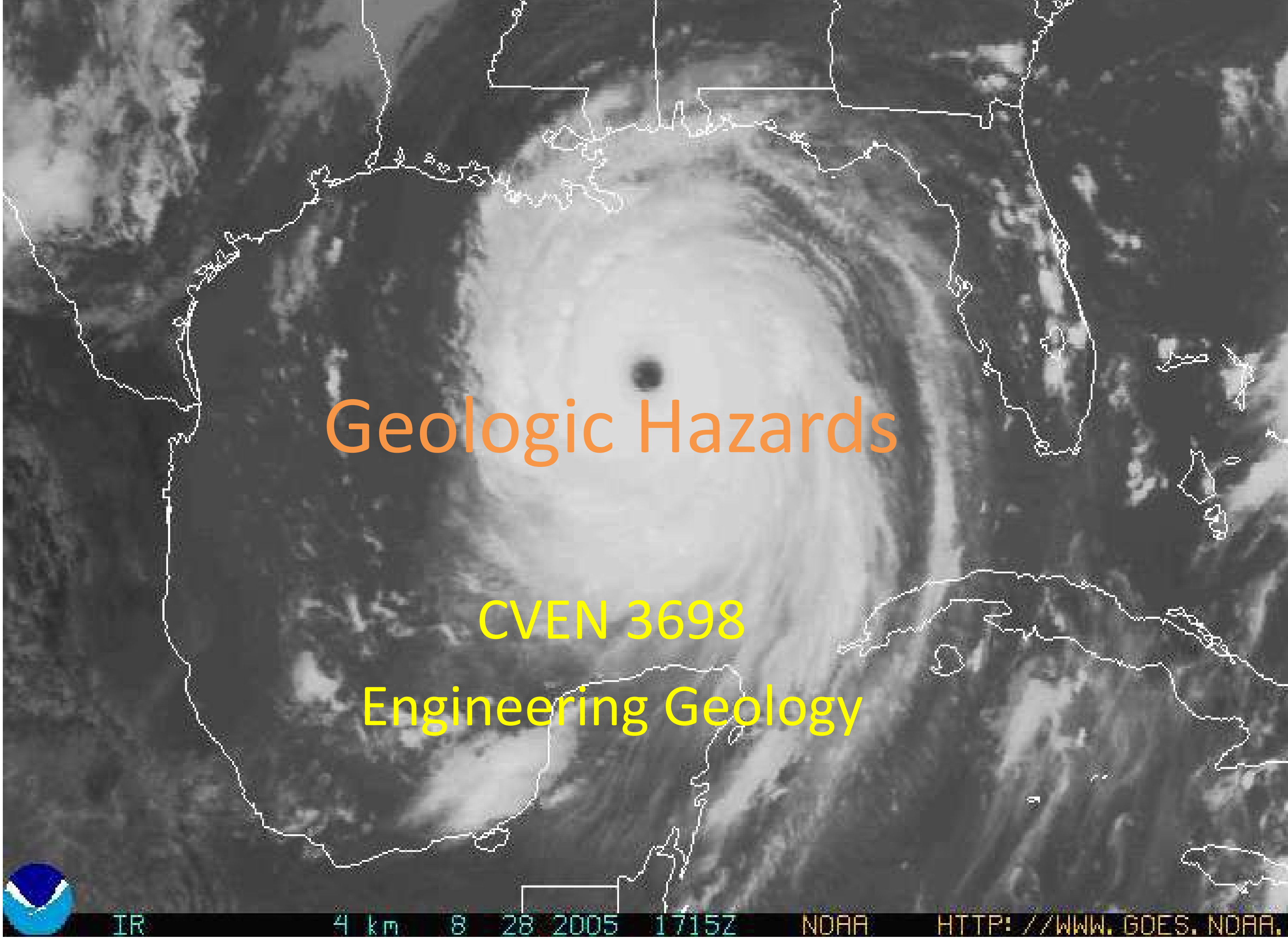
Geologic Hazards

CVEN 3698
Engineering Geology



Definitions

- A **geologic hazard** is one of several types of adverse geologic conditions capable of causing damage or loss of property and life (Wikipedia)
- A **geologic hazard** shall mean a geologic condition or geologic process which poses a significant threat to health, life, limb, or property. (BC Land Use Department)
- A **geologic constraint** shall mean a geologic condition which does not pose a significant threat to life or limb, but which can cause intolerable damage to structures (BC Land Use Department)
- A **geologic hazard** is a natural geologic event that can endanger human lives and threaten human property. Earthquakes, geomagnetic storms, landslides, sinkholes, tsunamis, and volcanoes are all types of geologic hazards. The U.S. Geological Survey (USGS) provides real-time hazard information on earthquakes, landslides, geo-magnetics, and volcanoes, as well as background information on all the types of hazards. http://geohazards.cr.usgs.gov

Counties and Municipalities in Colorado regulate geologic Hazards in four different ways

- Master and Land Use Plans for land use patterns and development
- Zoning Regulations
- 1041 Regulations where hazardous areas are identified
- Land Use or Subdivision Codes

https://www.bouldercounty.org/departments/land-use/

http://coloradogeologicalsurvey.org/
https://assets.bouldercounty.org/wp-content/uploads/2017/06/cesare-geologic-hazard-study-boulder-county-20170331.pdf

Front Range Geologic Hazards Field Trip:
http://coloradogeologicalsurvey.org/wp-content/uploads/2013/08/6.pdf

Two Types

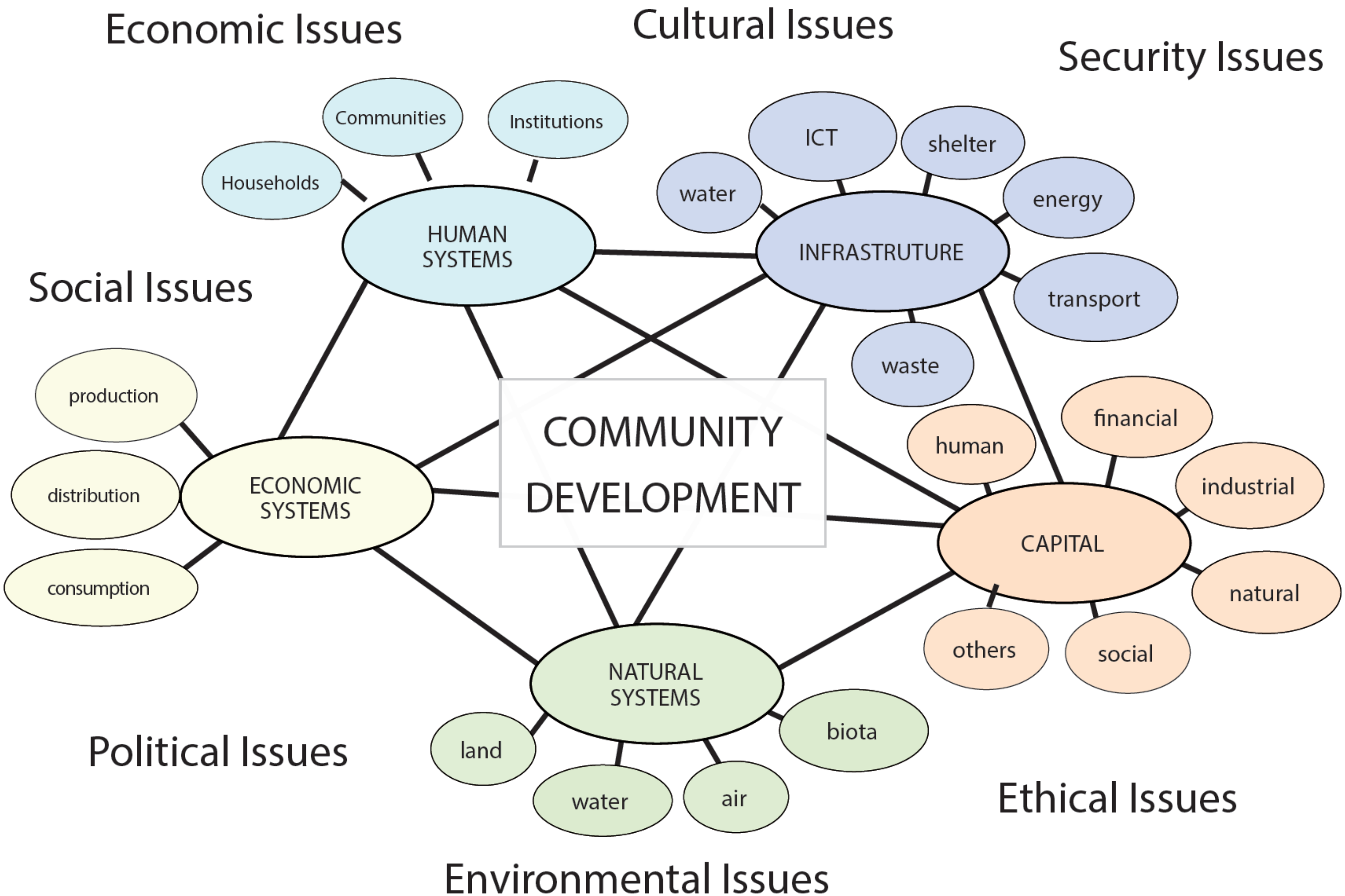
- Hazards associated with particular earth materials. Examples include swelling soils and rocks, toxic minerals (asbestos, acid drainage) and toxic gases (radon gas).
- Hazards associated with earth processes (earthquakes, volcanoes, landslides, avalanches, rock slides and rock falls, soil creep, subsidence, floods, frost heave, coastal hazards).

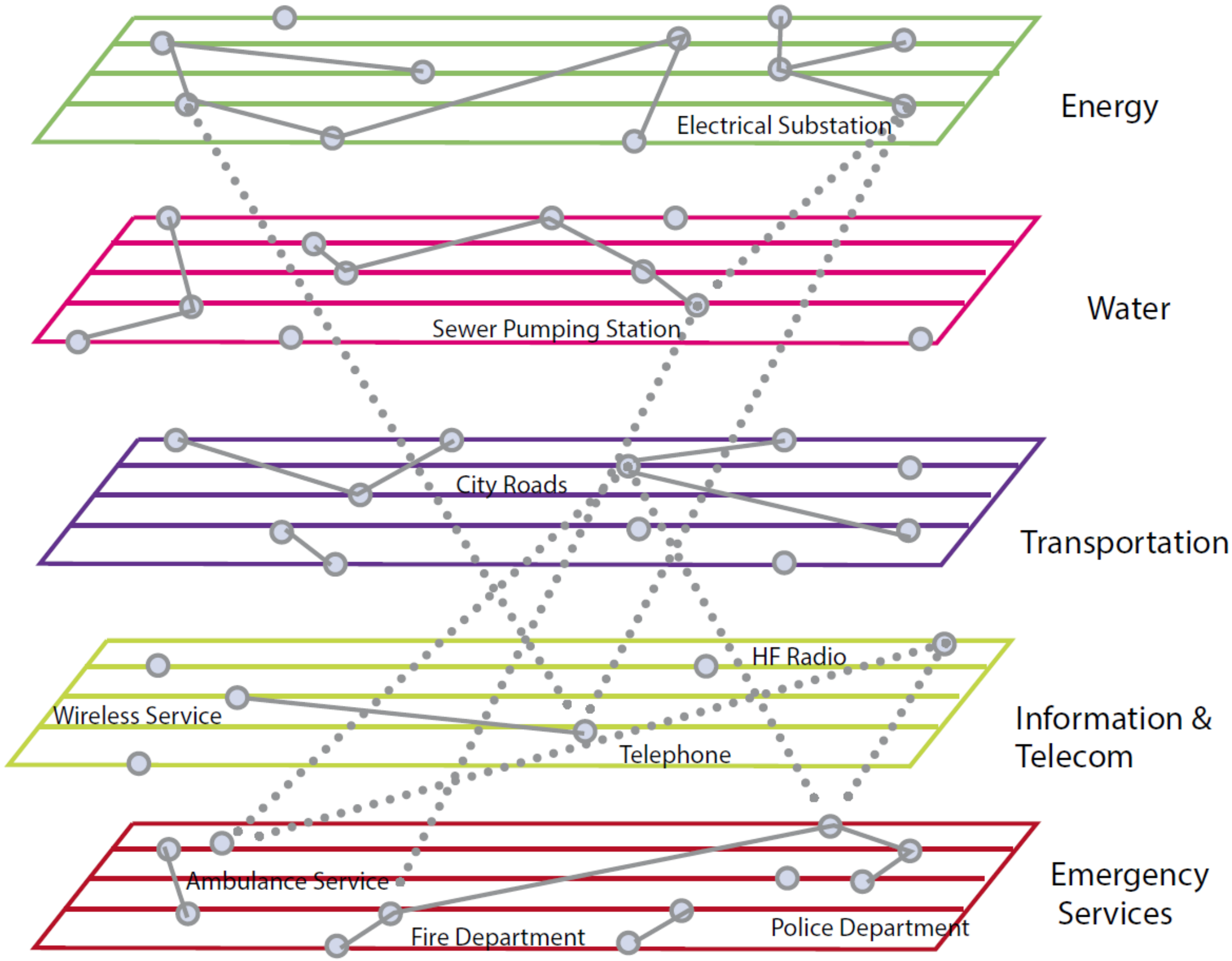
Geologic Hazards

- Earthquakes
- Landslides
- Rockfall
- Volcanic lahars
- Debris flows
- Sink holes
- Subsidence
- Expansive soils
- Melting permafrost

Man-made Hazards

- Natural hazards are complemented with man-made hazards such as water pollution, mine subsidence, rock bursts, pumping, waste disposal, carbon emission, global warming, and ozone depletion.
- Understanding these hazards requires a multidisciplinary approach. These issues are interdisciplinary with biology, engineering, chemistry, and environmental sciences.
- http://www.youtube.com/watch?v=_feWtkSucvE


Economic Issues
Cultural Issues
Security Issues
Social Issues
Political Issues
Ethical Issues
Environmental Issues
Communities
Institutions
Households
HUMAN SYSTEMS
ICT
shelter
water
energy
INFRASTRUTURE
transport
waste
production
distribution
consumption
ECONOMIC SYSTEMS
COMMUNITY DEVELOPMENT
human
financial
industrial
CAPITAL
natural
others
social
NATURAL SYSTEMS
land
water
air
biota



Energy
Electrical Substation
Water
Sewer Pumping Station
Transportation
City Roads
Information &
Telecom
HF Radio
Wireless Service
Telephone
Emergency
Services
Ambulance Service
Fire Department
Police Department

SOURCES of CASUALTIES	NUMBERS of CASUALTIES
Wars versus Earthquakes	
U.S. Battle Deaths in World War II	292,131
Atomic Bomb, Hiroshima, Japan 1945	80,000 to 200,000
EARTHQUAKE, Tangshan, China, 1976	242,000
U.S. Murders versus Single Volcanic Eruption	
Total murders U. S. , 1990	20,045
VOLCANIC ERUPTION, Colombia, 1985	22,000
AIDS Deaths in United States versus Single Landslide Event	
Total AIDS deaths U. S., through April, 1992	141,200
LANDSLIDES, Kansu, China, 1920	200,000
Greatest Atrocity versus Greatest Flood Events	
The Holocaust, Europe, 1939-1945	6,000,000
FLOOD Yellow River, China, 1887	900,000 to 6,000,000
FLOOD Yangtze River, China, 1931	3,700,000

(data on familiar societal catastrophes from *The World Almanac*, 1993, New York, Pharos Books; and *The Universal Almanac*, 1993, Kansas City, Andrews and McMeel; geological catastrophes compiled from Tufty, 1969, and Office of Foreign Disaster Assistance, 1992, *Disaster History*.)

Impacts of the 2004 Tsunami

- Death toll: 228,000 people along the coastal areas of 11 countries in the Indian Ocean (approx. as of 1/23/05)
  Source: http://coe-dmha.org/Tsunami/Tsu012305.htm

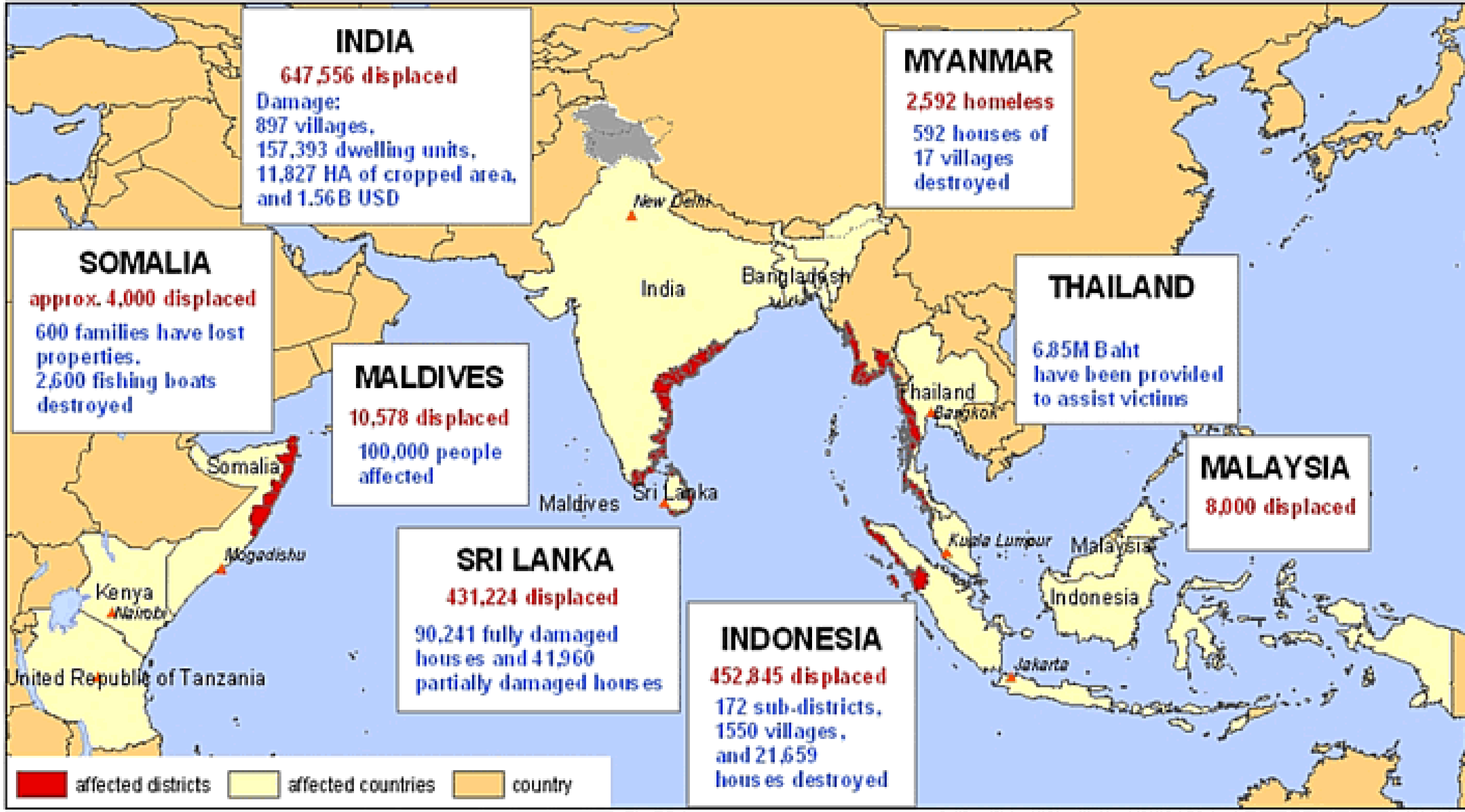
- Between three and five million people in the region are unable to access the basic requirements they need to stay alive - clean water, adequate shelter, food, sanitation and healthcare.
  Source: WHO 12/30/2004

- At least 1.6 million people affected by the disaster are in need of food aid.

  Source: Jan Egeland, UN Under-Secretary-General

In a small amount of time,
their world changed forever…

South Asia earthquake and tsunami: situation map as of 22 January 2005



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.
Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: WHO Tsunami Task Force
Map Production: Public Health Mapping & GIS
Communicable Diseases (CDS)
World Health Organization

Haiti Earthquake

- January 12, 2010, Magnitude 7.0
- 200,000+ people dead

GEOLOGIC HAZARD	COST in 1990 Dollars*	SOURCE(S)
	HAZARDS from MATERIALS	
Swelling Soils	$6 to 11 billion annually	Jones and Holtz, 1973, Civil Engrg. v. 43, n. 8, pp. 49-51; Krohn and Slosson, 1980, ASCE Proc. 4th Intnl. Conf. Swelling Soils pp. 596-608.
Reactive Aggregates 1	No estimate	———
Acid Drainage	$365 million annually to control; $13 to 54 billion cumulative to repair	USBM, 1985, IC 9027; Senate Report, 1977, 95-128
Asbestos	$12 to 75 billion cumulative for remediation of rental & commercial buildings; total well above $100 billion including litigation and enforcement	Croke and others, 1989, The Environmental Professional, v. 11, pp. 256-263. Malcolm Ross, USGS, 1993, personal communication. Costs depend on extent and kind of remediation done; removal is most expensive option.
Radon	$100 billion ultimately to bring levels to EPA recommended levels of 4 PCi/L	Estimate based on remediating about 1/3 of American homes at $2500 each plus costs for energy and public buildings.
	HAZARDS from PROCESSES	
Earthquakes	$230 million annually decade prior to 1989; over $6 billion in 1989	USGS, 1978, Prof. Paper 950; Ward and Page, 1990, USGS Pamphlet, "The Loma Prieta Earthquake of October 17, 1989"
Volcanoes	$4 billion in 1980; Several million annually in aircraft damage	USGS Circular 1065, 1991, and Circular 1073, 1992
Landslides/Avalanches	$2 billion /$0.5 million annually	Schuster & Fleming, 1986, Bull. Assoc. Engrg. Geols., v. 23, pp. 11-28/ Armstrong & Williams, 1986, *The Avalanche Book*
Subsidence 2 and Permafrost 3	At least $125 million annually for human-caused subsidence; $5 million annually from natural karst subsidence	Holzer, 1984, GSA Reviews in Engrg. Geology VI; FEMA, 1980, Subsidence Task Force Report
Floods	$ 3 to 4 billion annually	USGS Prof. Paper 950
Storm Surge 4 and Coastal Hazards	$700 million annually in coastal erosion; over $40 billion in hurricanes & storm surge 1989 - early 1993	Sorensen and Mitchell, 1975 Univ. CO Institute of Behavioral Sci., NSF-RA-E-75-014; Inst. of Behavioral Sci., personal comm.

*Costs from dates reported in "SOURCE(S)" column have been reported in terms of 1990 dollars. This neglects changes in population and land use practice since the original study was done but gives a reasonable comparative approximation between hazards. [1]**Aggregates** are substances such as sand, gravel or crushed stone that are commonly mixed with cement to make concrete. [2]**Subsidence** is local downward settling of land due to insufficient support in the subsurface. [3]**Permafrost** consists of normally frozen ground in polar or alpine regions that may thaw briefly due to warm seasons or human activities and flow . [4]**Storm surge** occurs when meteorological conditions cause a sudden local rise in sea level that results in water piling up along a coast, particularly when strong shoreward winds coincide with periods of high tide. Extensive flooding then occurs over low-lying riverine flood plains and coastal plains.

Coping with geologic hazards

- Avoid the areas where known hazards exist. Such areas can be converted into parks, for instance.
- Evaluate the potential risk of a hazard, if activated.
- Minimize the effect of the hazards by engineering design and appropriate zoning.
- Develop a network of insurance and contingency plans to cover potential loss or damage from hazards.

What is the Problem: The Need for a Resilient Nation

Photo: Joplin, MO after the May 22, 2011 tornado
Source: Charlie Ridel/AP Photo

- Beyond the unquantifiable costs of injury and loss of life from disasters, statistics for 2011 alone indicate economic damages from natural disasters in the United States exceeded $55 billion, with 14 events costing more than $1 billion in damages each.

- No person or place is immune from disasters or disaster-related losses.

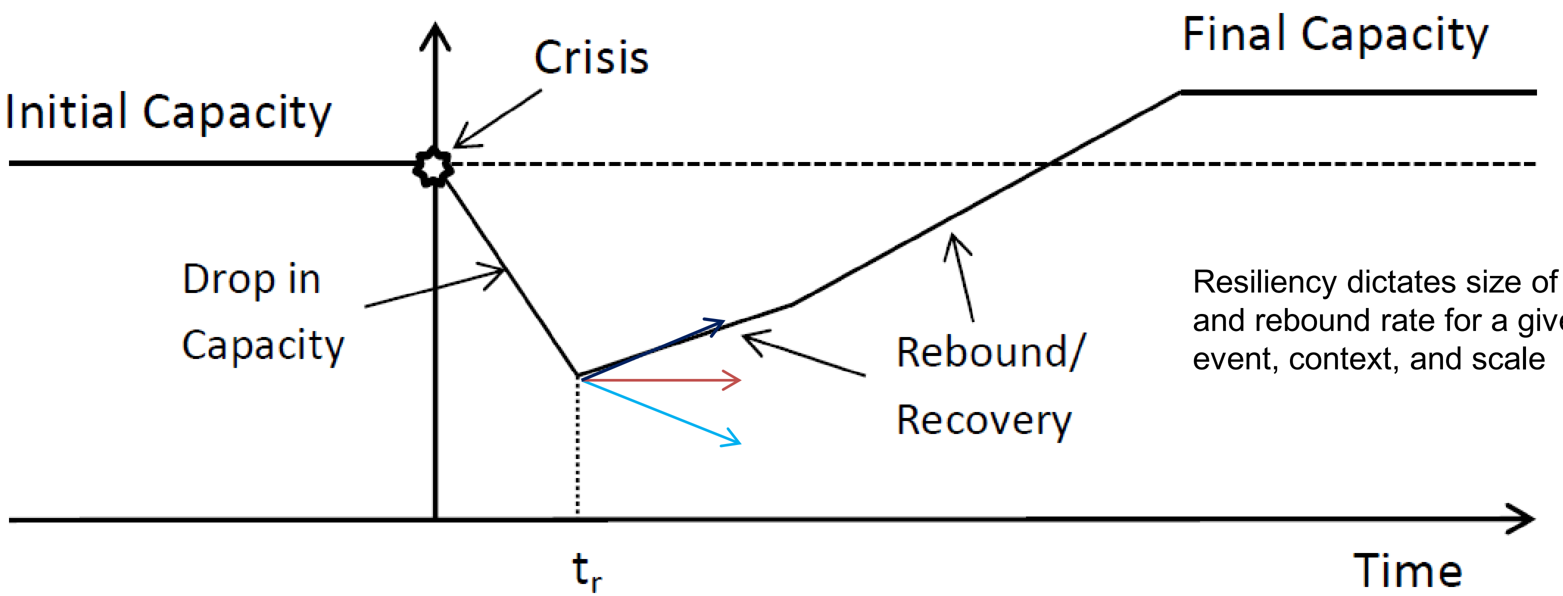
- Communities and the nation face difficult fiscal, social, cultural, and environmental choices about the best ways to ensure security and quality of life against natural and human-induced disasters.

Resilience to Risk

- Effective risk management and capacity building lead to community resilience

Risk = Event x Exposure x
(Vulnerability – Capacity)

Capacity and Resilience



Resiliency dictates size of drop and rebound rate for a given event, context, and scale

- What level of disruption is acceptable?
- What level of protection are we willing to pay for?
- Critical vs. non-critical

The Choice:
Proceed with the Status Quo OR Become More Resilient?

- Disasters continue to occur, both natural and human-made, throughout the country; costs of responding continue to rise
- More people are moving to coasts and southern regions – higher exposure to drought and hurricanes
- Population continues to grow and age
- Public infrastructure is aging beyond acceptable design limits
- Economic and social systems are becoming increasingly interdependent
- Risk can not be completely eliminated; residual risk must be managed
- Impacts of climate change and environmental degradation of natural defenses such as coastal wetlands make the nation more vulnerable

What is Resilience?

The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events

Photo: Cedar Rapids, IA during the 2008 flooding
Source: AP photo/Jeff Robertson

Characteristics of a Resilient Nation in 2030

- Individuals and communities are their own first line of defense against disasters.
- National leadership in resilience exists throughout federal agencies and Congress.
- Community-led resilience efforts receive federal, state, and regional investment and support.
- Site-specific risk information is readily available, transparent, and effectively communicated.
- Zoning ordinances are enacted and enforced. Building codes and retrofit standards are widely adopted and enforced.
- A significant proportion of post-disaster recovery is funded through private capital and insurance payouts.
- Insurance premiums are risk based.
- Community coalitions have contingency plans to provide service particularly to the most vulnerable populations during recovery.
- Post-disaster recovery is accelerated by infrastructure redundancy and upgrades.

A resilient nation in 2030 also has a vibrant and diverse economy and a safer, healthier, and better educated citizenry than in previous generations.

Risk Analysis

- What could wrong? Impact? Costs? Probability?
- Risk management: identification, prioritization, resolution, and monitoring of risks and their management

Definitions

- Substitute "surprises" for "risks"
- Risk is the possibility that an undesired outcome – or the absence of a desired outcome – disrupts a project.
- Risks exist in all parts of ADIME-E framework
- An issue = certain (100%) risk
- Risk could be an opportunity
- Risk earmarks: uncertainty, loss, time component
- Risks prior to project and risks after projects

Risks originate from

- Factors that are under the control of those involved in the project such as poor planning, design, management, and/or execution;
- Decisions made by others such as policy makers and institutions not necessarily directly involved in the project; and
- Uncontrollable factors such as those associated with natural hazards or socio-economic or political issues.

DFID, 2002

Risk vs. Uncertainty

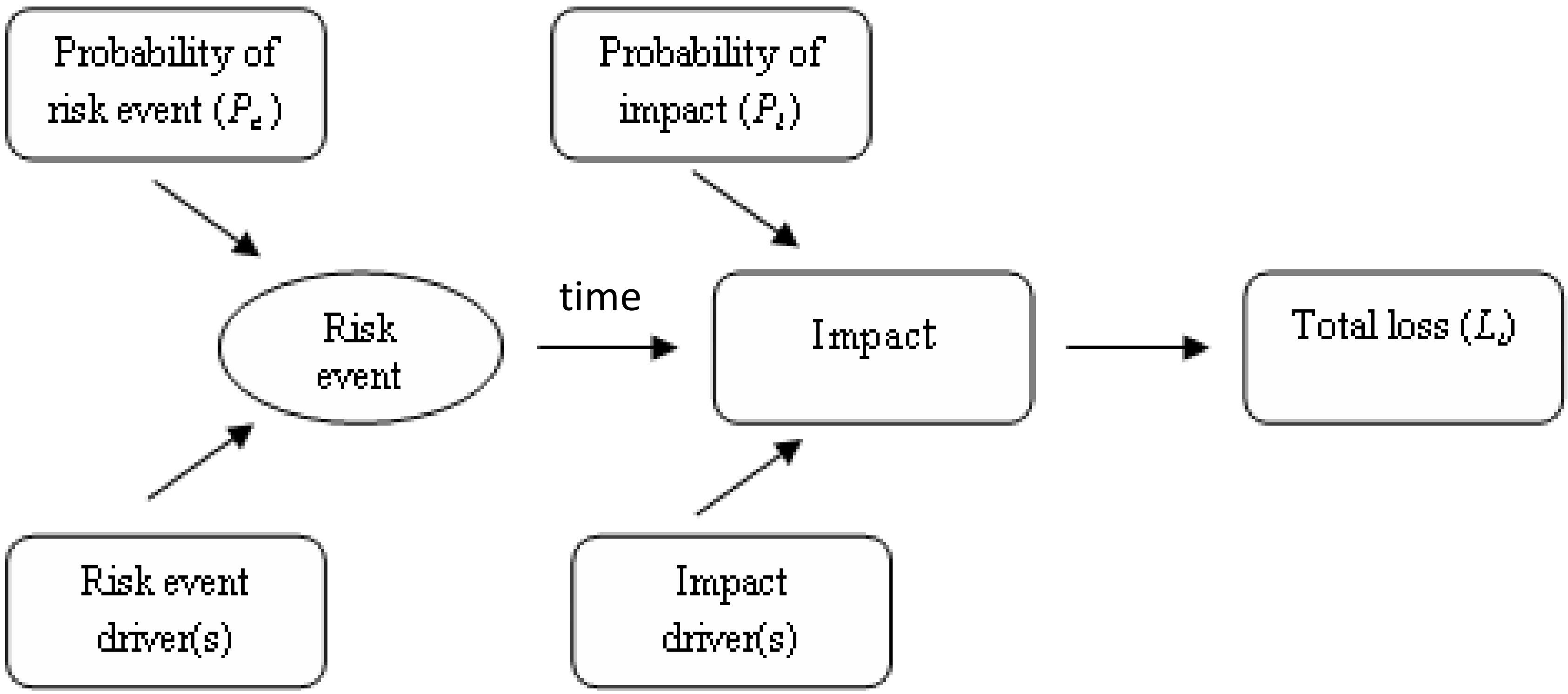
- Risks arise with the uncertainty of the situation the project is faced with.
- Risk differs from uncertainty in the sense that with risks, we have some ideas of the odds that something will happen and we can assign probabilities for that happening (Knight, 1921).

- Risks (what could go wrong?), risk drivers (what makes each risk real), and likelihood (probability estimated based on risk drivers);
- Impacts (cost, work days, calendar days, staff months, space, etc), impact drivers (what makes each impact real) and likelihood (probability estimated based on impact drivers)
- Total possible loss expressed in quantitative way (time, money, etc) or qualitative way (high, medium, low, critical, etc).

Risk and Drivers	Risk Likelihood	Impacts and Drivers	Impact Likelihood	Action Plan	Monitoring and Metrics

Standard Risk Model

Expected loss: $L_e = L_t * P_e * P_i$

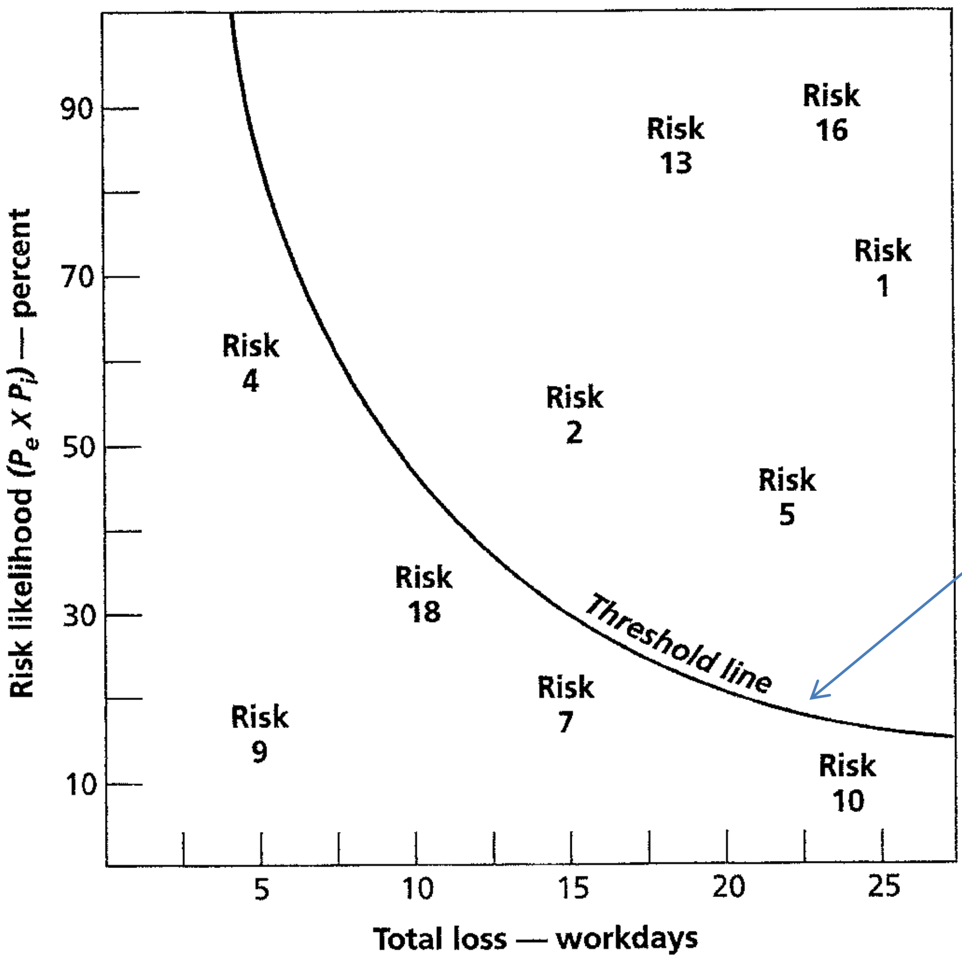


Smith and Merritt, 2002

Risk Management Process

Steps	Critical Information
• Identify risks >>>>>>>>>>>	• Risks events and impacts
• Analyze risks >>>>>>>>>>>	• Drivers, probabilities, and total loss
• Prioritize and map risks >>>	• Subset of risks to be managed
• Resolve risks >>>>>>>>>>>>	• Action plan: avoidance, transfer, redundancy, mitigation (prevention, contingency, reserves)
• Monitor risks >>>>>>>>>>>>	• Status and closure of risks; identify new risks

Risk Map

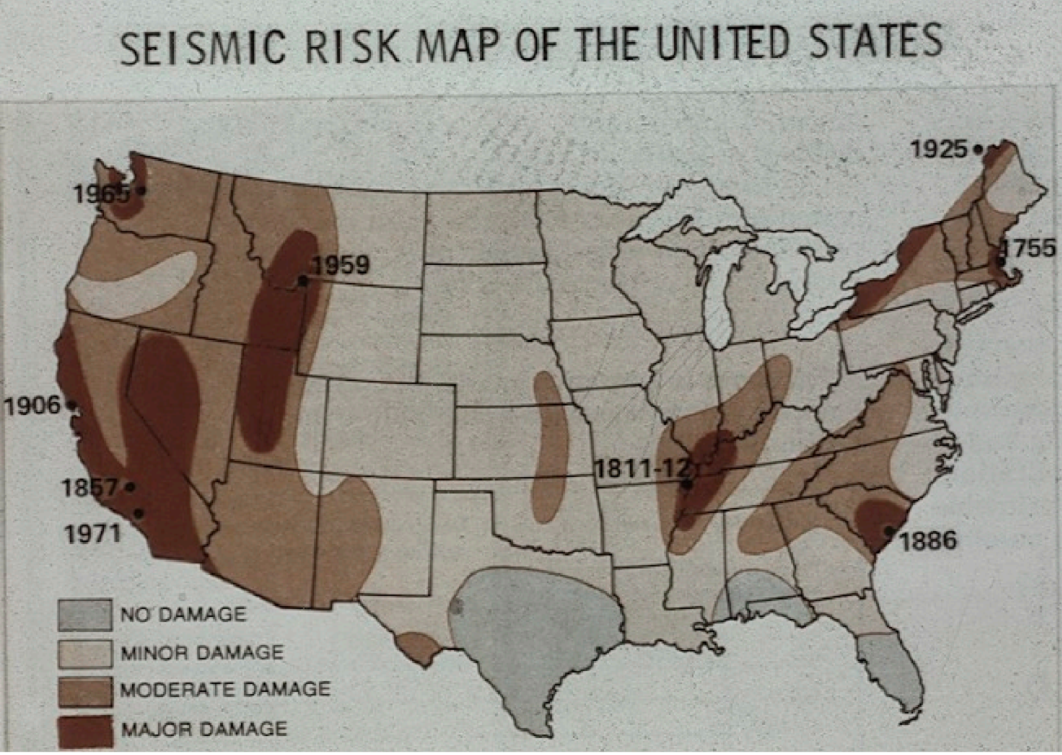


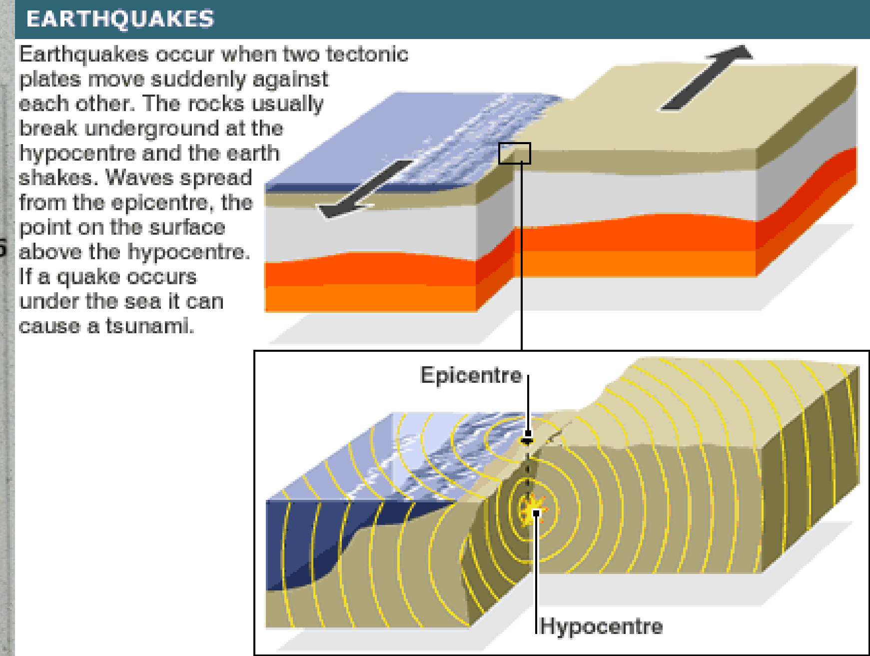
For given expected loss

$P_e * P_i = L_e / L_t$

Risk Management Strategies

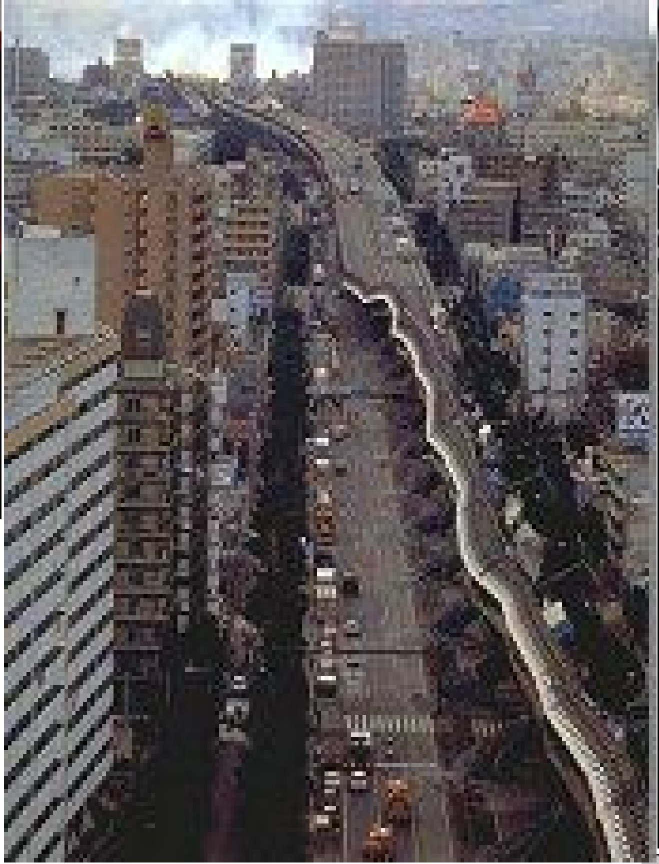
- *Avoid* the risk by reversing decisions that were made that would cause the risk. Abandoning the project might be an option.
- *Transfer* the risk (or impact) to another party that may have a better potential (knowledge, resources) to tackle the problem
- *Redundancy* thus reducing the effect of the risk event by providing parallel solutions paths, and back-up options
- *Tolerate* risk but at the same time *mitigate* the risk/impact and risk/impact drivers (to make it less severe) either by developing: a *prevention* plan (works on reducing risk and risk drivers); a *contingency* plan (works on impact and impact drivers); or a *reserve plan* (risk occurs and we need to cover the losses)


SEISMIC RISK MAP OF THE UNITED STATES
1965
1959
1925
1755
1906
1857
1971
1811-12
1886
NO DAMAGE
MINOR DAMAGE
MODERATE DAMAGE
MAJOR DAMAGE


EARTHQUAKES
Earthquakes occur when two tectonic plates move suddenly against each other. The rocks usually break underground at the hypocentre and the earth shakes. Waves spread from the epicentre, the point on the surface above the hypocentre. If a quake occurs under the sea it can cause a tsunami.
Epicentre
Hypocentre

Link


NIIGATA, APARTMENT BUILDINGS




FRISCO





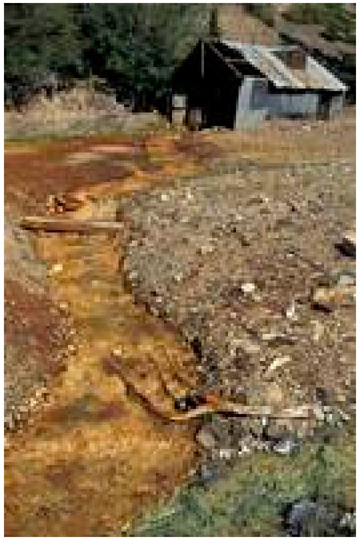
http://video.nationalgeographic.com/video/environment/environment-natural-disasters/earthquakes/earthquake-101/



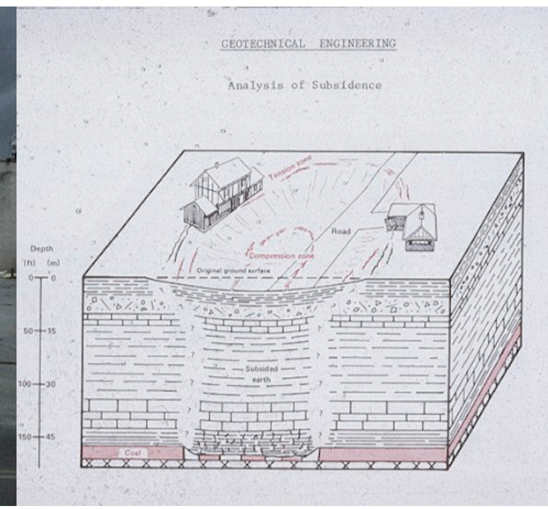



http://www.wimp.com/extremelandslide/
http://mefeedia.com/entry/3158814/
http://www.bing.com/videos/search?q=landslides+videos&mid=4D4E8E0A86218092ABB34D4E8E0A86218092ABB3&view=detail&FORM=VIRE1

http://www.youtube.com/watch?v=vBJ9xZws7ro&feature=related



http://www.youtube.com/watch?v=j-zczJXSxnw


GEOTECHNICAL ENGINEERING
Analysis of Subsidence
Tension zone
Road
Compression zone
Original ground surface
Depth
(ft) (m)
0 0
50 15
100 30
150 45
Subsided earth
Coal

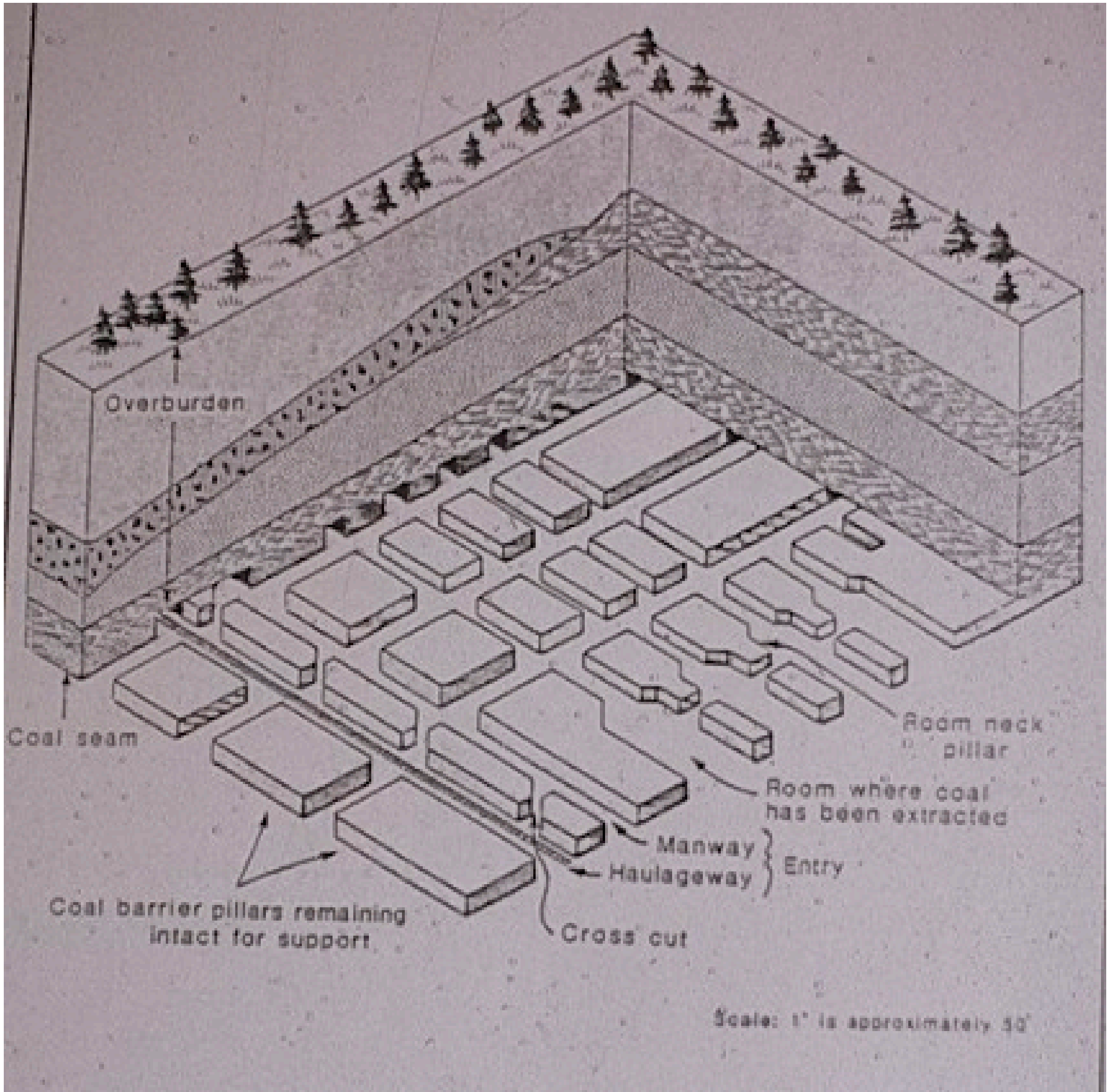
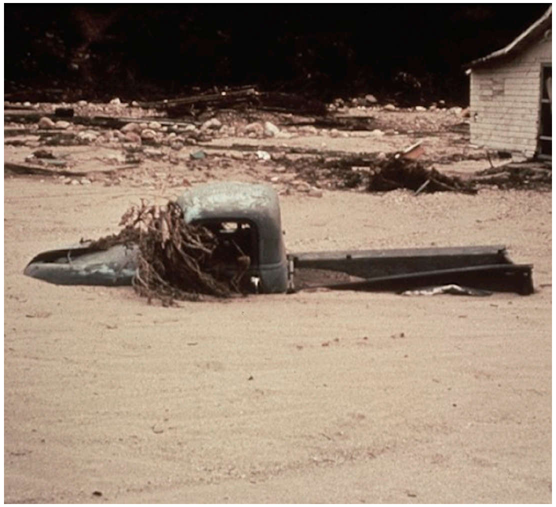
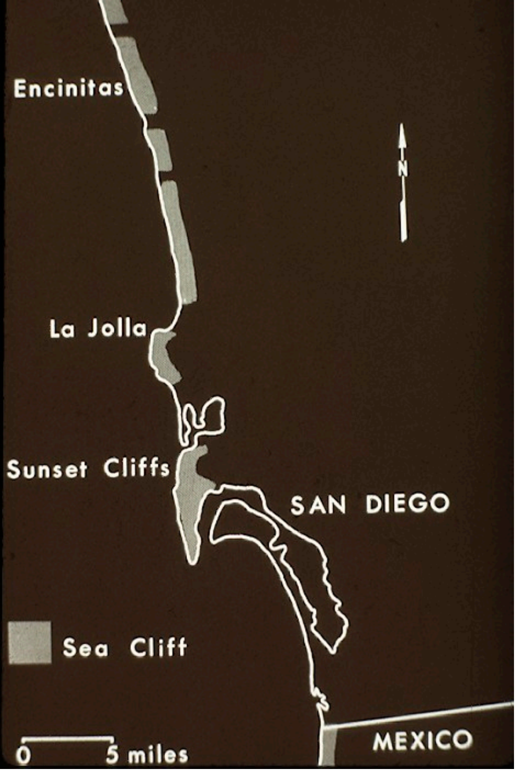


Figure 5
Typical Room And Pillar Mining System



http://www.flixxy.com/japanese-tsunami-viewed-from-a-car.htm

http://www.youtube.com/watch?v=rF0dy5DjEmQ


Encinitas
N
La Jolla
Sunset Cliffs
SAN DIEGO
Sea Cliff
0 5 miles
MEXICO

Earthquake Movie

http://www.bing.com/videos/search?q=when+the+bay+area+quakes+video&FORM=VIRE1#view=detail&mid=222EF4F4896797349C06222EF4F4896797349C06