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- The following slide set contains the presenter's notes (when provided) explaining the slide.
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- Double click the icon and the notes will appear. Adjust the size of the text box containing the notes by dragging the lower corners.

Economic Consequences of the ARkStorm Scenario

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BIOGRAPHICAL SKETCH

Dr. Anne Wein is an Operations Research Analyst in the Western Geographic Science Center of the U.S. Geological Survey. She has analyzed agricultural, manufacturing, computer, environmental, geologic, and economic systems from positions in industry, academia, and government. The common thread has been undertaking quantitative analysis within an interdisciplinary research environment to inform decision-making.

She coordinated the economic consequences of the ShakeOut earthquake scenario and took the lead on community focus studies and the recovery phase of the scenario. She is executing a similar role for the ARkStorm Winter Storm Scenario.

Dr. Wein received a Ph.D. in Decision Sciences from the Graduate School of Business at Stanford University (1988), an M.S. in Operations Research from Stanford University (1985), and a B.Sc. Honors in Operations Research from the University of Canterbury, New Zealand (1983).

ABSTRACT

We contribute an economic perspective on the ARkStorm winter storm scenario and resiliency to natural hazards. The economic consequences of the ARkStorm scenario emanate from the physical, agricultural, and environmental damages resulting from precipitation, runoff, wind, flooding, landslides and coastal processes. The economic impacts are also determined by both the workings of individual businesses and the macroeconomy.

The ARkStorm damages are transformed into sources of business interruption including evacuation, loss of building use and output, lifeline service (power, water, waste water) outages, reduced highway capacities, agricultural losses, and environmental damages. These business interruptions are described spatially and temporally to estimate effects on various economic sectors. The interdependencies among the sectors in the California economy are captured in a computable general equilibrium model to produce estimates of direct and indirect (ripple effects) economic impacts to sector activity over a two year period.

Detailed results for the ARkStorm scenario were not available at the time of abstract submittal, but preliminary results of the impacts to the California economy will be presented at the Extreme Precipitation Symposium.

Experience from the ShakeOut earthquake scenario indicates that analysis of economic consequences is useful in the following ways: the preparation of building and lifeline service restoration times is informative to emergency response and recovery planning; the results of the economic impact analysis provide insight into the relative effects of business interruption sources, draw attention to the largest contributor(s), and motivate collaborative action; incorporation of economic resilience strategies conveys their potential effectiveness, and comparison of the economic impacts with replacement costs elucidates the importance of understanding economic losses across all phases of the disaster.



THE ECONOMICS OF ARKSTORM

ARKSTORM

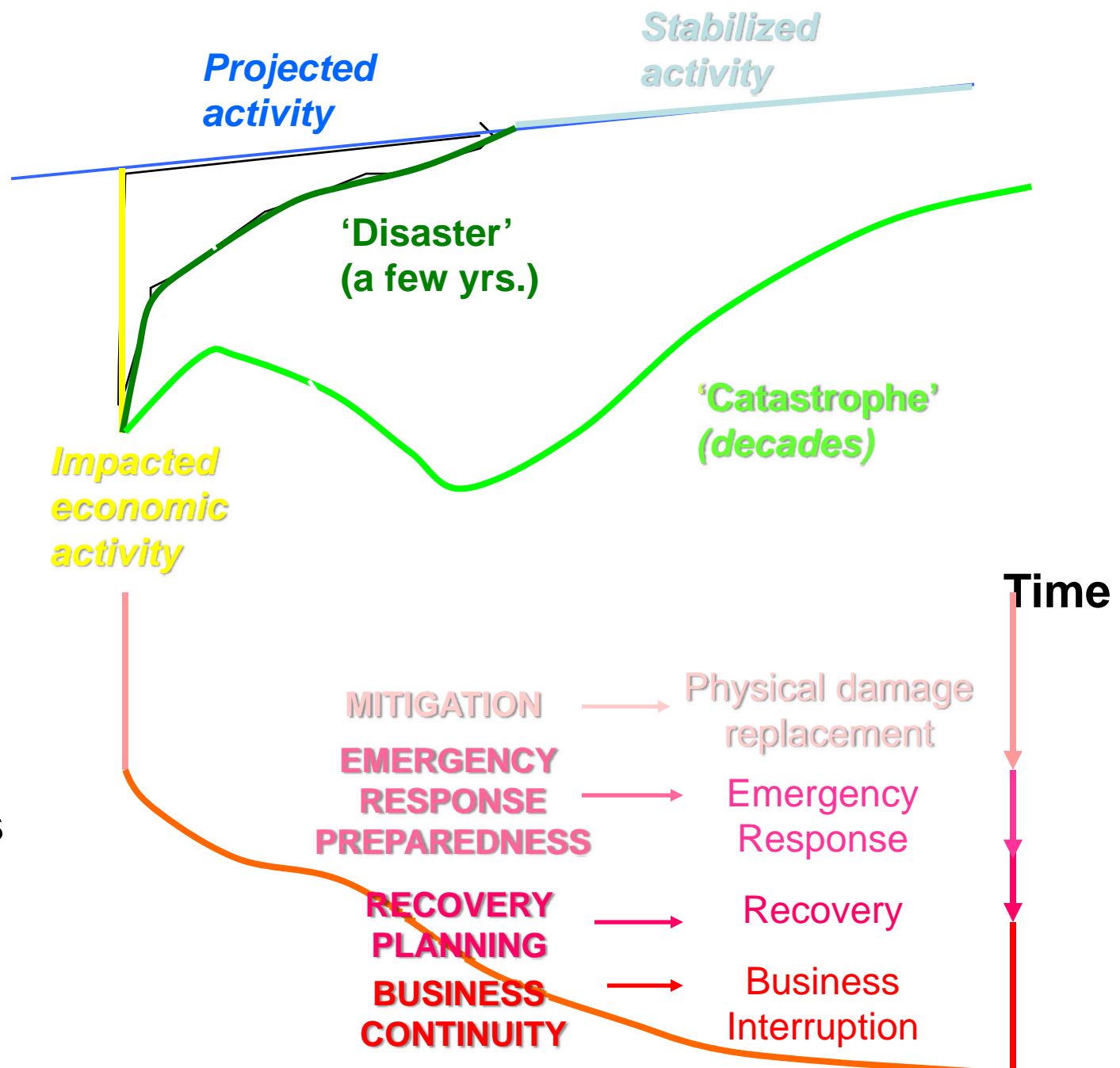
Anne Wein, USGS, and Adam Rose, University of Southern California



ECONOMICS OF A NATURAL DISASTER

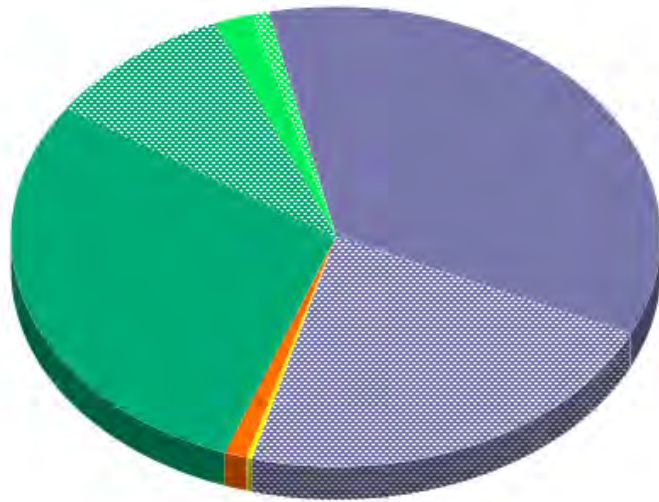
Economic Activity

Cumulative Losses/costs \$s





ShakeOut Economic Costs and Impacts



Replacement Costs

- Building (\$32.7 billion)
- ▨ Building Content (\$10.6b)
- High-Rise (\$2.2b)
- ▨ High-Rise Content (\$0.7b)
- Fire (\$40b)
- ▨ Fire-Damaged Content (\$25b)
- Highway (\$0.4b)
- Pipeline (water, sewer, gas; \$1.1b)

- Damage to Structures and Contents (\$112.7b)

Fire is biggest cause

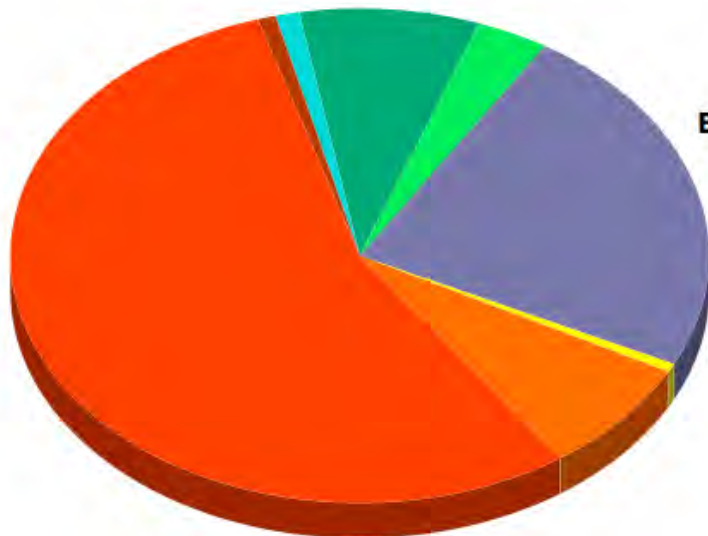
- Business Interruption (\$96.2b)

Water is biggest shock

- Additional Costs

Relocation (\$0.1b)

Traffic Delay (\$4.3b)



Business Interruption

- Non-High-Rise Buildings (\$8 billion)
- High-Rise Buildings (\$3.2b)
- Fire (\$22.4b)
- Transportation (\$0.5b)
- Power (\$7.3b)
- Water (\$53b)
- Gas (\$0.8b)
- Ports (\$1b)

BENEFITS OF ANALYZING ECONOMIC IMPACTS

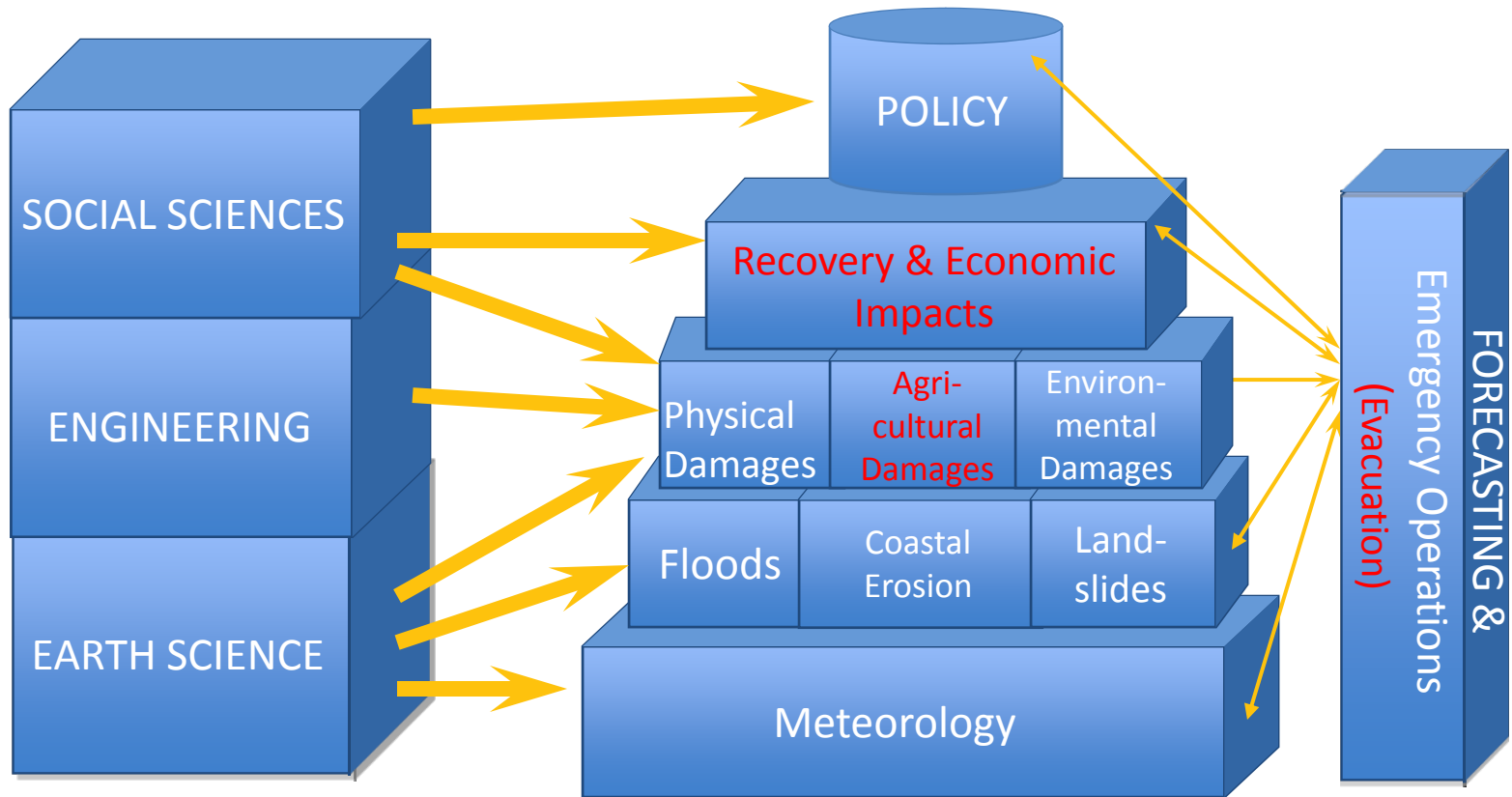
- Requires further interpretation of damages:
 - damages => functionality => business interruption
- Uses a common unit of measurement (the \$) to compare
 - sources of business interruption
 - replacement costs versus business interruption (BI) losses
 - direct BI losses versus indirect BI losses
- Increases understanding of the interdependencies in the California economy in the event of a disaster
- Provides insights into strategies to reduce losses and increase economic resilience

ECONOMIC ANALYSIS FOR ARkSTORM

Calculate the impact of ARkStorm to the California economy from sources of business interruption:

- Loss of building use/function
- Lifeline (power, water, waste water) service outages
- Reduced highway capacities
- Agricultural damages
- Evacuation
- Environmental damages
- Coastal resource damages

BUILDING THE ARkSTORM SCENARIO





CONTRIBUTORS

- Building and lifeline damage and restoration inputs: Keith Porter (U. Colorado)
- Spatial data processing, preparation ,and mapping: Alessandra Corsi (IPT, Brazil), Lori Dinitz, and Peter Ng (USGS)
- Historical research: James Carter (retired), Sue Perry (USGS)

- Agricultural damages and losses: David Mitchell (M.Cubed) , Rick Champion (USGS)
- Evacuation estimates and issues: Allan Baez (BA Risk Mgmt)
- Economic impacts from reduced highway capacities: Hahn Le Griffin (DBE Consulting)
- Economic Impacts from all other sources of business interruption: Ian Sue Wing (Boston University), Adam Rose


AGRICULTURAL DAMAGES

1861-62 Storm:

- Grain and potato losses
- Grape vines, pasture, and orchards washed away
- Swimming, drowning, floating, starving livestock (unprecedented)
- Farmland covered in sand



NOAA early flooding along a levee



AGRICULTURAL DAMAGES- HISTORICAL STORM LOSSES

- 1938
 - Millions \$ crop losses
- 1969
 - \$45M vegetable, citrus, and stock losses
 - \$ 1M crop loss from LA county mudslide
- 1986:
 - \$70M loss to almonds; ½ normal yield
 - \$16M to clean up in Napa Valley
- 1997:
 - Nearly \$300 million in damage affecting 30 counties and 30 agricultural commodities (FEAT, 1997)
 - \$109 M farm infrastructure
 - \$ 49 M crop damages: fruit and nut trees and vines
 - \$107 M crop losses : walnuts, winegrapes, winter wheat and alfalfa
 - \$ 16 M damage to nurseries
 - \$ 12 M livestock

TYPES OF AGRICULTURAL DAMAGES

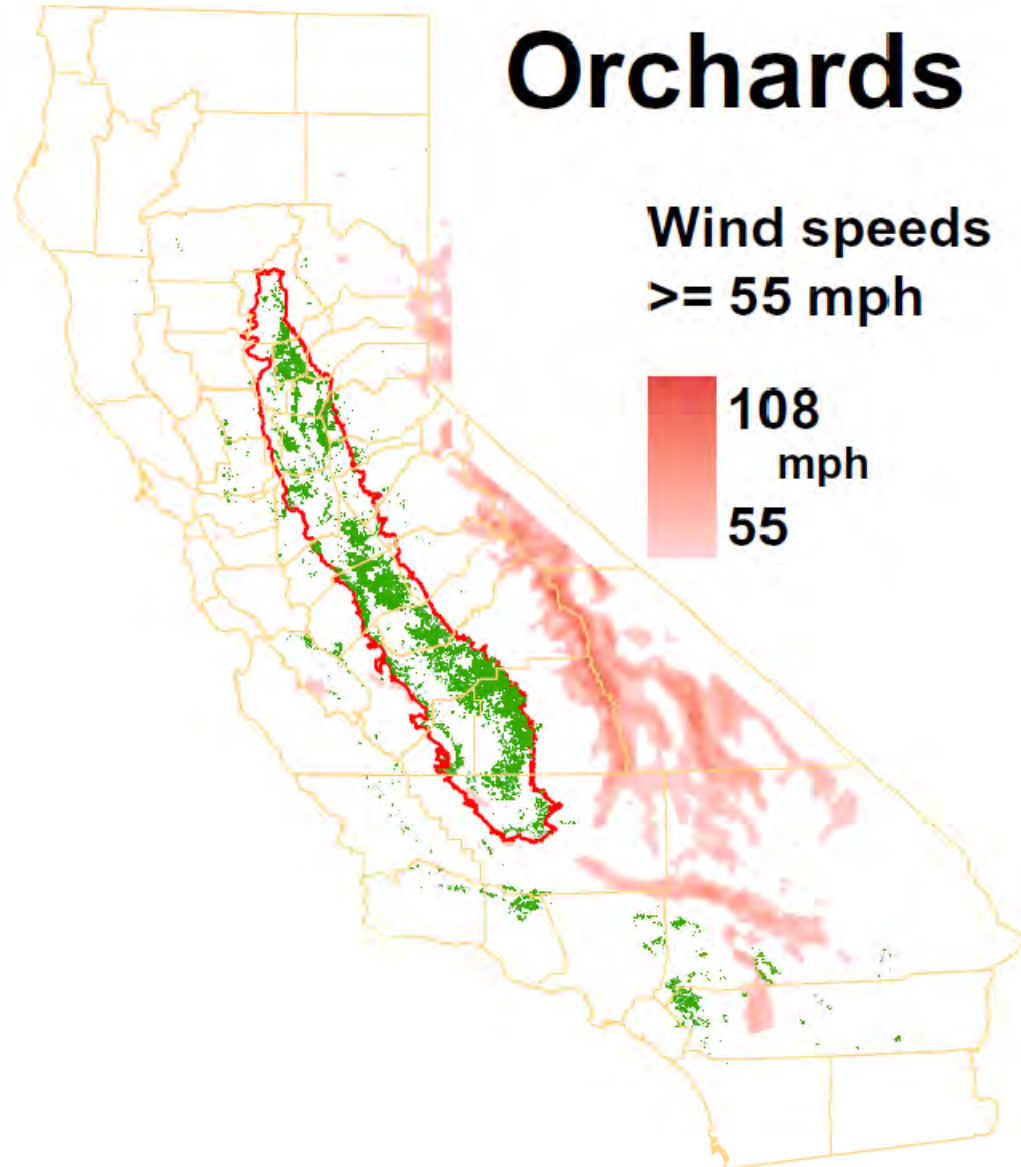
- 1986 reports
- Drowning of field crops, fruit trees, vineyards and livestock in floodwater
- 86,500 acres severely damaged by
 - soil erosion
 - 1000s tons of the world's finest irreplaceable soil
 - clogging dams and weirs
 - wind
 - fields not planted or not harvested
 - bacterial diseases
 - delay in pollination & maturity

Photograph by A Booher for Federal Emergency Management Agency

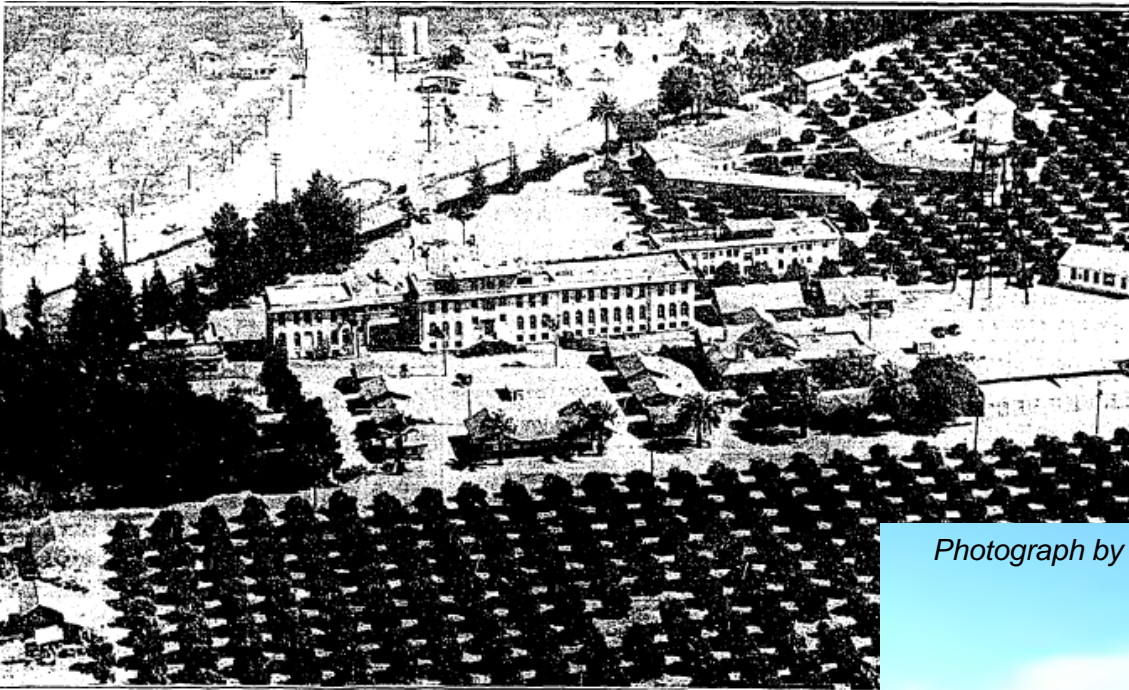


AGRICULTURAL LOSSES - WIND

- Negligible overlap between ArkStorm 3 sec max wind speeds greater than 55mph and orchards



AGRICULTURAL DAMAGES - FLOOD



The flood invades the orange orchard area. This picture shows conditions at Citrus Experimental Station of University of California, Riverside.

LA Times 1938

In 1986, 310,000 California acres were under water in February . Farmers hoped for a crop once pumping-out was finished.



In 1938, 8000 acres of Orange county citrus lands suffered damage from flooding:

- 5000 slight damage
- 2000 medium damage
- 868 severe damage
- 88 destroyed

Photograph by A Dubrowa for Federal Emergency Management Agency



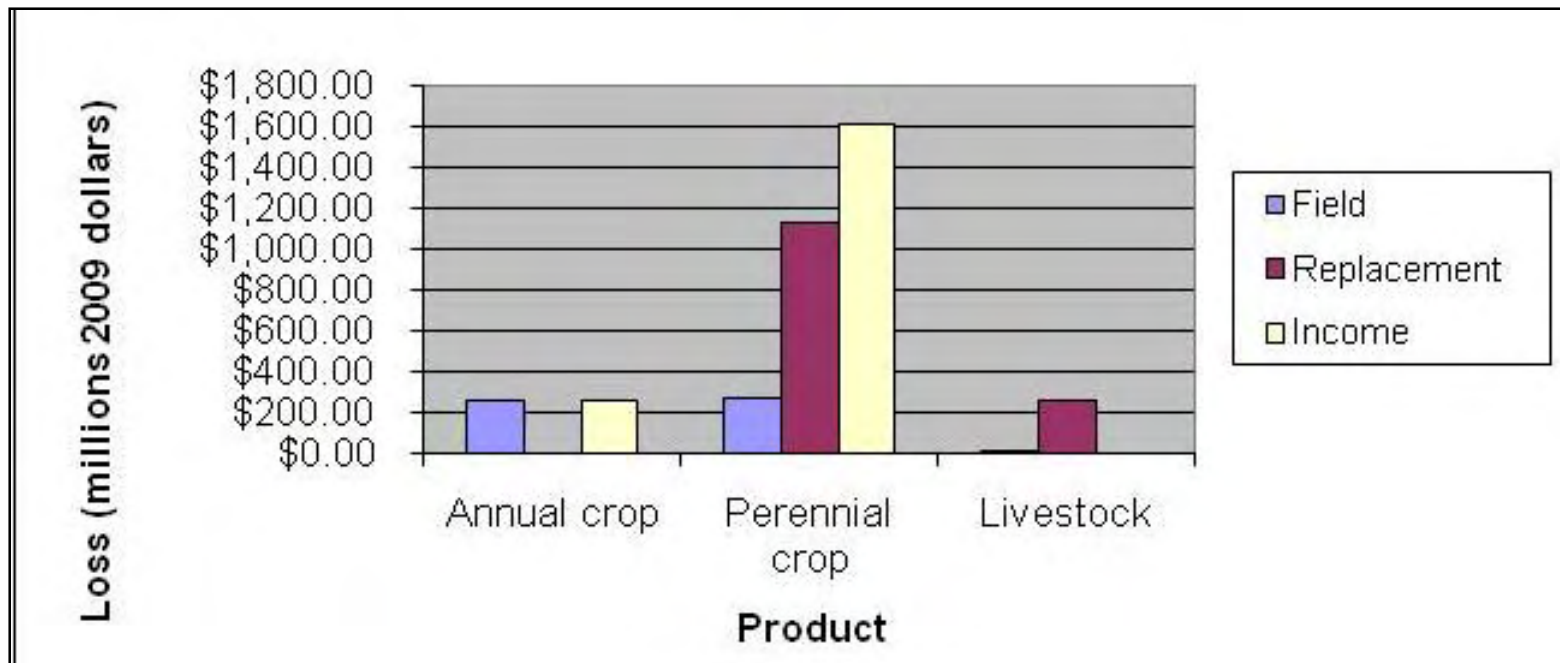


AGRICULTURAL DAMAGES – ARkSTORM FLOOD

- “Significant damage” if
 - flooding of planted annual crops
 - 14 or more days of inundation of perennial crops
 - 6 feet or more flood depth in livestock areas
- 1993-2006 DWR survey crop data
- Acres of agricultural production and significant damage

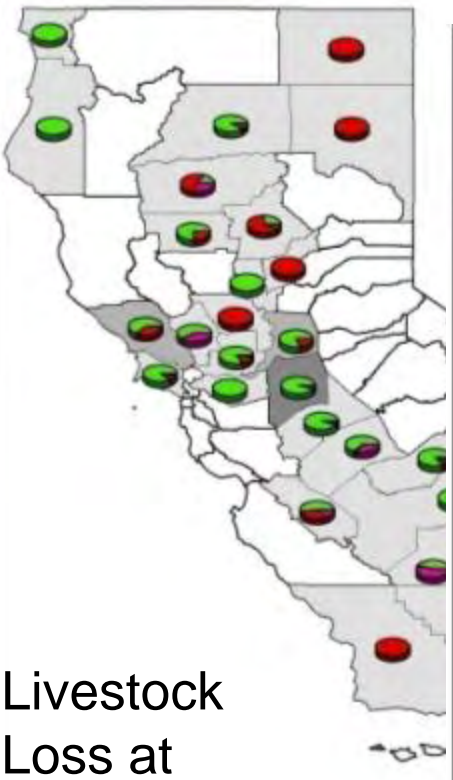
Product	Acres Production (thousands)	Significant Damage (thousands)	Percent
Annual crop	18,582	4,323	23%
Perennial crop	5,673	261	5%
Livestock	285	13	5%

AGRICULTURAL DAMAGES - ARkSTORM

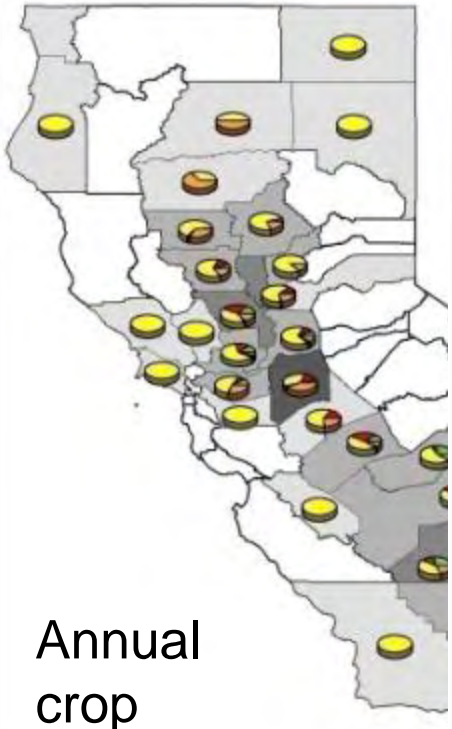


- \$3.75B “low end” of flood depth and duration estimates
- High end flood estimates: 25 % Annual crop , 100% Perennial , 1% Livestock increases in losses

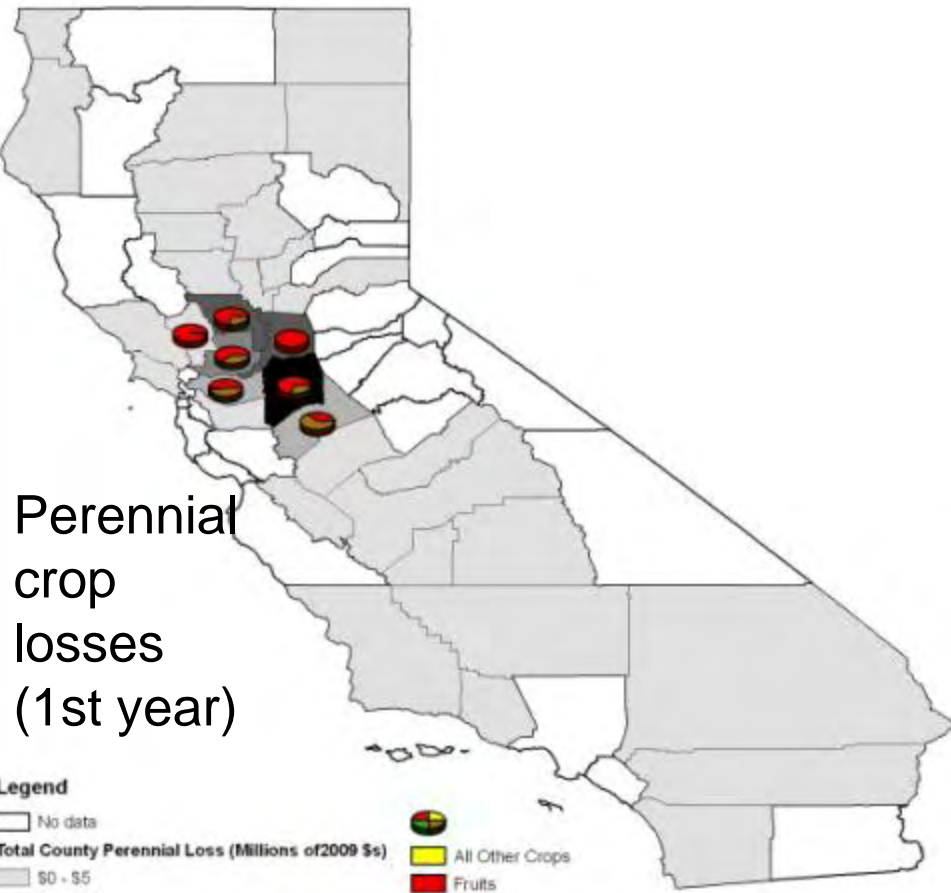
AGRICULTURAL FLOOD DAMAGES – first year



Livestock
Loss at
Risk



Annual
crop
losses

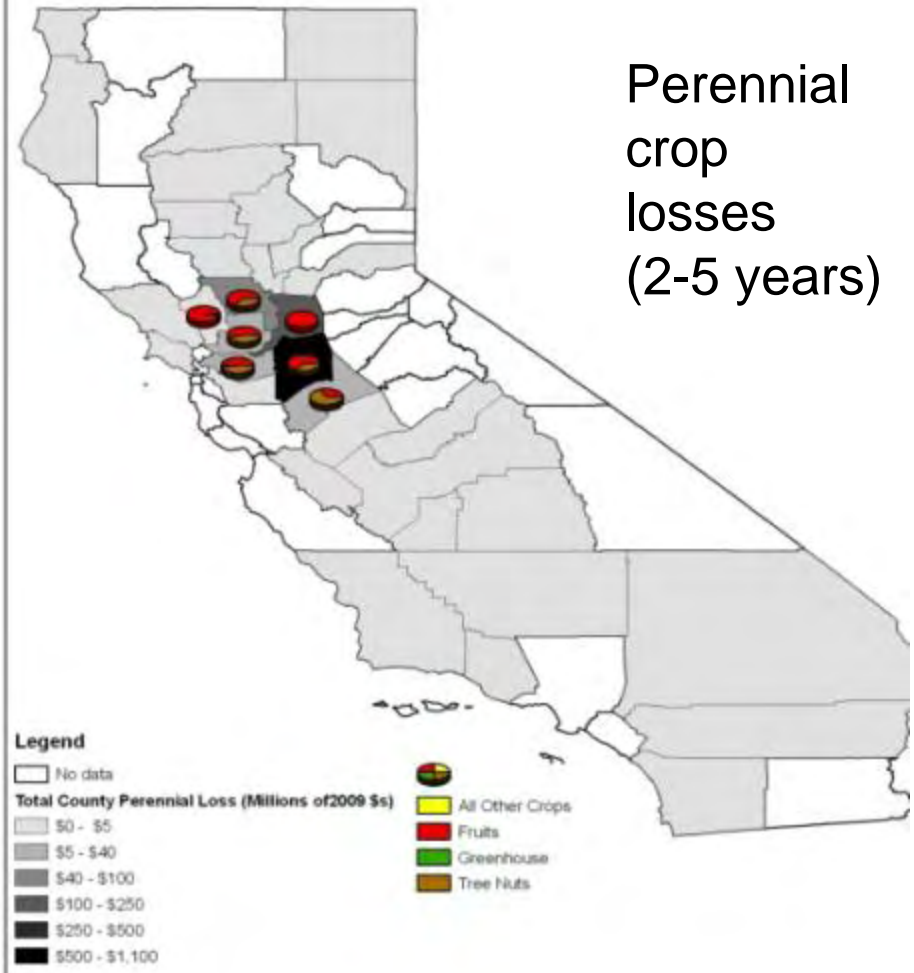
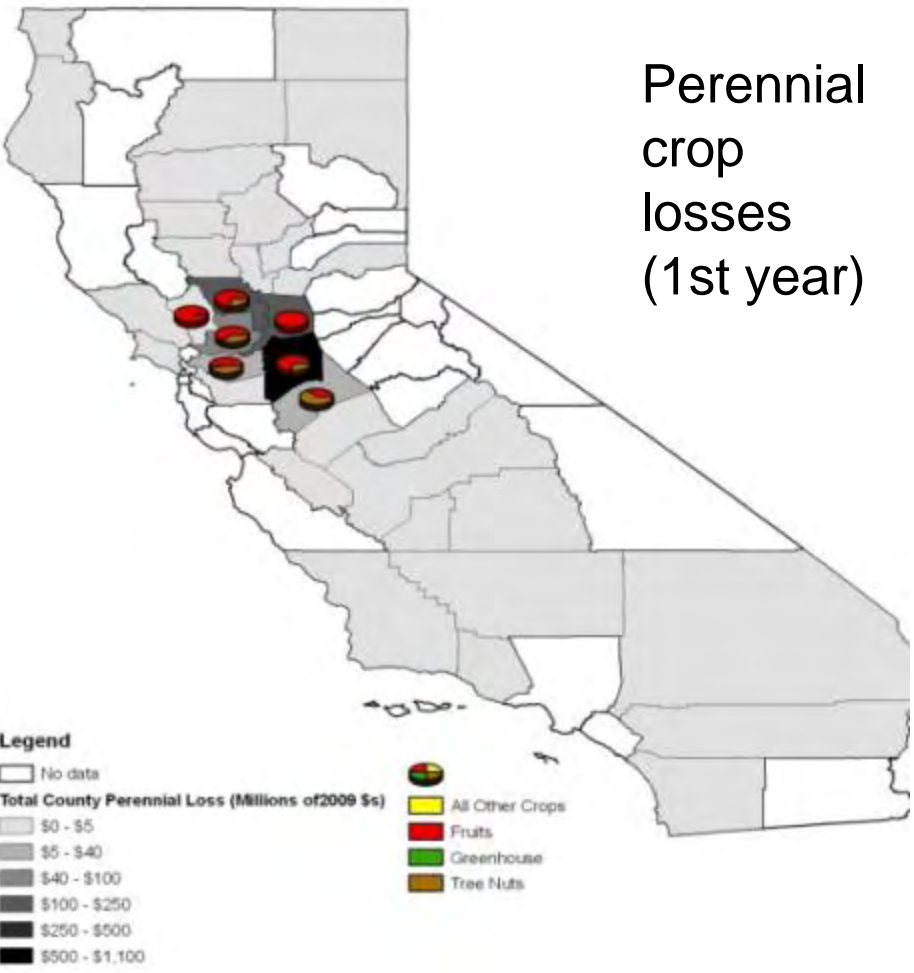


Perennial
crop
losses
(1st year)





AGRICULTURAL FLOOD LOSSES – MULTIPLE YEARS



- 1st year: field clear up & repair cost & forgone income
- 2nd -5th year: replacement cost & forgone income





EVACUATION

1938

LA Times photo by Frank Q. Brown



THE ROAD BACK—Mrs. Peter Sargent and sons Sam, in foreground, and Peter, carried by city workman Jerome Willis, returning to their home at 3321 Mandeville Canyon Road. The Sargent family had left during the rainstorm Saturday night, fearing the house soon would be without electricity and water.
Times photo by Frank Q. Brown

LA Times photo by Frank Q. Brown

1969



Lifeguards and Red Cross brought aid in flooded sections to the stranded. Above is a picture of rescue boat manned by Goldie Nevis, Los Angeles county lifeguard, rescuing Mr. and Mrs. J. S. Johnson of 11125 Larch street, Lennox.
Times photo

EVACUATION OR RESCUE?



1986
Near Linda

LA times, Mike Meadows

Stranded movie celebrities in Palm Springs:
400lbs of food, 500 candles, 50 copies of
the latest LA times flown in.



LA times, James Pease



EVACUATION – NUMBERS

CA 1861-62 :

- 6-7 families sharing houses; 60 people in one room
- Scarcity of boats for evacuation; slapped together boats

CA 1938:

- 10,000s evacuated

CA 1969

- Helicopters evacuated sick and aged in isolated foothill areas

CA 1986:

- 45,000 evacuated, some refusals

CA 1997:

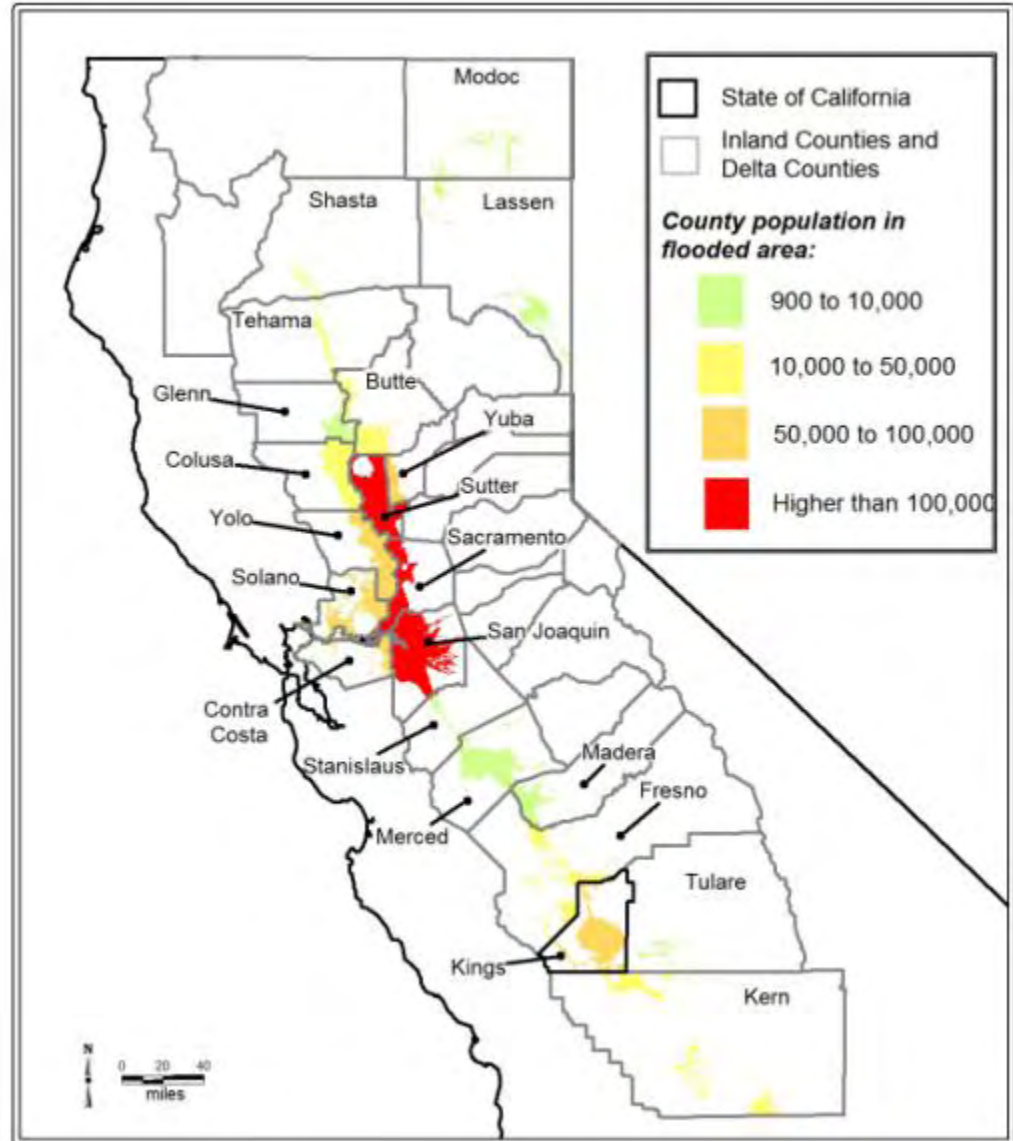
- 125,000 evacuated, some refusals (pets)

Massive Evacuations 2005

- Katrina: 1-1.2 million
- Rita: 2.5 million (models predicted .8-1 million)

EVACUATION – NUMBERS FOR ARKSTORM

- *ESRI population Update 2009*
- Population in flooded study area: 1,200,000 (16%)
- HAZUS formula
F(flooded pop'n, age, income)
Census 2000
- Displaced/shelter needs (HAZUS) : 120,000 (10% of population in flooded area)
- Of regional, State, and federal scope

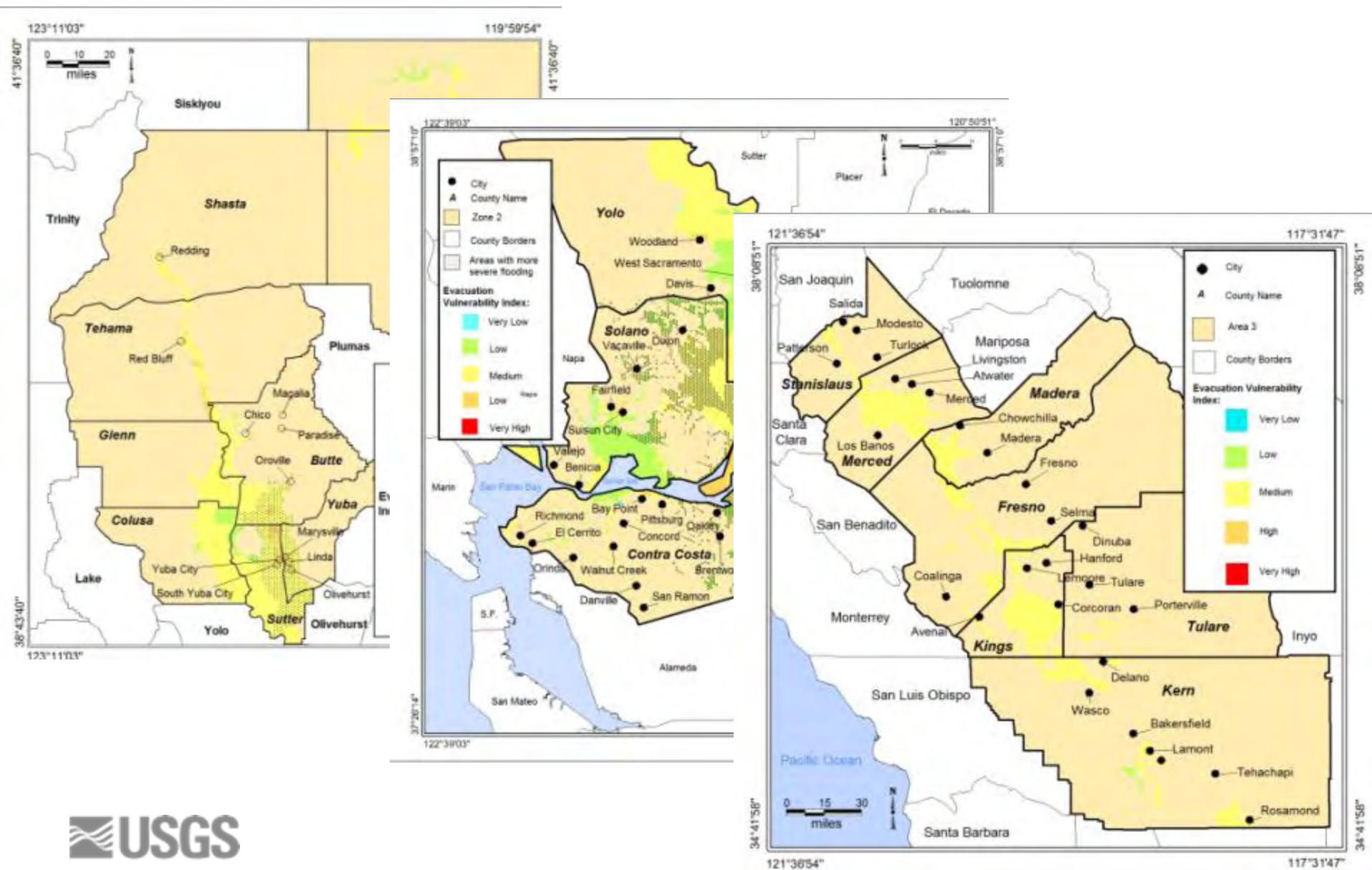




EVACUATION –SOCIAL VULNERABILITY

- Census block intersected with flooded areas
 - Population
 - Age
 - % population over 65
 - Income
 - % HH income < \$30K
 - Population Density
 - Diversity
 - Index of spread of ethnic grps & races
- Warnings and shelters not accomodating of people with disabilities (FEAT, 1997)

EVACUATION – VULNERABILITY





EVACUATION – TRANSPORTATION

- Public and private transportation
 - Number of private cars? e.g., Hurricane Rita.
 - Public transportation is an asset and key to a successful evacuation, need to overcome stigma and rally points
 - Education
- Evacuation planning includes public services for the evacuees (gas stations, supermarkets, healthcare, public buses) AND management and retention of staff behind those services.



Photograph by D. Saville for Federal Emergency Management Agency





ECONOMIC IMPACT OF REDUCED HIGHWAY CAPACITY

- National highway network model => truck distance & time
- Transportation cost model => cost of truck distance & time
- Demand driven model => price effects passed to consumer



1986 near Linda, LA times

ECONOMIC IMPACT OF REDUCED HIGHWAY CAPACITY

- 4 snapshots of highway truck traffic on reduced capacity network

- Day 3
- Day 14
- Day 90
- Day 180





ECONOMIC IMPACT OF REDUCED HIGHWAY CAPACITY

- Truck traffic unaffected 6 months later
- Losses and gains from rerouting and price increases
- Preliminary approximate time-distance truck cost (\$2009) results
 - California: \$33 M
 - Southern California: 30% greater than northern California (port traffic?)
 - Out-of-state approx. \$33 M (2009)
- Economic impacts (from decrease in demand in response to increase in price) 7 times greater out-of-state than in CA

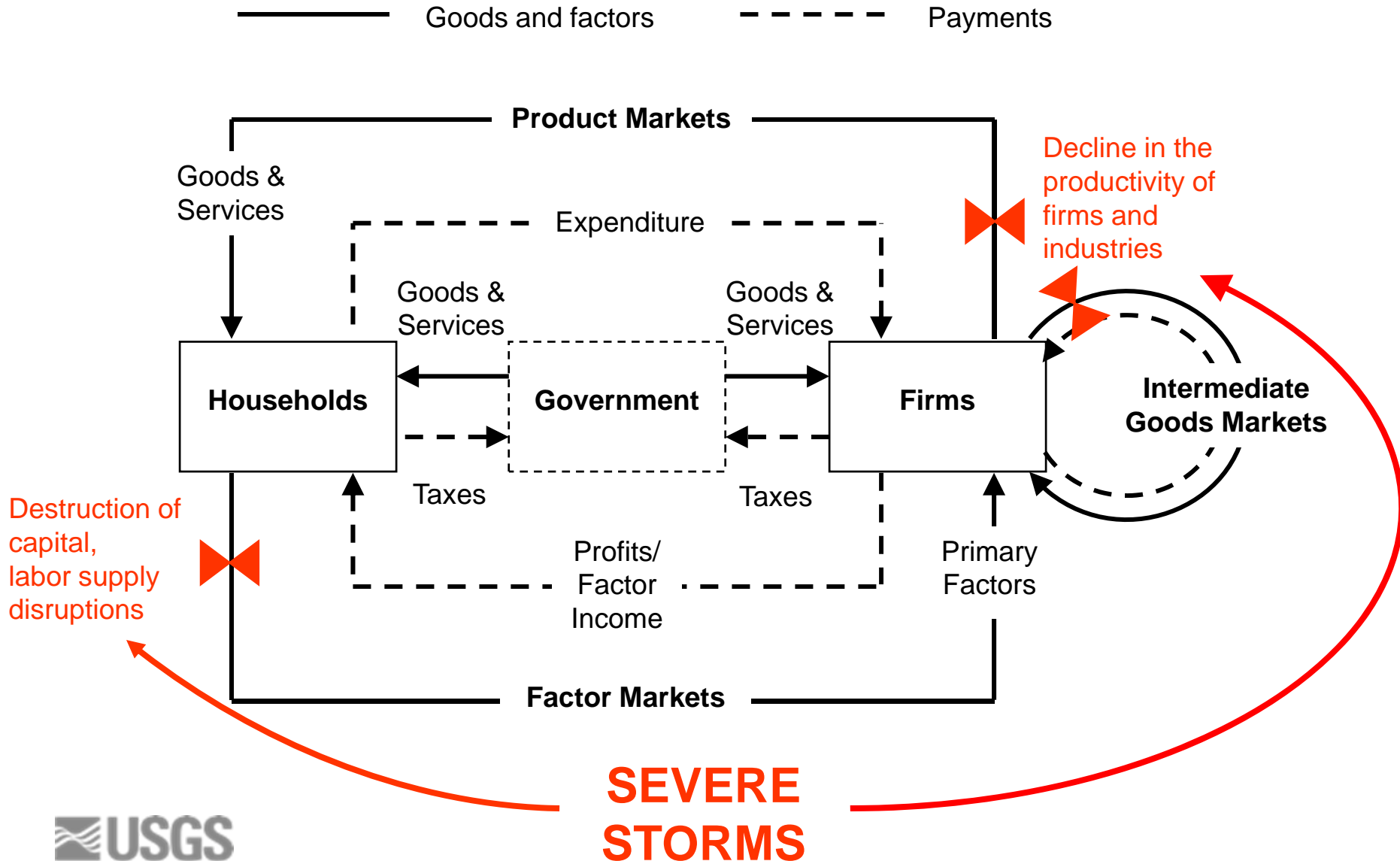


ECONOMIC IMPACTS

- Industry productivity losses (1986)
 - Restaurants struggled to obtain sufficient water
 - Airport closed to save power
 - Some farmers bankrupted
- Reduced tax base
 - Nearly 1/3 taxable land lost (1861-62)
- Market responses (1986)
 - Almond shortage; higher prices of no help to those whose almond crops are decimated
 - Recapturing export markets is a slower process than losing them through a low-volume harvest
- Interventions
 - Tourism stimulus (1997)
- Opportunities:
 - Lucrative ferry business (1861-62)
 - Mines profiting from newly exposed gold & quartz (1861-62)
 - Booming casino business (1997)



The Circular Flow of the Economy and the General Equilibrium Effects of Severe Storms



MODELING THE ECONOMIC IMPACTS OF ARKSTORM

Initial destruction of economy-wide capital

Longer term productivity adjustment of affected industries

Building damages and downtimes

=> occupancy /sector output losses

Lifeline damages and services outages

=> % customers served in each sector

Evacuated population

=> % sector labor evacuated

Agricultural sector losses



Federal Emergency Management Agency News Photo

MODELING THE ECONOMIC IMPACTS OF ARkSTORM

Economy-wide impacts of propagating these shocks through the inter-industry framework of interacting markets

Shocks will have feedback effects on supply-demand equilibration and price levels

Economic resilience mute effects

changes in relative prices induce firms and households to improve resource allocation, engage in input and import substitution

diminishing ability to recapture production

factors in importance



The Times went through yesterday by truck and by boat. Tommy Coffey of The Times circulation staff is shown in his boat making a delivery to Lillian Wurzel on Forty-third Place. He reached every subscriber.

MODELING THE ECONOMIC IMPACTS OF ARkSTORM

Simulation procedure

Perform a baseline run of the model

Impose storm's ex ante sector output losses effects and perform a counterfactual model run

Compare runs 1 and 2 to assess storm's macroeconomic impact

Four categories of impact have been analyzed

Flood and wind building damage

Electric and water service outage



STATEWIDE ECONOMIC IMPACTS : REDUCTIONS IN GSP, 2010-12 (in billion 2008 dollars)

Time Period	Flood Building Damage	Wind Building Damage	Electricity Disruption	Water Service Disruption
Year 1	\$182	\$0.69	\$7.49	\$24.10
Year 2	210	\$0.47	\$0.63	0.99
Year 3	<u>116</u>	<u>\$0.28</u>	<u>\$0.60</u>	<u>0.66</u>
Total	\$508	\$1.44	\$8.72	\$25.75

CA Gross State Product : \$1.7 trillion



SECTORS MOST ADVERSELY AFFECTED BY ARkSTORM

Flood Building Damage	Wind Building Damage	Electricity Disruption	Water Service Disruption
<ul style="list-style-type: none">•Machinery, Plastics and Rubber•Furniture Mfg.	<ul style="list-style-type: none">•Machinery, Plastics and Rubber•Recreation & Gambling	<ul style="list-style-type: none">•Construction•Building Materials,•General Merchandise Stores•Education and Health Services*	<ul style="list-style-type: none">•Health•Education•Retail Trade•Amusements and Recreation•Construction•Furniture Mfg.

* not adjusted for back-up generators at most major health facilities

CONCLUSIONS

- So far, flooded buildings is the biggest shock to the economy
- Water service still relatively greater impact than other shocks, but not the big impact of the ShakeOut earthquake
- Complete analyses for wastewater, agricultural damages, evacuation
- Isolate effect of each shock, then consider double counting
- Conduct sensitivity analysis
- Explore and interpret results – get back to the promised benefits
- Accomplishments
 - expanded analysis of sources of BI
 - state of the art model of the economy
 - integration

Additional slides

Most of these additional slides provide further details on the Computable General Equilibrium (CGE) Model of the California economy as shown on the earlier slide, “The Circular Flow of the Economy and the General Equilibrium Effects of Severe Storms.”



A CGE Model of California's Economy

- Producers
 - Supply side of the economy is divided into 100 sectors, with particular detail in agriculture, manufacturing, services
 - Each industry is modeled as a representative firm with a nested constant elasticity of substitution (CES) production technology (Rose et al, 2009)
 - Short-run costs of adjustment to storm effects are captured via sluggish intersectoral reallocation of capital and labor
- Consumers
 - Households are modeled as a representative agent with nested CES preferences and a constant marginal propensity to save out of income
- Calibration
 - The static equilibrium sub-model is numerically calibrated using IMPLAN input-output data for California in 2007
- Dynamics
 - The economy evolves over 3 years, on a 6-month time-step
 - Saving by the representative agent accrues as new investment which expands the aggregate endowment of capital
 - The aggregate endowment of labor is endogenously determined in each period according to a labor supply curve, without explicitly modeling the growth of population or the workforce

Computable General Equilibrium: A Primer

- The circular flow implies the conditions of general equilibrium
 - Market clearance (MC): supply = demand for each reproducible good (e.g., electricity) or primary factor of production (e.g., labor)
 - Zero profit (ZP): each firm's output price = marginal cost of production
 - Income balance (IB): hholds' factor income from factor returns = expenditure on commodities
- A CGE model is an algebraic expression of the above
 - Parameters numerically calibrated on real-world data
 - System of equations solved for a set of goods prices (P), factor prices (W), industry activity levels (A), and household income levels (I)
- Key is to assume optimizing behavior by producers and hholds
 - Households maximize utility \Rightarrow Final commodity demands(P, I)
 - Firms maximize profits \Rightarrow Factor demands(W, A), Intermediate commodity demands(P, A)
- A CGE model combines circular flow conditions with the demand functions


Computable General Equilibrium: A Primer

- CGE model in a nutshell

$$\begin{aligned} \underline{MC}: \text{Factor endowment} &= \sum \text{Factor demands}(\underline{\mathbf{W}}, \underline{\mathbf{A}}), \\ \text{Goods supply}(\underline{\mathbf{A}}) &= \sum \text{Intermediate goods demands}(\underline{\mathbf{P}}, \underline{\mathbf{A}}) \\ &\quad + \sum \text{Final goods demands}(\underline{\mathbf{P}}, \underline{\mathbf{I}}) \end{aligned}$$

$$\begin{aligned} \underline{ZP}: \text{Goods price}(\underline{\mathbf{P}}) \times \text{Goods supply}(\underline{\mathbf{A}}) &= \\ \sum \{ \text{Goods prices}(\underline{\mathbf{P}}) \times \text{Intermediate goods demands}(\underline{\mathbf{P}}, \underline{\mathbf{A}}) \} &+ \\ + \sum \{ \text{Factor prices}(\underline{\mathbf{W}}) \times \text{Factor demands}(\underline{\mathbf{W}}, \underline{\mathbf{A}}) \} & \end{aligned}$$

$$\begin{aligned} \underline{IB}: \sum \{ \text{Goods prices}(\underline{\mathbf{P}}) \times \text{Final goods demands}(\underline{\mathbf{P}}, \underline{\mathbf{I}}) \} &= \\ = \sum \{ \text{Factor prices}(\underline{\mathbf{W}}) \times \text{Factor endowments} \} & \end{aligned}$$

- Solve for prices and quantities *simultaneously*
 - Find commodity/factor prices industry/household activity levels which satisfy the system of equations \underline{MC} , \underline{ZP} , \underline{IB}
- We integrate a severe storm's ex-ante effects  (red bow tie) into the above framework in a consistent fashion

Modeling the Impacts of a Severe Storm

- Four categories of impacts have been analyzed
 - Flood and wind building damage
 - Electric and water service outage
- “Ex ante” impacts
 - We assume that the storm occurs at $t = 0$, and represent initial destruction of capital as a decline in the aggregate endowment of capital in the initial 6-month period
 - We model longer term business interruption as an adverse neutral productivity shock in the affected industries
- “Ex post” impacts of propagating these shocks through the inter-industry framework of interacting markets
 - Shocks will have feedback effects on supply-demand equilibration and price levels
 - Changes in relative prices will induce firms and households to improve resource allocation, engage in input and import substitution
 - Substitution \Rightarrow attenuating effects on ex ante shocks, ex-post distribution of impacts can differ substantially from ex-ante pattern of losses
 - Production recapture (25% decay of the HAZUS Recapture Factor per calendar quarter, such that there is no recapture after the first year)
 - Importance : utilizing the portion of the business that has no need for the input (e.g., water)
- Simulation procedure
 1. Perform a baseline run of the model
 2. Impose storm’s ex ante effects and perform a counterfactual model run
 3. Compare runs 1 and 2 to assess storm’s macroeconomic impact

EVACUATION – warnings and orders

1997 FEAT

- Evacuation orders unclear
- Authority to order not understood
- Methods of dissemination not used
- Mixed messages broadcasted
- Miscomprehension

BUILDING THE ARkSTORM SCENARIO

