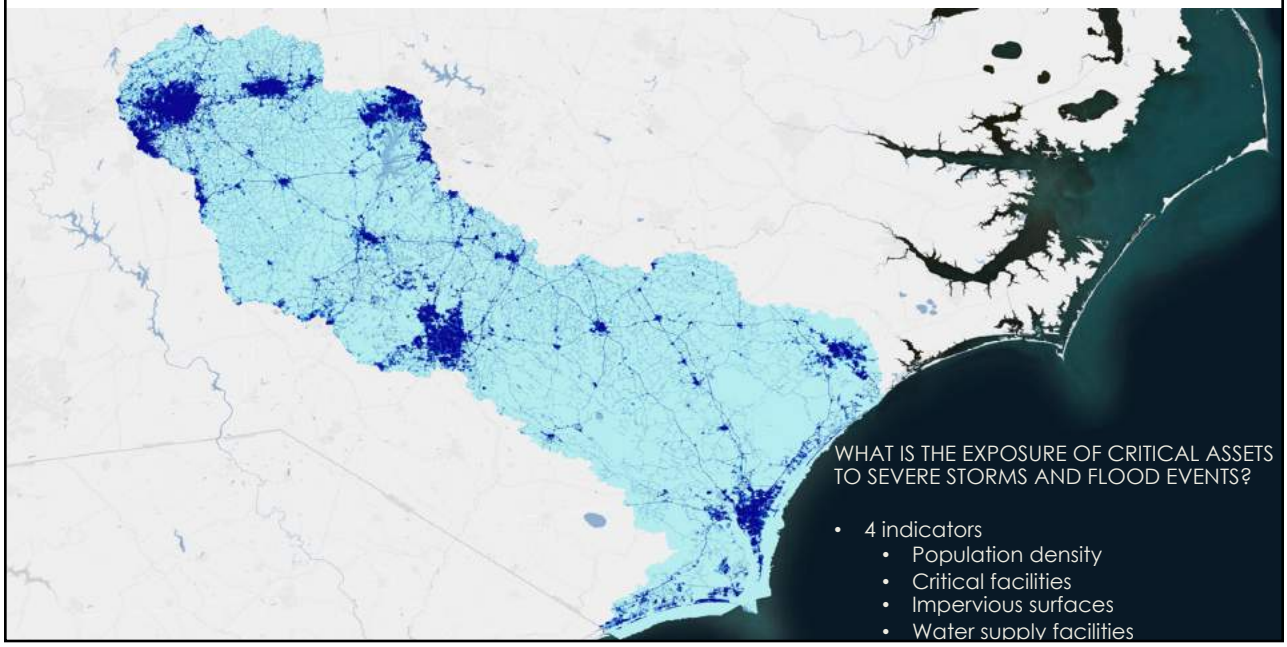
33

## *WHAT IS THE LEVEL OF THREAT?*

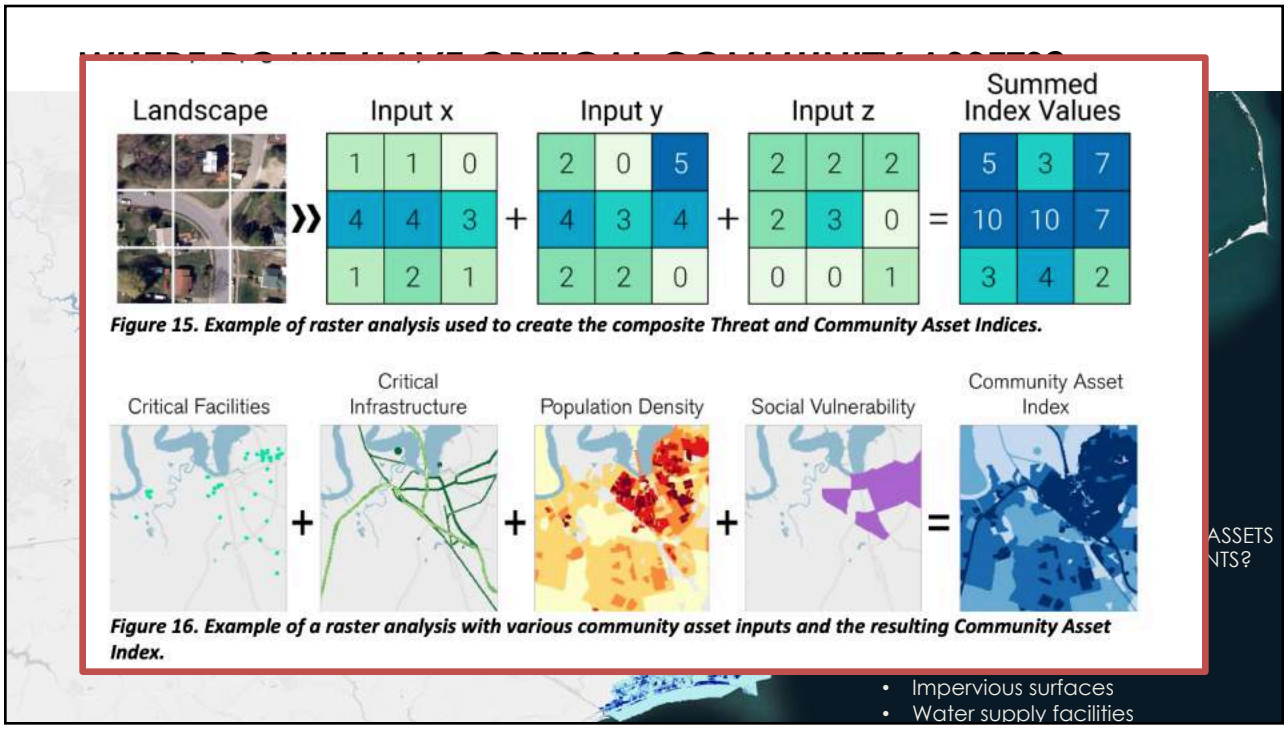



34

## *WHERE DO WE HAVE CRITICAL COMMUNITY ASSETS?*

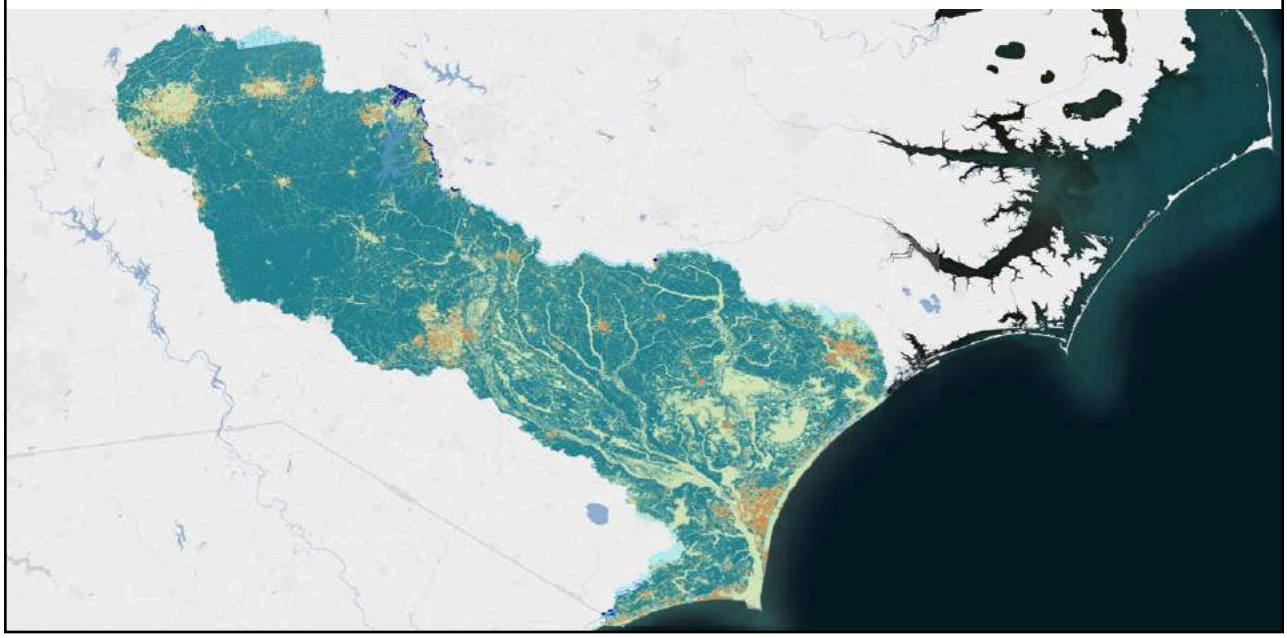



35

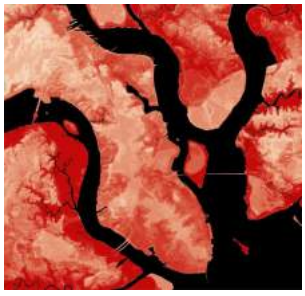



36

## *HOW VULNERABLE ARE THE COMMUNITIES AND ASSETS?*

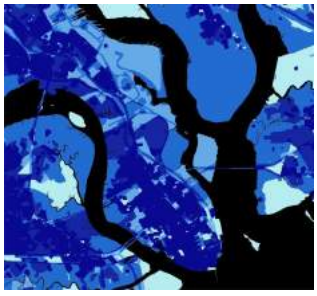


37



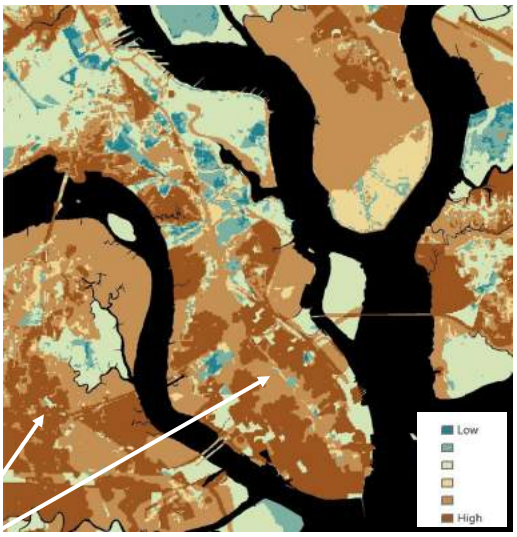
**Threat Index**

X

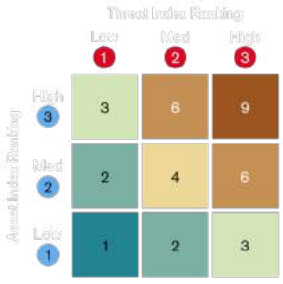


**Community Asset Index**

=



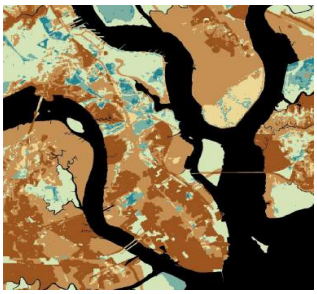

**Community Exposure Index**




Helps communities understand where the most people and assets are exposed to climate related risks

38

## *USING THE RESULTS*



**Community Exposure Index**

X

**Aquatic Habitat Index**
(existing dataset)

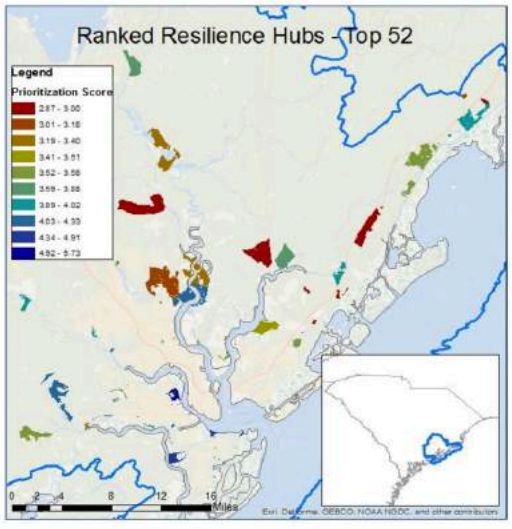
**Protected Area Index**
(existing dataset)

=

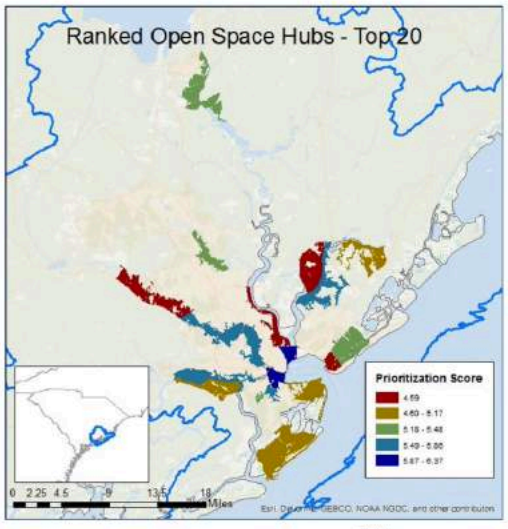
Landscapes that can be used to help communities respond to and recover from flood-related events

39

## *AREAS TO BE ADDED TO PROTECTED AREA STATUS*




ENSURING FUTURE SPECIES RICHNESS AND DIVERSITY




COMMUNITY RESILIENCE TO RESPOND AND RECOVER

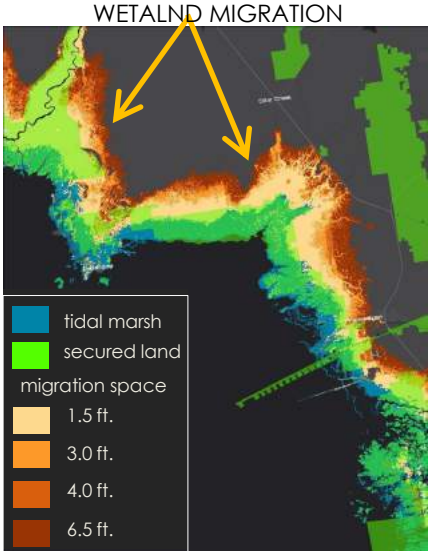
40

## *WHERE WILL WETLAND HABITATS MIGRATE TO?*

Identifying unsecured wetland migration areas:

How can they be protected?

LAND PROTECTION FOR FUTURE WETALND MIGRATION




Big Bend area of Florida's Gulf Coast

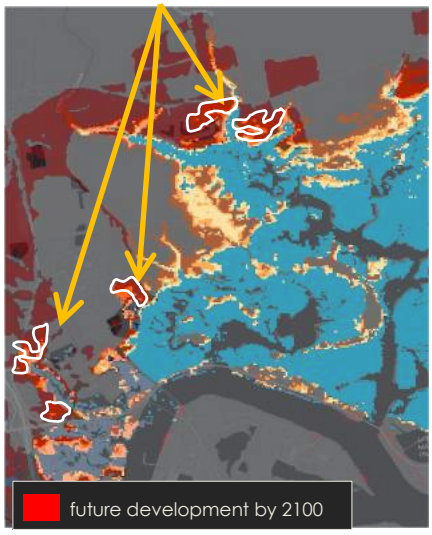
41

## *IF DEVELOPMENT HAS ALREADY BEEN APPROVED, WHERE ARE THE CRITICAL AREAS WHERE PLAN MODIFICATIONS ARE NEEDED?*

Wetland migration areas that are projected to be developed by 2100 :

What type of development (if any) should be allowed?

FUTURE DEVELOPMENT




near Timucuan Ecological and Historic Preserve (Jacksonville, Florida area)

42

***CASE STUDY 2 –***
***IMPACTS OF SEA LEVEL RISE ON THE PUBLIC HEALTH OF VULNERABLE POPULATIONS IN SOUTHEAST FLORIDA***

43

***IMPACTS OF SEA LEVEL RISE ON THE PUBLIC HEALTH OF VULNERABLE POPULATIONS IN SOUTHEAST FLORIDA***

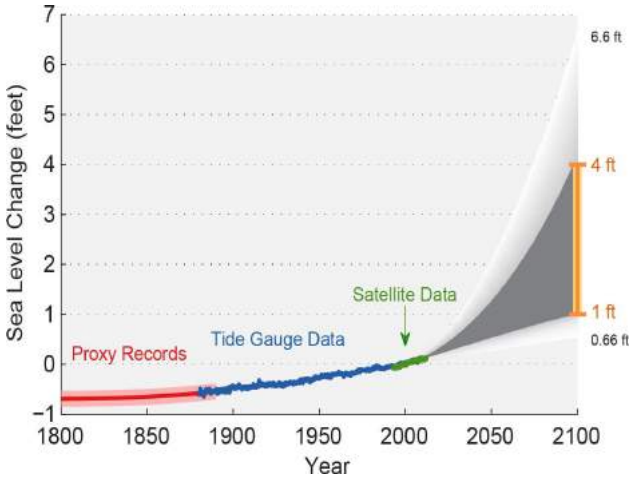
- Research question –

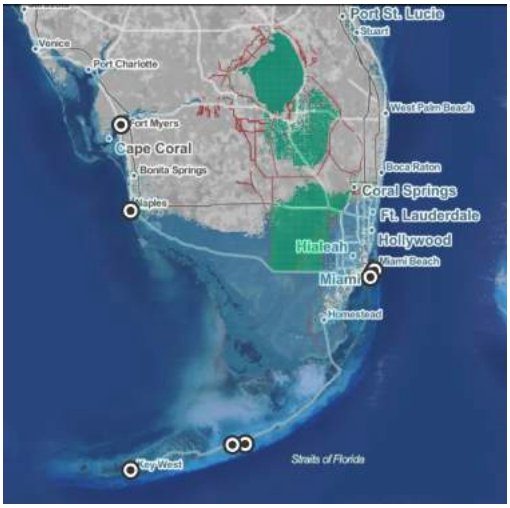
  Is there a correlation between potential public health risks from tropical diseases associated with a changing climate to identified vulnerable populations

- Looked at 4 tropical diseases
  - Giardia (linked to flooding); Cryptosporidiosis (linked to flooding); Dengue (linked to water); Chikungunya (linked to water)

44

## CLIMATE CHANGE CONTEXT

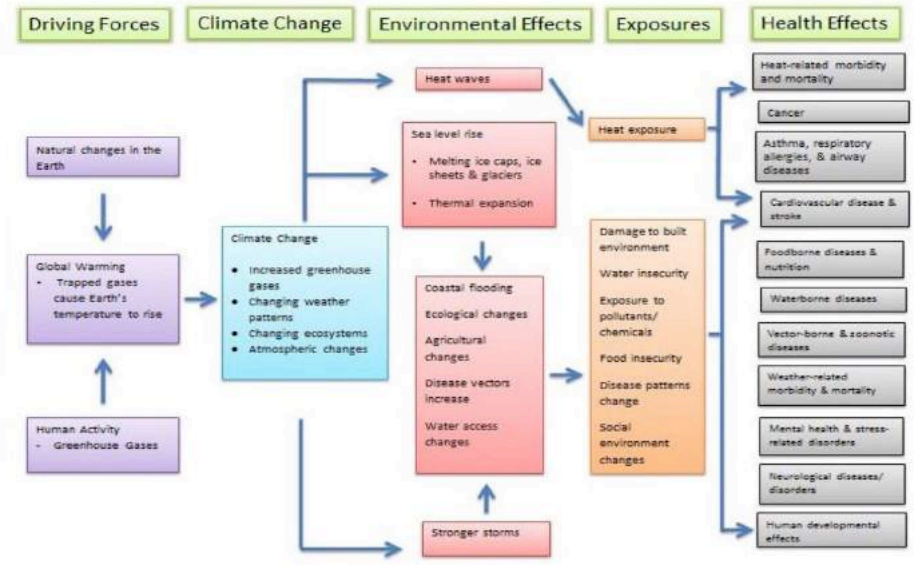



Source: 2014 U.S. National Climate Assessment

45

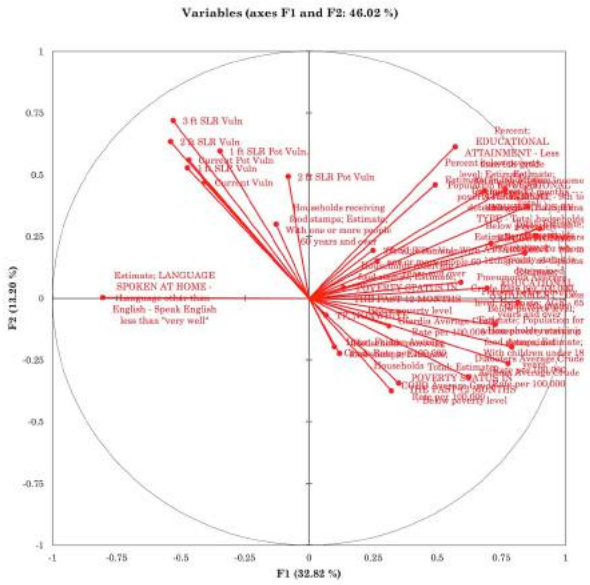
## PUBLIC HEALTH AND CLIMATE CHANGE IN S. FLORIDA




46

## *KEY IDNDICATORS*

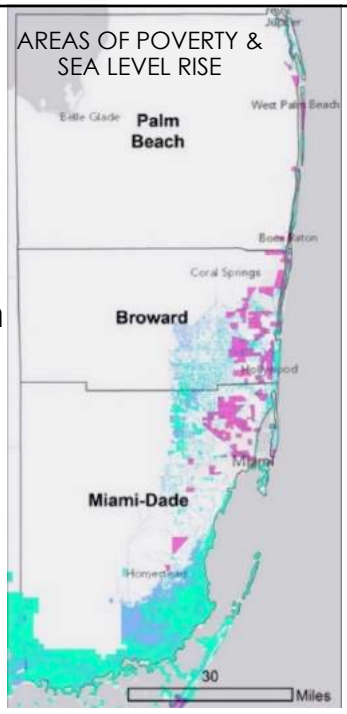
- Communities vulnerable to impacts of sea level rise in the coming decades
  - SLR scenarios to 2030 and 2060
- Poverty
- Death rates from non-communicable diseases
- Vulnerability to heat waves
- Death rates from tropical diseases associated with climate

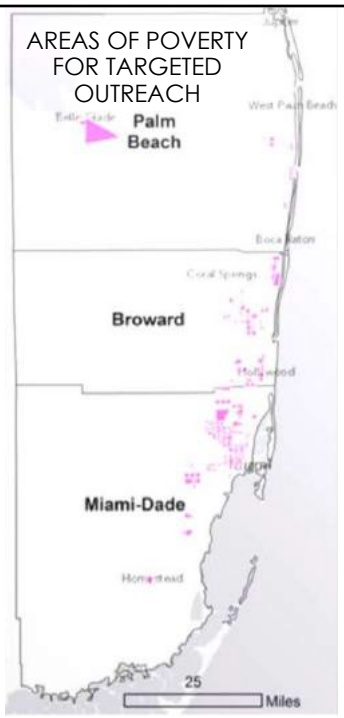



47

## *RESPONSE*

- Poverty is linked to negative health results
- Adaptation plan is a **targeted health outreach program**



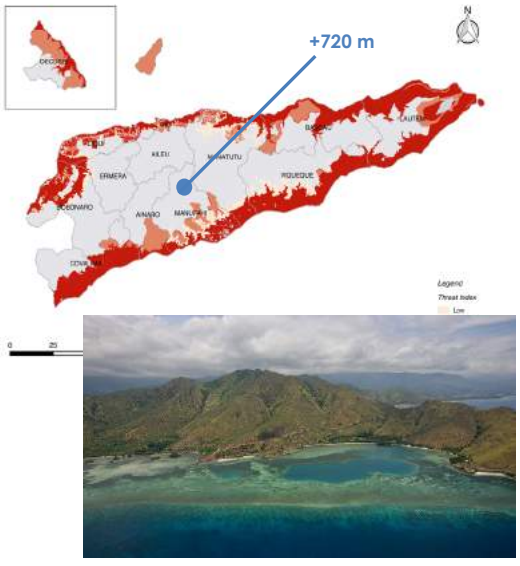

48

## *CASE STUDY 3 – ECOSYSTEM-BASED ADAPTATION POTENTIAL OF MANGROVE FORESTS NEAR VULNERABLE COASTAL COMMUNITIES, TIMOR-LESTE*

49

## *A FUNCTION OF TOPOGRAPHY, WITH RISK MULTIPLIED BY CLIMATE CHANGE*

- What is the level of exposure to climate change facing coastal communities?
  - Climate impacts
    - Impact to livelihoods
    - Impact of sea level rise and shoreline erosion
    - Impact of climate change on high-hazard areas / at-risk areas due to flooding and rain-caused landslides
  - Critical connectivity routes




50

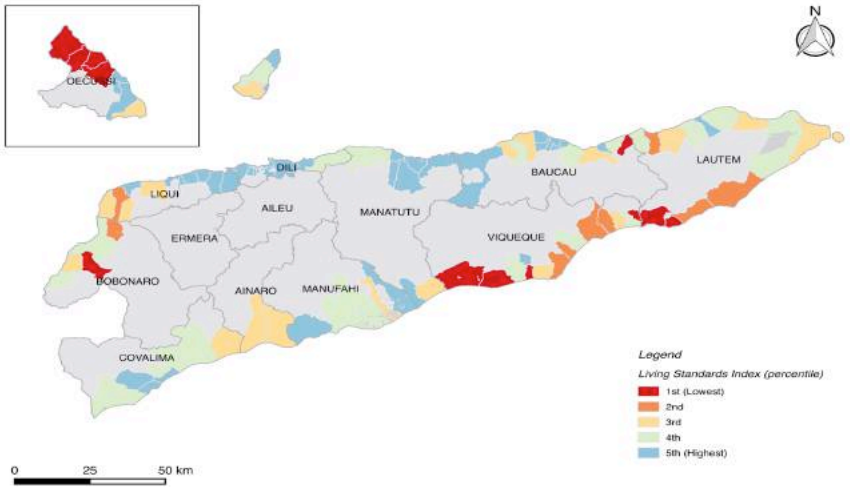
## *WHAT IS SOCIO-ECONOMIC VULNERABILITY OF COMMUNITIES?*

- Tribal tenure-based settlements
  - No individual ownership
- Socio-economic vulnerability determined through an index of living standards indicators
  - Gender
  - Dependency ratio
  - Literacy ratio
  - Access to basic infrastructure (share of households with electricity, improved water, and improved sanitation)
  - Asset ownership (vehicles, boats, livestock, etc.)

51

## *WHAT IS SOCIO-ECONOMIC VULNERABILITY OF COMMUNITIES?*

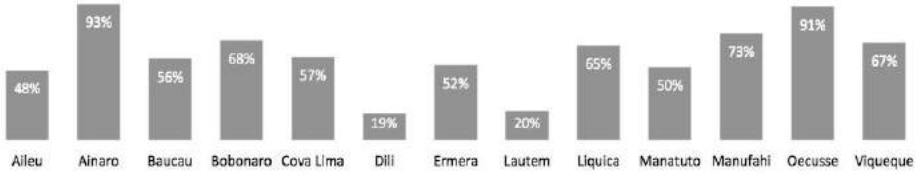
- Tribal tenure-based settlements
  - No individual ownership
- Socio-econom
  determined th
  living standarc
  - Gender
  - Dependency
  - Literacy ratio
  - Access to bas
    of households
    improved wat
    sanitation)
  - Asset ownersh
    livestock, etc.)



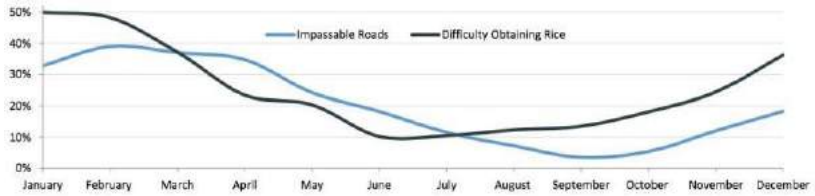

52

## *REASON FOR FOCUSING ON LIVING STANDARDS*

Communities with roads inaccessible to 4WD over 12 months



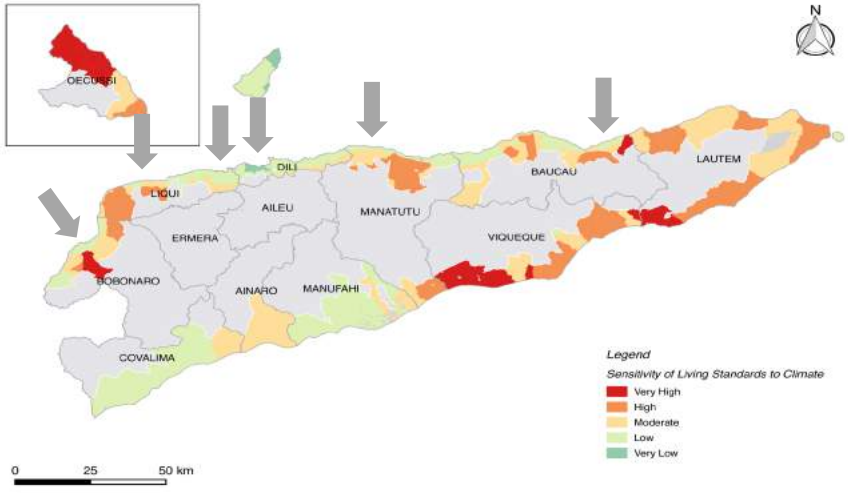

Correlation between road conditions and rice availability




53

## *WHAT IS SOCIO-ECONOMIC VULNERABILITY OF COMMUNITIES?*

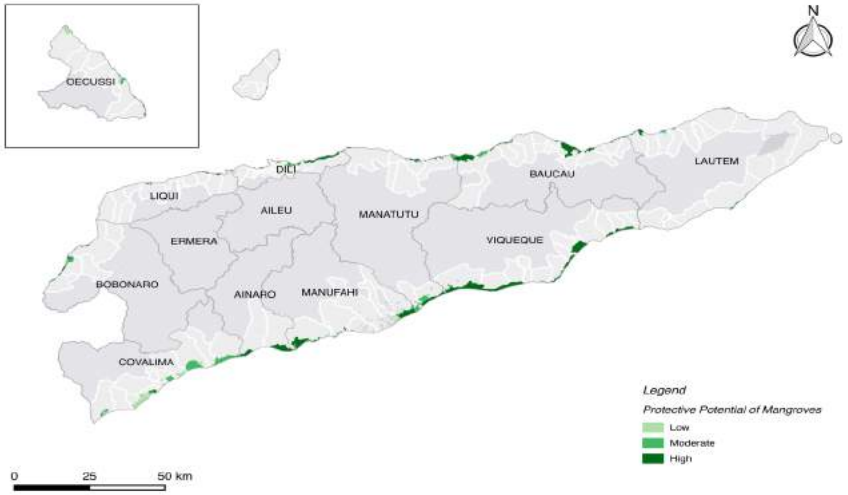
- What happens to living standards when we account for climate change?




54

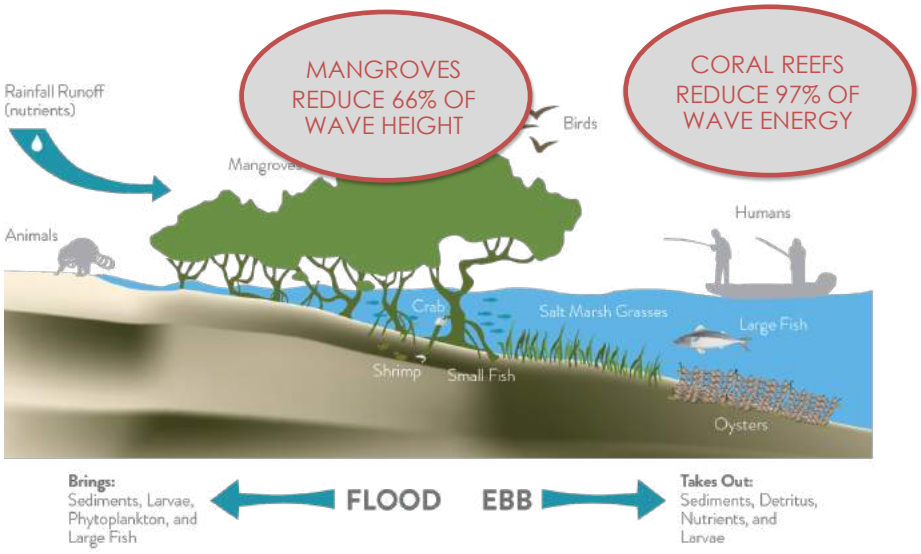
## *WHERE IS THERE POTENTIAL TO REHABILITATE OR RESTORE MANGROVE FORESTS TO REDUCE AND ALLEVIATE CLIMATE IMPACTS ?*

- Potential of mc
  impacts and p
  - Coastal ecosy
    (historic range
    development,



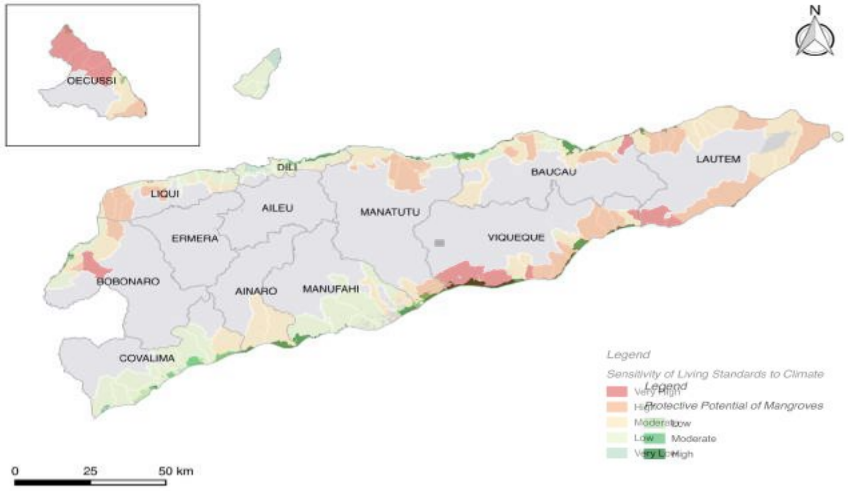

55

## *WHY ARE MANGROVE HABITATS IMPORTANT?*




56

## *WHERE MANGROVES HAVE GREATEST POTENTIAL TO ALLEVIATE POVERTY AND PROTECT THE SHORELINE*




57

## *CASE STUDY 4 – VULNERABILITY OF STORMWATER & DRAINGE INFRASTRUCTURE IN MINNESOTA, USA*

58

## CONTEXT: SEVERE FLOODING EVENTS

**Minneapolis, MN – July 1987**

Rainfall: ~10" (25.4 cm) over 8 hrs
Damage Total: 30 million USD

**Hokah, MN - August 2007**

Rainfall: 15.10" (38.3 cm) over 24 hrs (state record)
Damage Total: $27 million USD

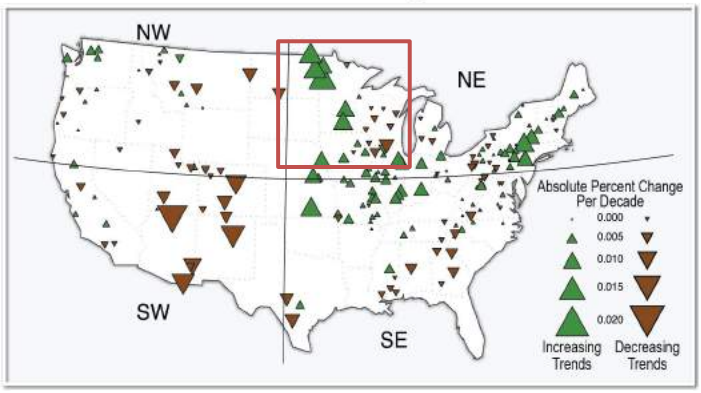
**Duluth, MN – June 2012**

Rainfall: ~9-14"(22.8-35.5) over 24 hrs
Damage Total: 108 million USD

59

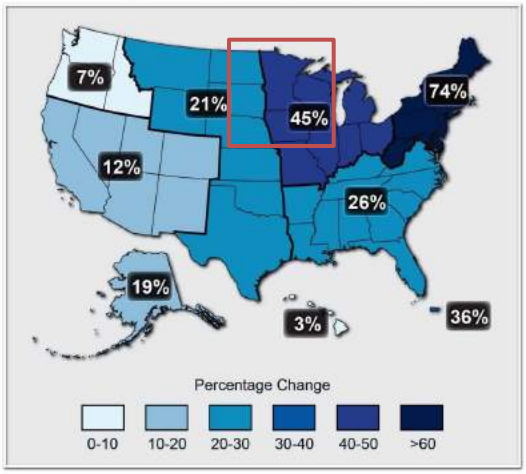
## HEAVY PRECIPITATION & FLOODING TRENDS

Trends in Flood Magnitude




National Climate Assessment Report 2013

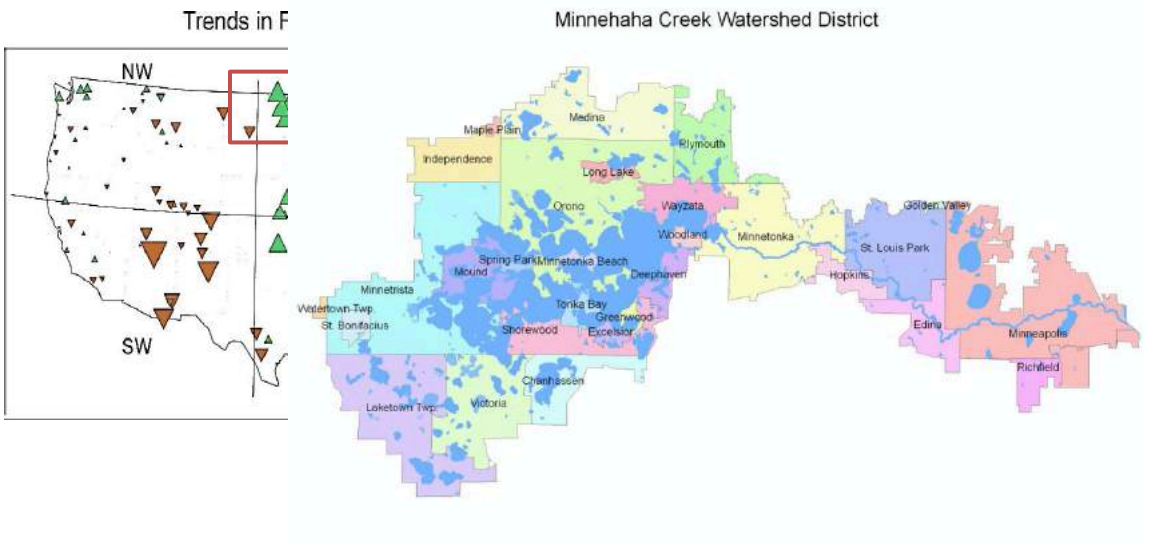
Percentage increase in very heavy precipitation (heaviest of 1% of all events) from 1958–2011




Karl et al. 2011

60

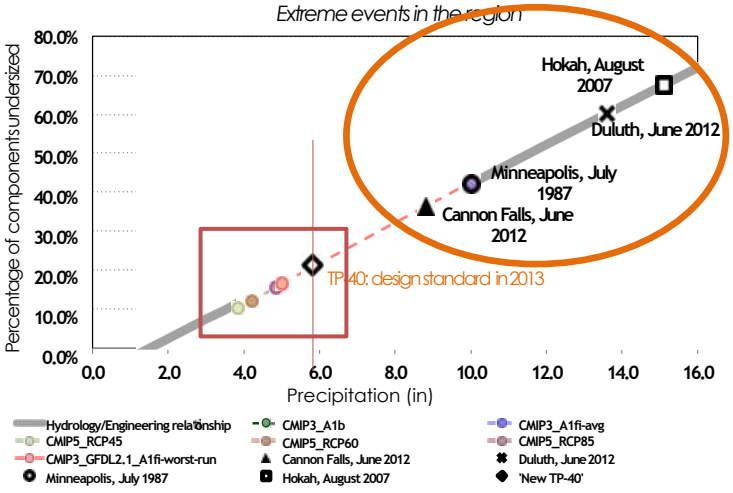
## MINNEHAHA CREEK WATERSHED




61

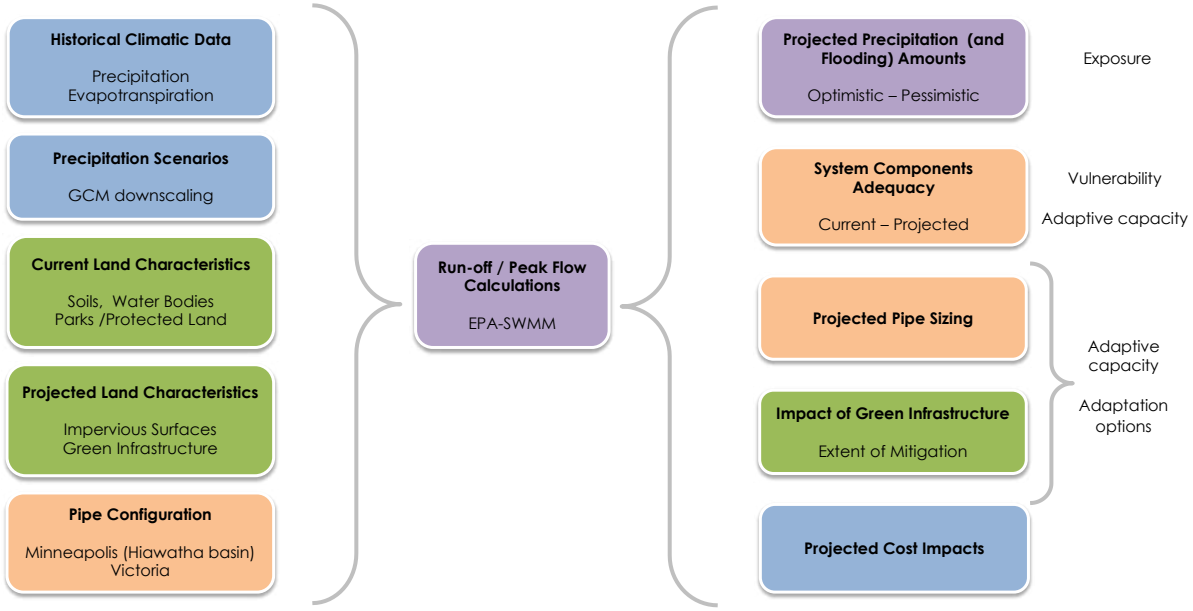
## STORMWATER INFRASTRUCTURE

Historical engineering design standard: design storm is 10 year – 24-hour precipitation event




62

## APPLIED RESEARCH APPROACH




63

## PROJECTED PRECIPITATION AMOUNTS AND FREQUENCY: CURRENT AND FUTURE

| | Return period (years) | Recent climate | mid-21st cent. Optimistic | mid-21st cent. Moderate | mid-21st cent. Pessimistic |
|---|---|---|---|---|---|
| | 2.5 | 2.5 | 2.84 | 3.3 | 6.86 |
| | 5 | 3.17 | 3.47 | 4.11 | 8.4 |
| | 7.5 | 3.57 | 3.88 | 4.66 | 9.39 |
| "Design Storm" | 10 | 3.86 | 4.19 +9% | 6.56 +70% | 10.13 +157% |
| | 25 | 4.84 | 5.28 | 6.74 | 12.75 |
| | 50 | 5.67 | 6.22 | 8.31 | 15.03 |
| | 75 | 6.2 | 6.82 | 9.39 | 16.5 |
| | 100 | 6.59 | 7.27 | 10.23 | 17.59 |

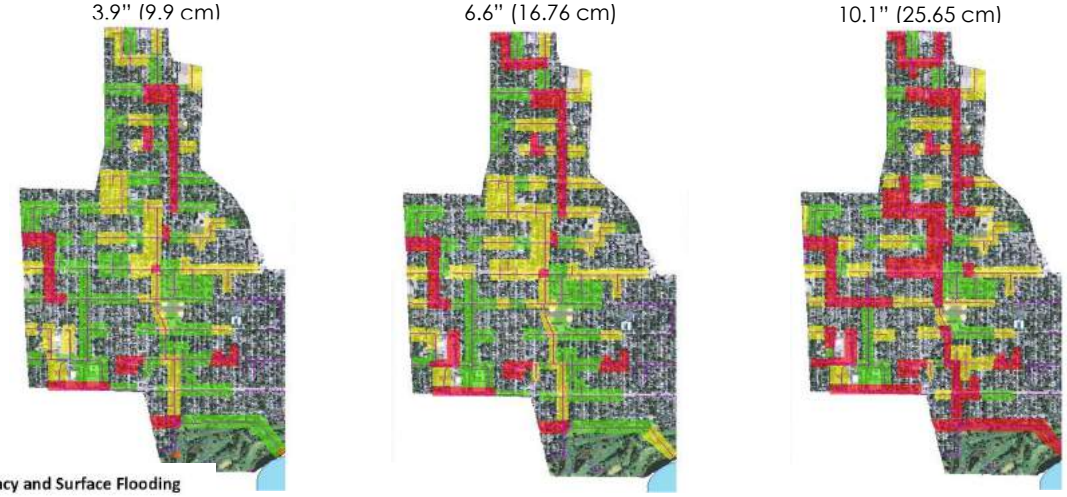
64

## HIAWATHA CATCHMENT, MINNEAPOLIS

Recent storms
3.9" (9.9 cm)

Moderate projection
6.6" (16.76 cm)

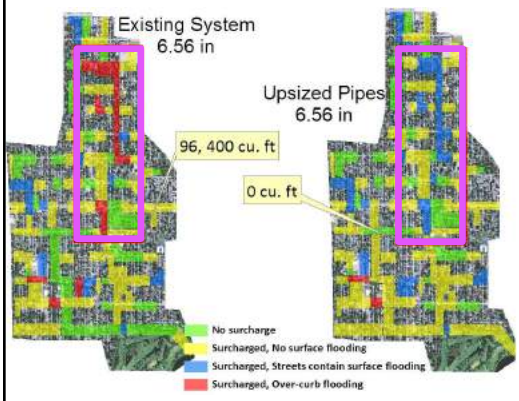
Pessimistic projection
10.1" (25.65 cm)

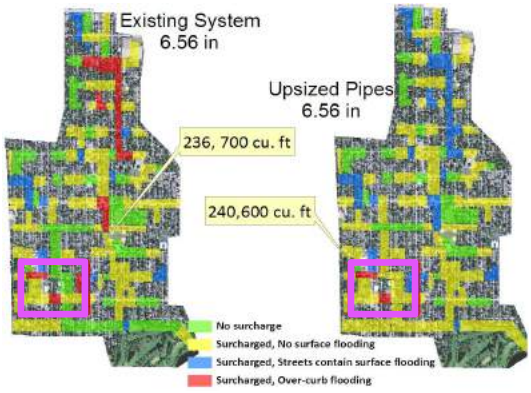


Pipe Adequacy and Surface Flooding
- No surcharge
- Surcharged, No surface flooding
- Surcharged, Streets contain surface flooding
- Surcharged, Over-curb flooding

65

## COST OF PIPE UPSIZING




| 10-yr Event | Flood volume (over curb) | Increase undersized pipes to eliminate over-curb flooding | |
|---|---|---|---|
| | Million gallons | Length of pipe | Cost |
| 3.9" (9.9 cm) | 2.92 | 3,439 ft | 6.5 million |
| 6.6"(16.76 cm) | 6.34 | 20,405 ft | 38.8 million |
| 10.1" (25.65 cm) | 34.11 | — | — |

66

## ADAPTATION COSTS IN CONTEXT

| 10-yr Event | Flood volume (over curb) | Increase undersized pipes to eliminate over-curb flooding | |
|---|---|---|---|
| | Million gallons | Length of pipe | Cost |
| 3.9" (9.9 cm) | 2.92 | 3,439 ft | 6.5 million |
| 6.6"(16.76 cm) | 6.34 | 20,405 ft | 38.8 million |
| 10.1" (25.65 cm) | 34.11 | — | — |

COST OPTIONS IN $/MG

| Dry detention basin | Upsizing pipes | Underground storage | Cost of damages (per flood) |
|---|---|---|---|
| 0.11 $/gal | 1.72 $/gal | 2.4 $/gal | 41,000 – 157,000 $/gal |

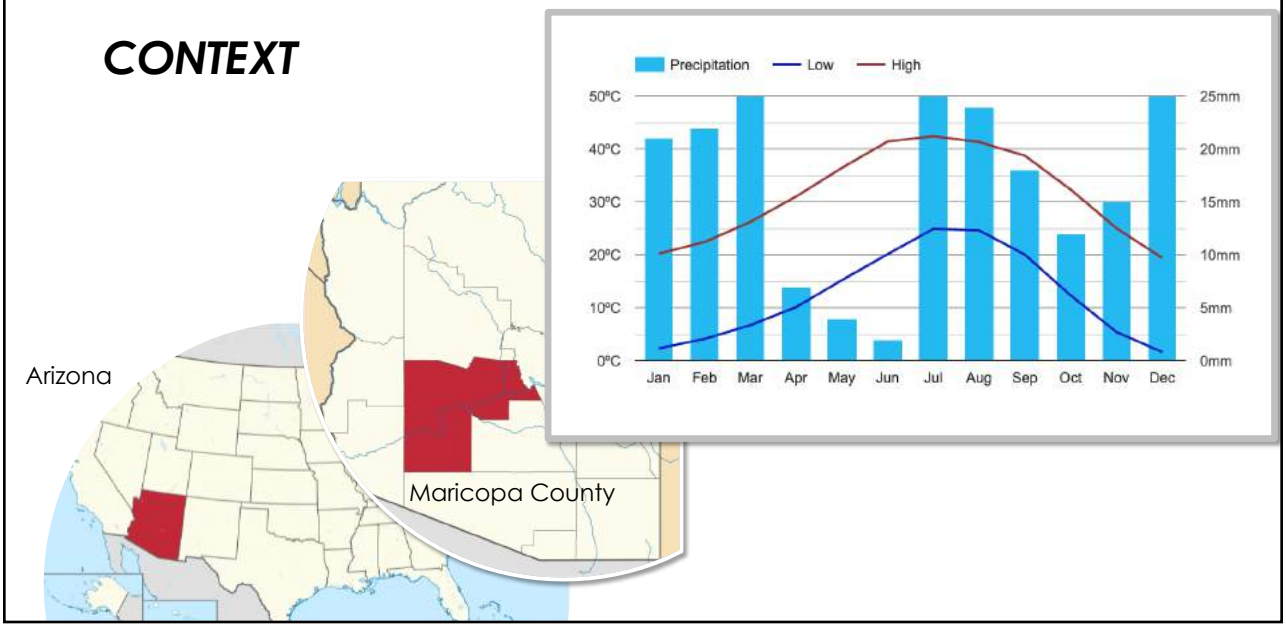
Cost of damages to property (low end) 1.197 billion

67

## CASE STUDY 5 – CONVERGENCE OF HEAT, HEALTH AND HOUSING VULNERABILITIES OF MOBILE HOME RESIDENTS IN MARICOPA COUNTY, ARIZONA, USA

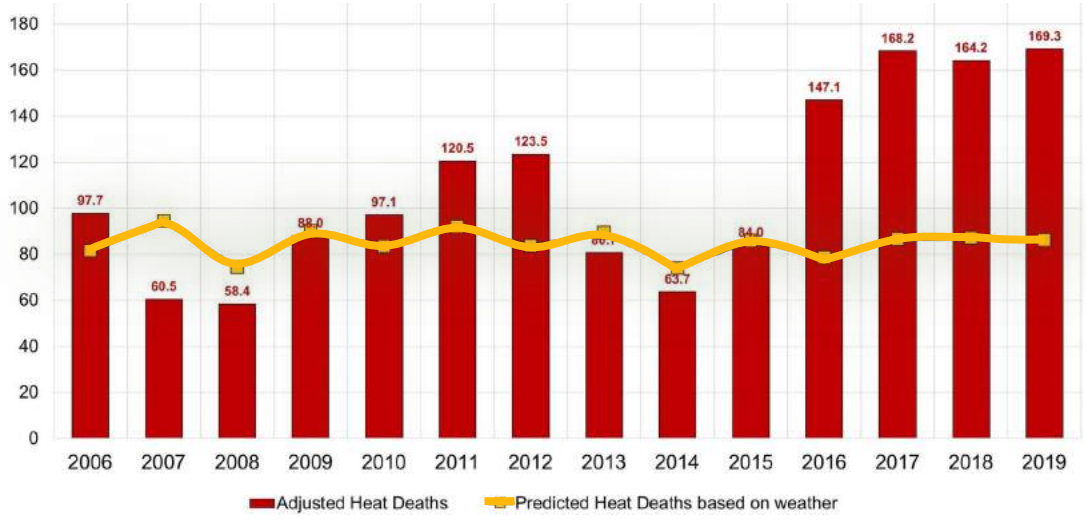
68

## CONTEXT




69

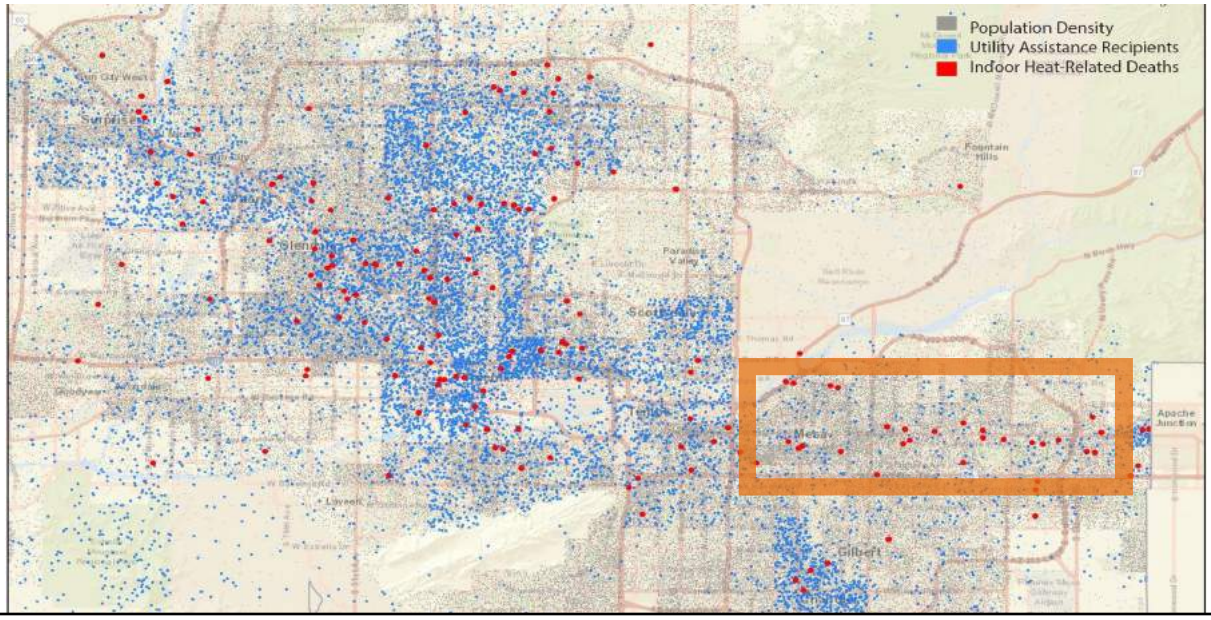
## PREDICTED MORTALITY ESTIMATES ARE NOT EXPLAINED BY WEATHER PATTERNS



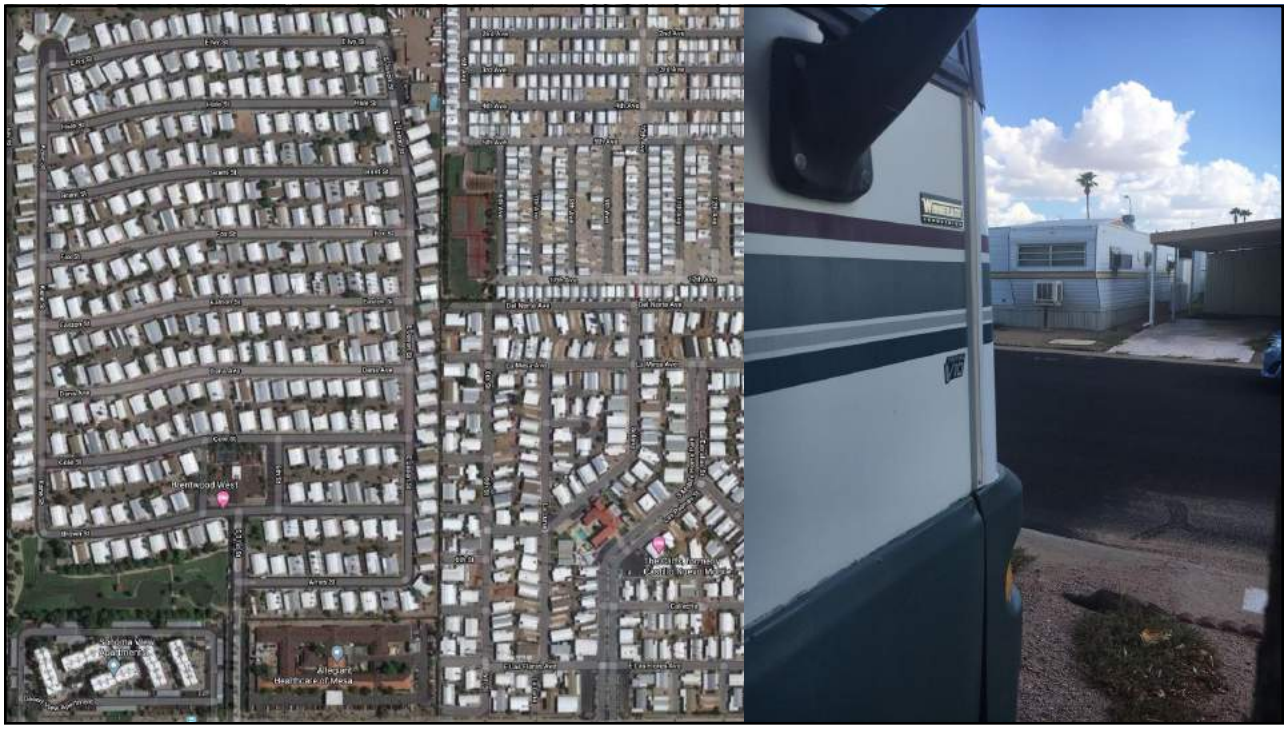

Heat related deaths in Maricopa County 2006–2019

70

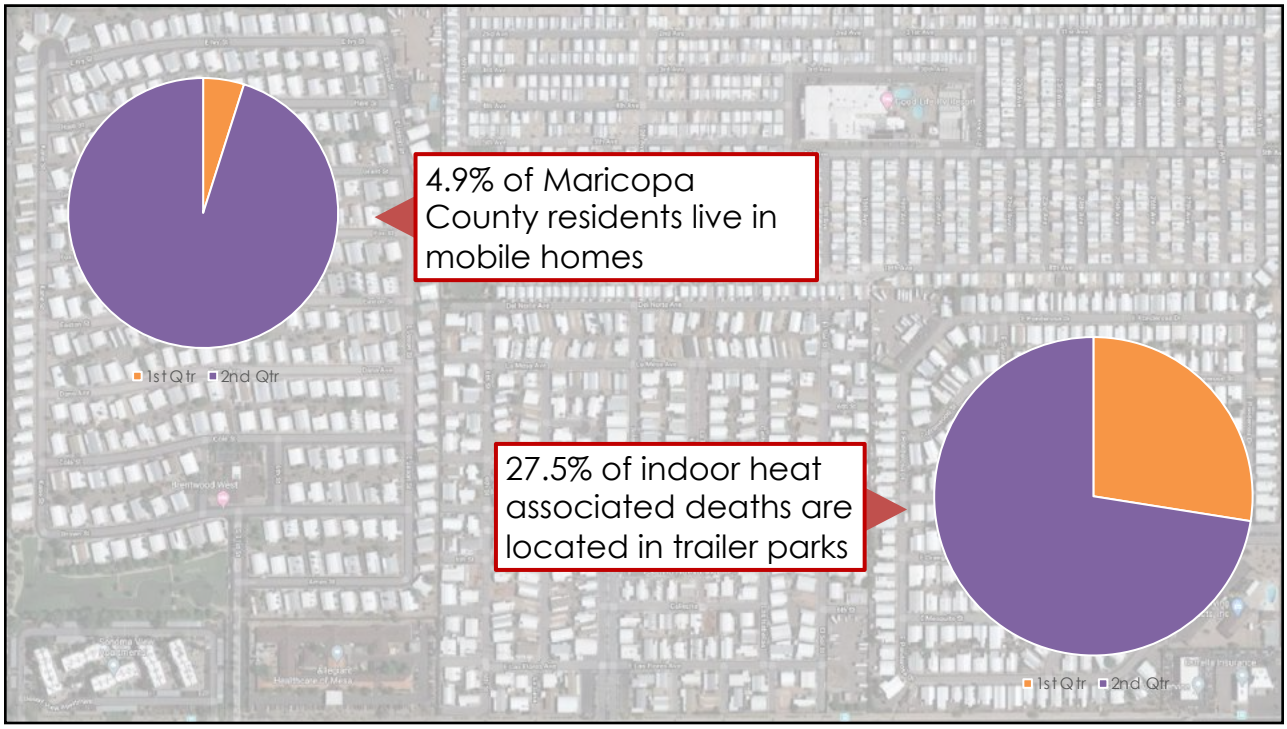
## *THE PATTERN OF HEAT-RELATED DEATHS DOES NOT CORRESPOND TO UTILITY ASSISTANCE PROGRAMS*




71



72




73

## *INDOOR HEAT-RELATED DEATHS IN TRAILERS ARE TWICE AS LIKELY WHEN AIR-CONDITIONING IS NOT PRESENT, MOST OFTEN BECAUSE OF NO ELECTRICITY*

*ALL INDOOR DEATHS*

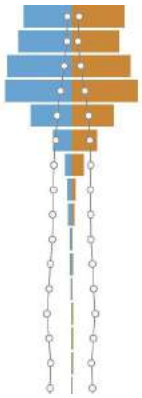
| Air Conditioning Status | Indoor Deaths | Deaths in Trailers | Percent of Indoor Deaths in Trailers | Deaths not in Trailers | Percent of Indoor Deaths not in Trailers |
|---|---|---|---|---|---|
| Not Present | 74 | 23 | 31% | 51 | 15% |
| Present* | 342 | 96 | 28% | 246 | 73% |
| Unknown | 51 | 11 | 22% | 40 | 12% |
| Total | 467 | 130 | 28% | 337 | 100% |

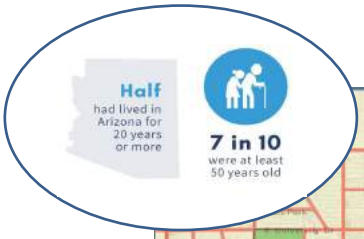
**Among Indoor Deaths with AC Present and Known Reason*

| Reason for no AC | Indoor Deaths | Deaths in Trailers | Percent of Indoor Deaths in Trailers | Deaths not in Trailers | Percent of Indoor Deaths not in Trailers |
|---|---|---|---|---|---|
| Non-Functioning | 191 | 55 | 29% | 136 | 60% |
| No Electricity | 34 | 11 | 32% | 23 | 10% |
| Not in Use | 87 | 21 | 24% | 66 | 29% |
| Total | 312 | 87 | 28% | 225 | 100% |

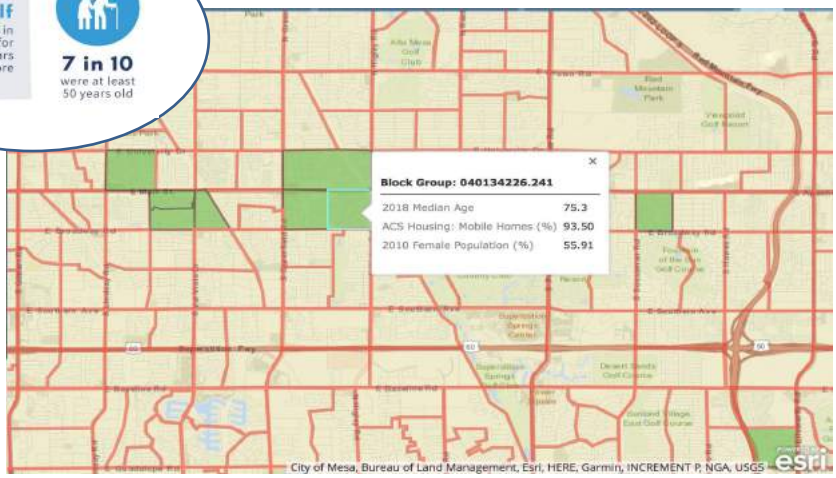
74

## *MANY PEOPLE IN THESE 'BLOCK GROUPS' ARE DISPROPORTIONATELY ELDERLY AND FEMALE, LIVING ALONE*



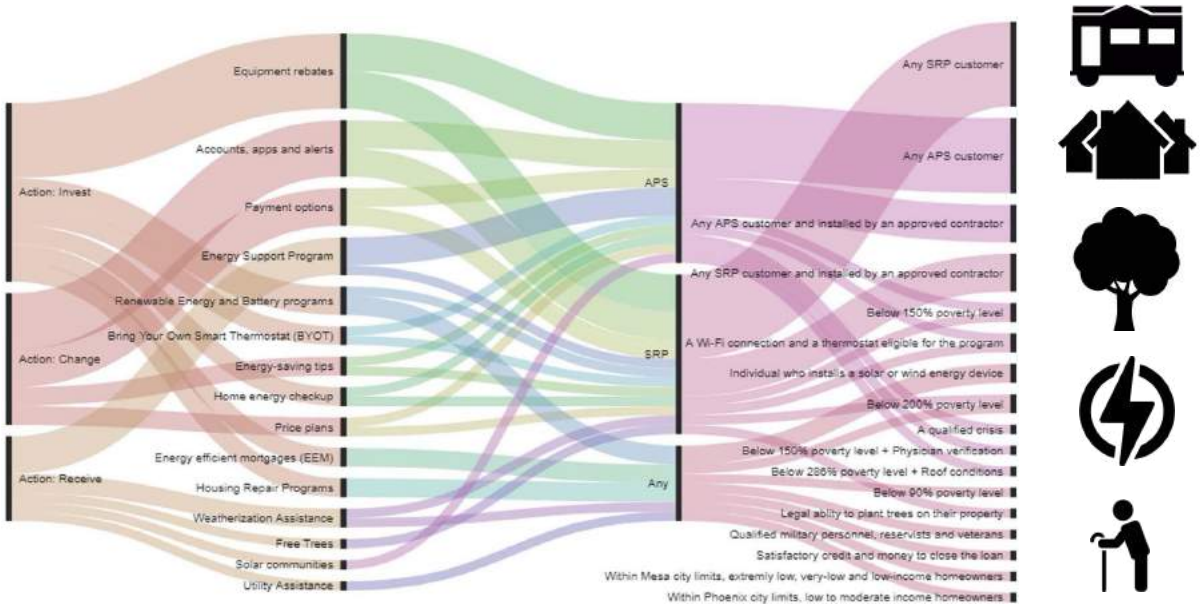







75

## *ANALYSIS OF POLICY & TECHNOLOGY ASSISTANCE OPTIONS*




76


Ephrat Yovel
ephrat @counterpoint-cs.com

77