

Infrastructure Report Card

Mega Trends & Externalities

- It's so much more than roads and bridges
- Expenditures as % of GDP have fallen precipitously
- Pipelines: unseen but critical component
- Water is the next oil
- 7 Billion and heading for 10
- It's all about energy

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ASCE's average grade for all forms of infrastructure

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Components of Infrastructure

Category	1988*	1998	2001	2005	2009	2013
Aviation	B-	C-	D	D+	D	D
Bridges	-	C-	C	C	C	C+
Dams	-	D	D	D+	D	D
Drinking Water	B-	D	D	D-	D-	D
Energy	-	-	D+	D	D+	D+
Hazardous Waste	D	D-	D+	D	D	D
Inland Waterways	B-	-	D+	D-	D-	D-
Levees	-	-	-	-	D-	D-
Public Parks and Recreation	-	-	-	C-	C-	C-
Rail	-	-	-	C-	C-	C+
Roads	C+	D-	D+	D	D-	D
Schools	D	F	D-	D	D	D
Solid Waste	C-	C-	C+	C+	C+	B-
Transit	C-	C-	C-	D+	D	D
Wastewater	C	D+	D	D-	D-	D
Ports	-	-	-	-	-	C
America's Infrastructure GPA	C	D	D+	D	D	D+
Cost to Improve	-	-	\$1.3 trillion	\$1.6 trillion	\$2.2 trillion	\$3.6 trillion

**The first infrastructure grades were given by the National Council on Public Works Improvements in its report *Fragile Foundations: A Report on America's Public Works*, released in February 1988. ASCE's first Report Card for America's Infrastructure was issued a decade later.*

Series of 3 minute videos to
discus, describe, define some
components of the infrastructure

Introduction

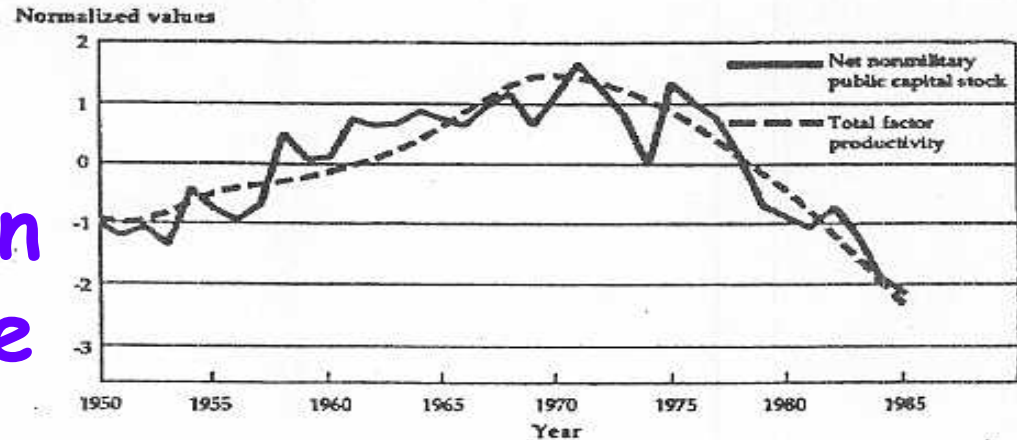
Transportation

Water

Energy

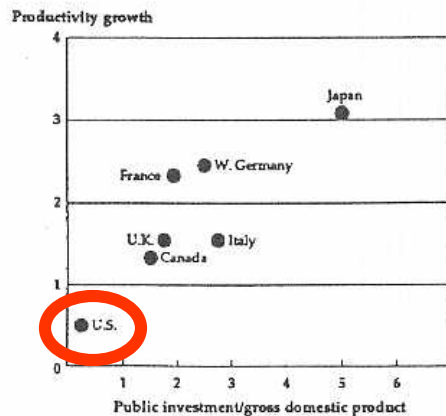
US is
under spending on
its infrastructure

Figure 1: Net Nonmilitary Public Capital Stock and Total Factor Productivity



SOURCE: David A. Aschauer, *Journal of Monetary Economics*, 23 (1989).

Figure 2: Cross-Country Comparison of Growth Rate for Labor Productivity and Public Investment to Gross Domestic Product Ratio



SOURCE: David A. Aschauer, *Journal of Monetary Economics*, 23 (1989).

Figure 3: Total Capital Outlays for Public Works as a Percentage of Gross National Product



SOURCE: Merrill Lynch Capital Markets, in *National Journal*, September 2 (1989).

— $\frac{((\text{Total Public Construction Spending: Highway and street}/1000))/\text{Gross Domestic Product}}{100}$

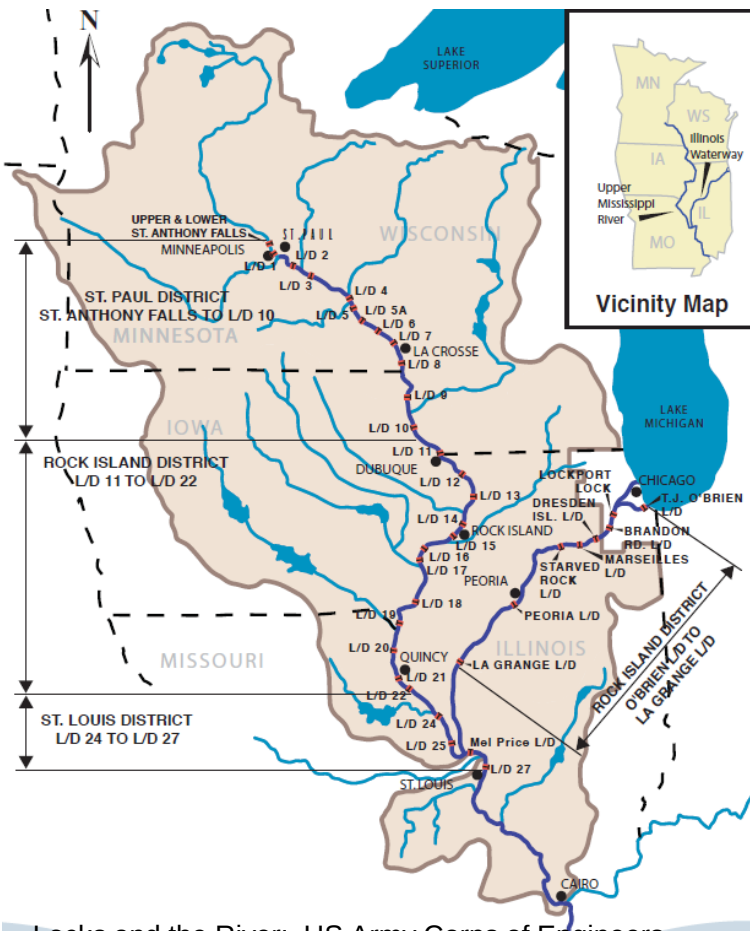


Shaded areas indicate US recessions - 2015 research.stlouisfed.org

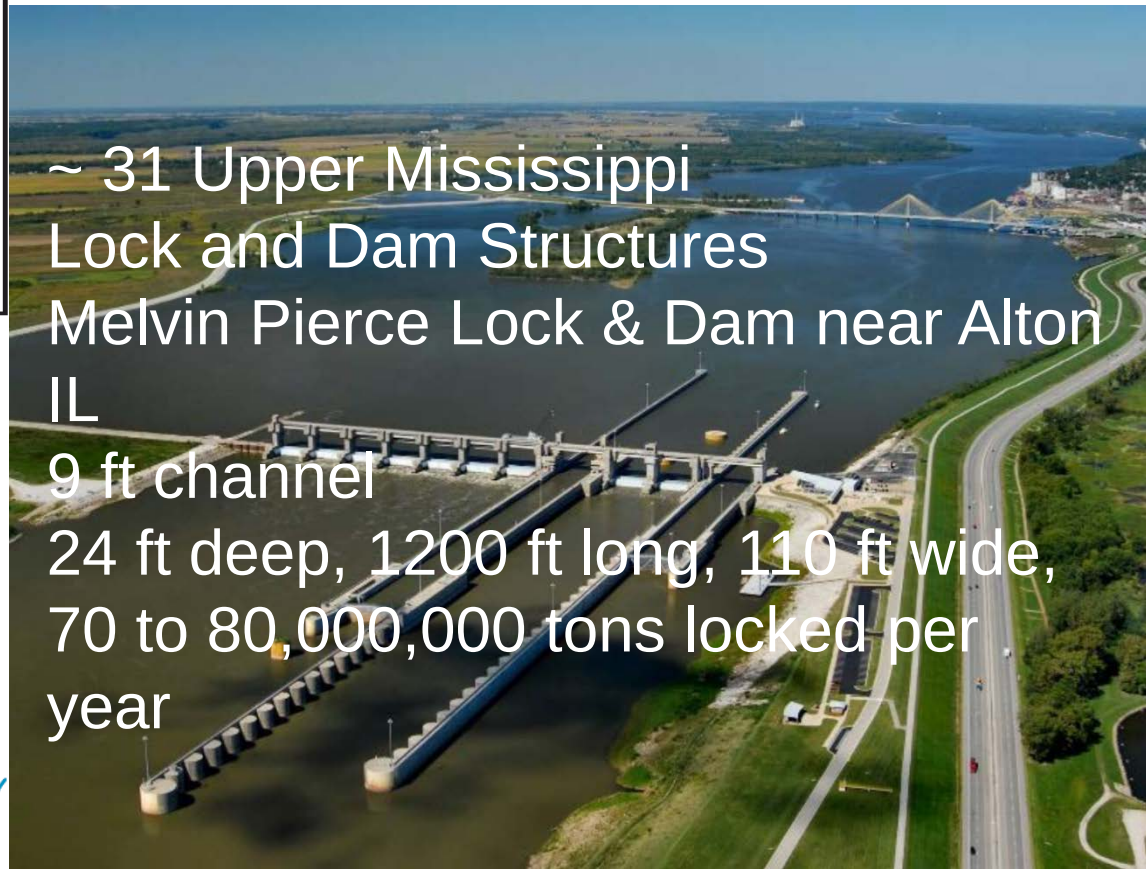
Comparison ASCE Needs in 12-13 to expenditures in 2015 from FRED

			Billions						
			Need		Likely			2015	
			12 to 20	per yr	12 to 20	per yr			
Surface Transportation ¹			\$1,723	\$215	\$877	\$110		Illiana HWY = 1.25B (25 M/mi)	
Airports ^{1,2}			\$134	\$17	\$95	\$12		O'Hare runway = 1.3 B	
Rail ⁷			\$100	\$13	\$89	\$11			
Inland Waterways & Marine Ports ¹			\$30	\$4	\$14	\$2		Olmstead Lock & Dam = 3.1 B	
				\$248		\$134		\$123	
Water/Wastewater Infrastructure ¹			\$126	\$16	\$42	\$5		Kenilworth to buy water from Winn	
Hazardous & Solid Waste ⁴			\$56	\$7	\$10	\$1			
				\$23		\$7		\$3	
Electricity ¹			\$736	\$92	\$629	\$79		\$8	USBR/ACE?
Schools ⁸			\$391	\$49	\$120	\$15		5	
Public Parks & Recreation ⁶			\$238	\$30	\$134	\$17		1	
Levees ⁵			\$80	\$10	\$8	\$1		0.2	HH Dike = 10M/mi
Dams ³			\$21	\$3	\$6	\$1			
TOTALS						\$253		\$140	

Upper Mississippi River



Locks and the River: US Army Corps of Engineers



~ 31 Upper Mississippi
Lock and Dam Structures
Melvin Pierce Lock & Dam near Alton
IL
9 ft channel
24 ft deep, 1200 ft long, 110 ft wide,
70 to 80,000,000 tons locked per
year

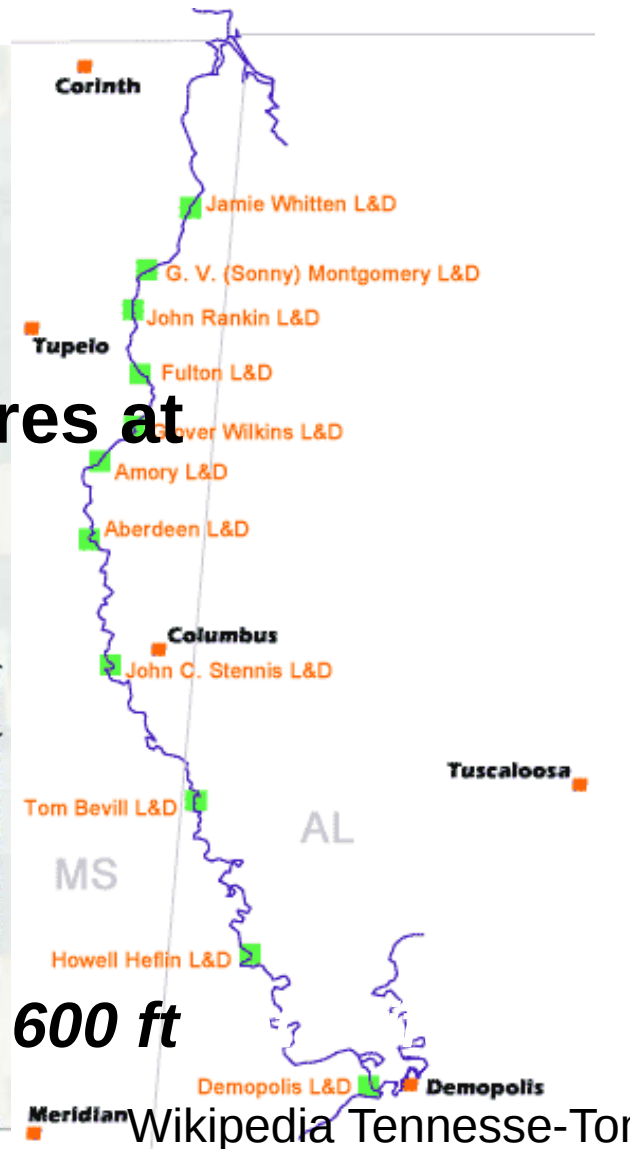
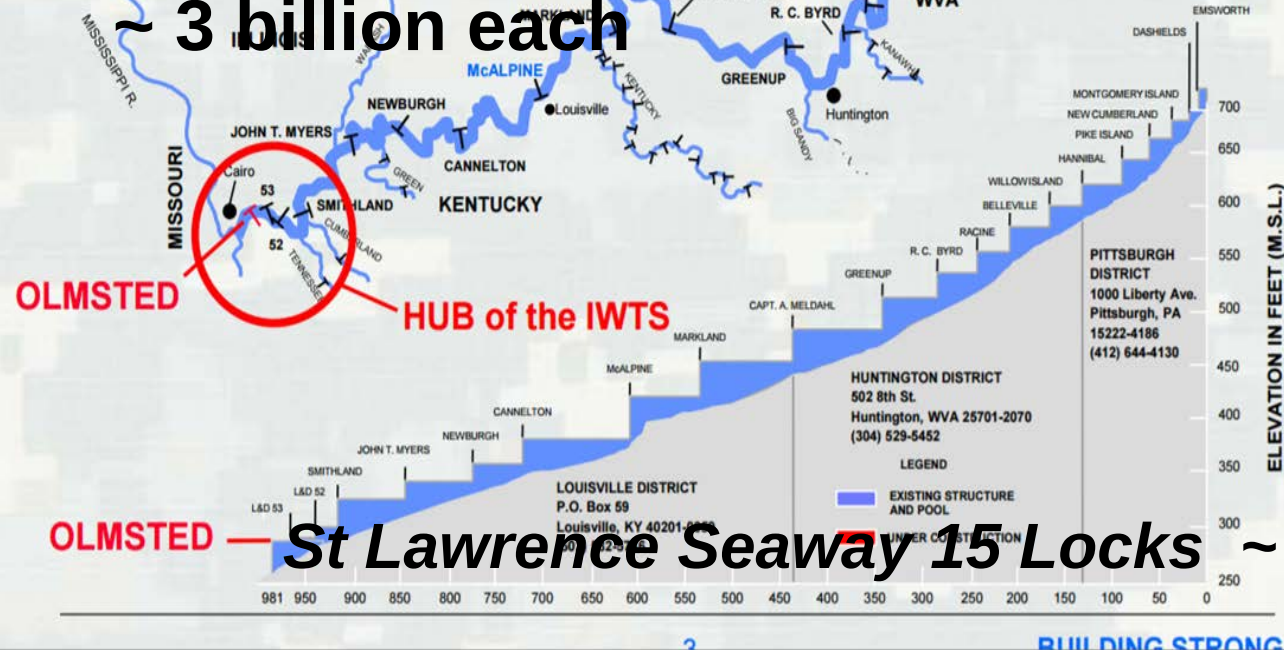
UMR Locks and Dams 2016: US Army Corps of Engineers



US Army Corps
of Engineers
Ohio River & Great Lakes Division

Ohio River Main Stem Locks & Dams

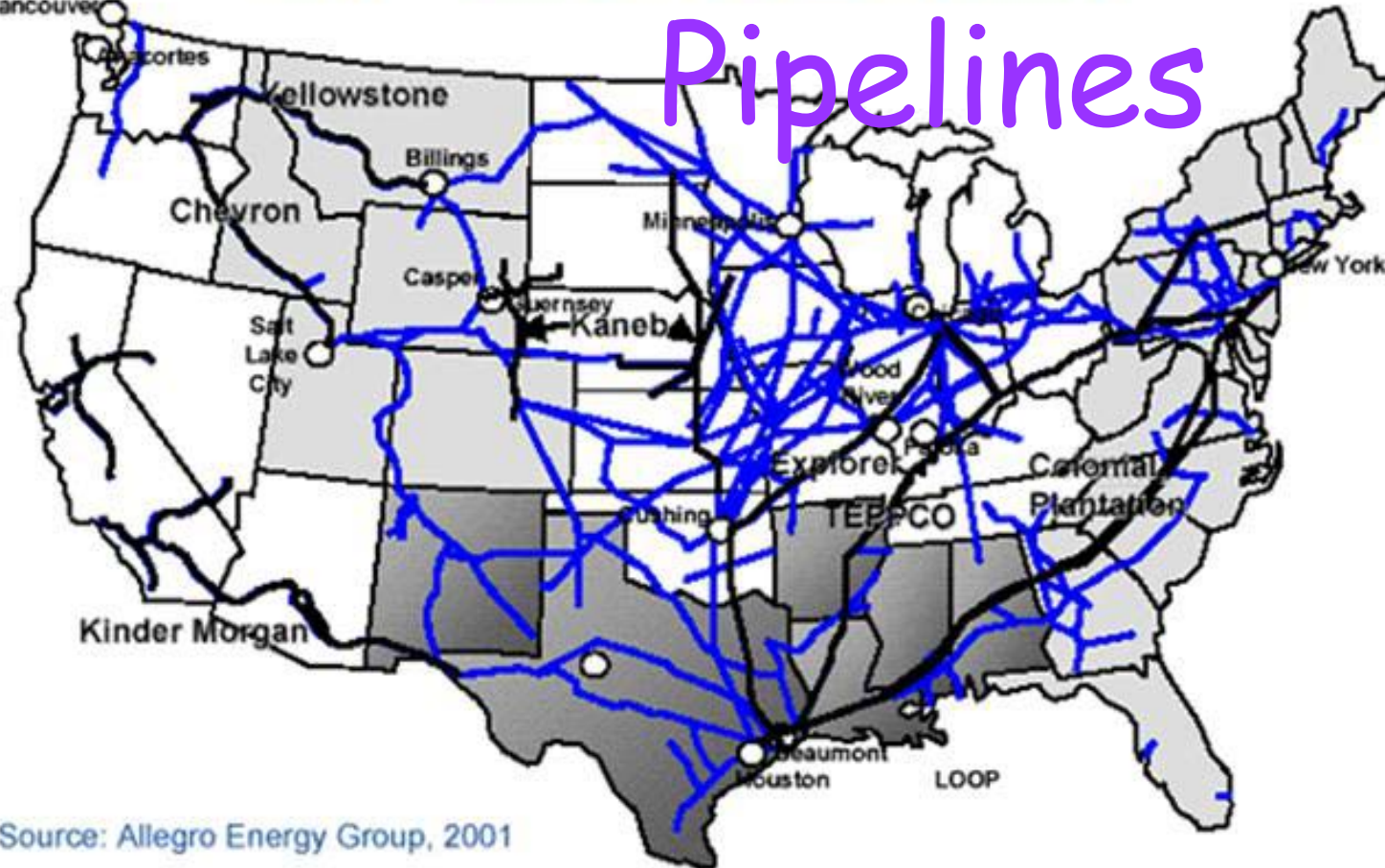
Another 30+ lock and dam structures at
~ 3 billion each



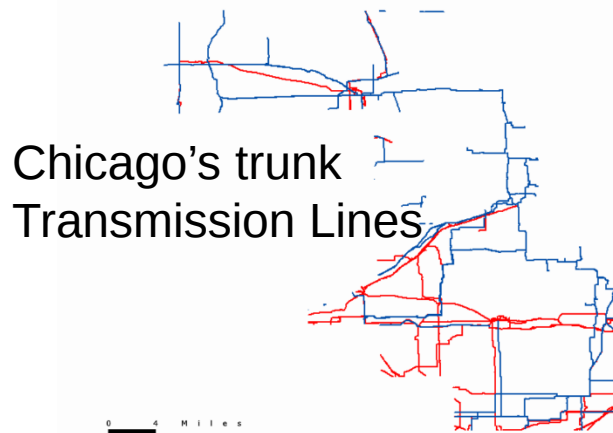


Olmstead lock and dam construction site on Ohio River

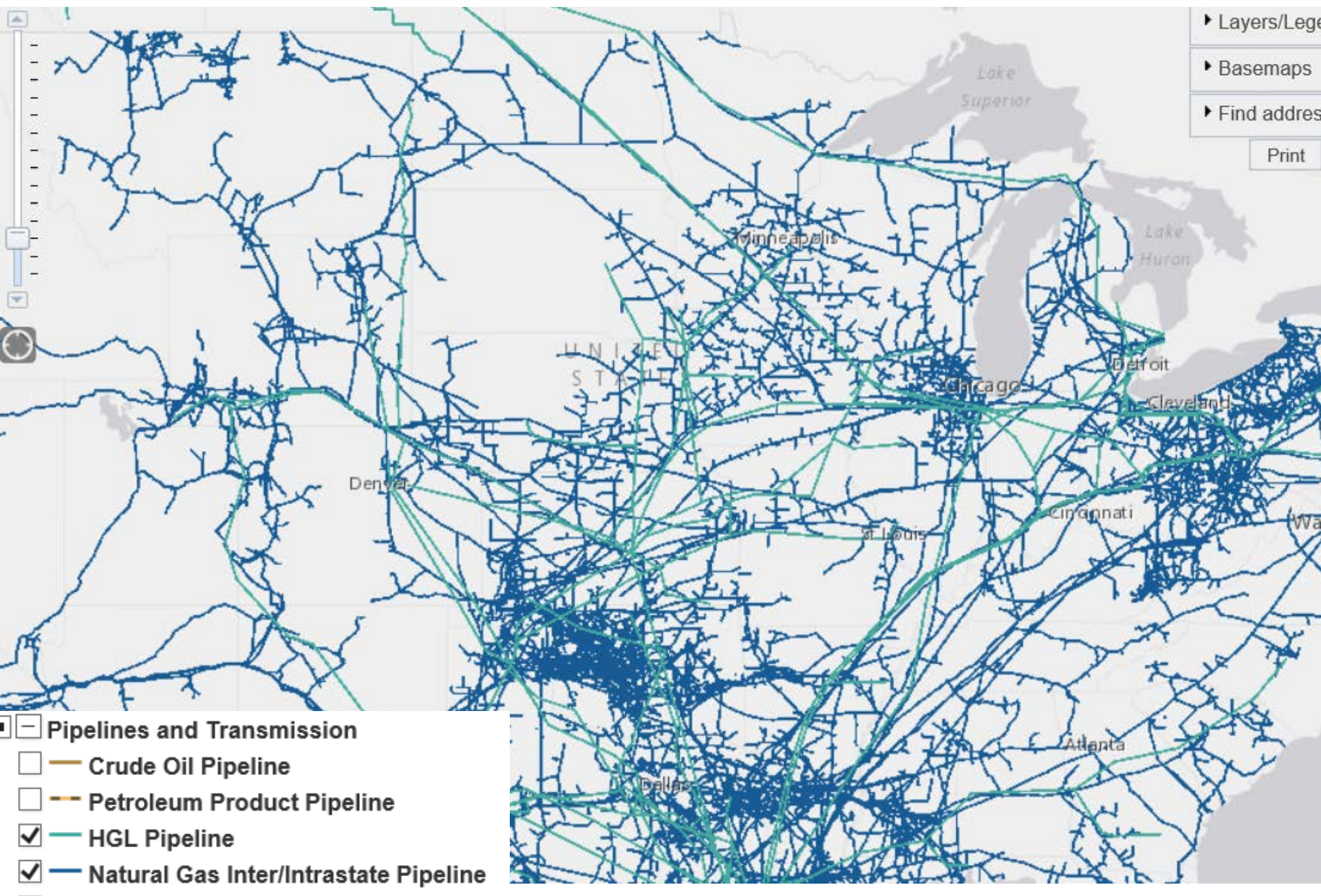
Pipelines



Source: Allegro Energy Group, 2001



Type	Miles
Hazardous Liquid	161,000
Natural Gas Transmission	
Gathering	20,000
Transmission	280,000
Natural Gas Distribution	
Mains	1,120,000
Service Lines	730,000



The nation's more than 2.6 million miles of petroleum pipelines

PHMSA -USDOT

It would take a constant line of tanker trucks, about 750 per day, loading up and moving out every two minutes, 24 hours a day, seven days a week, to move the volume of even a “single” modest pipeline.

The railroad-equivalent of this single pipeline would be a train of 75 2,000-barrel tank rail cars everyday.

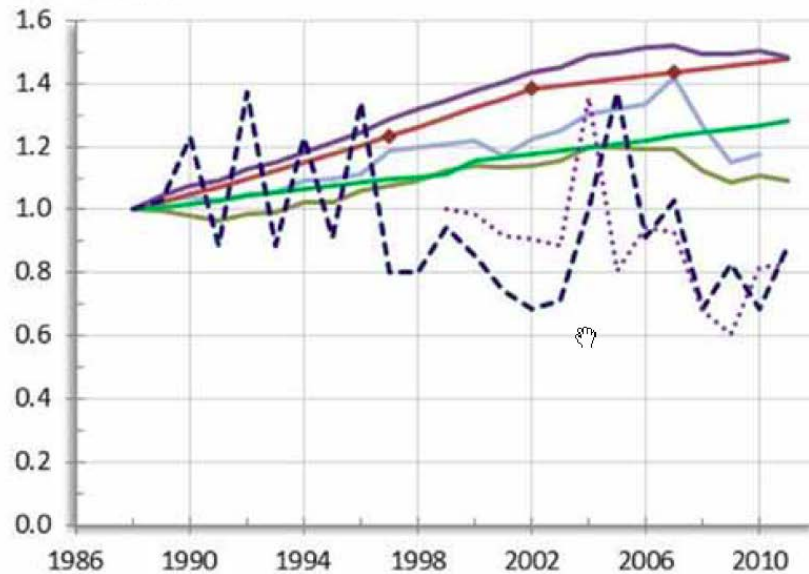
Pipeline systems are the safest means to move these products

At an estimated replacement cost of \$643,800 per km (\$1,117,000 per mile), the asset replacement value of the transmission pipeline system in the United States is \$541 billion; therefore a significant investment is at risk with corrosion being the primary factor in controlling the life of the asset.



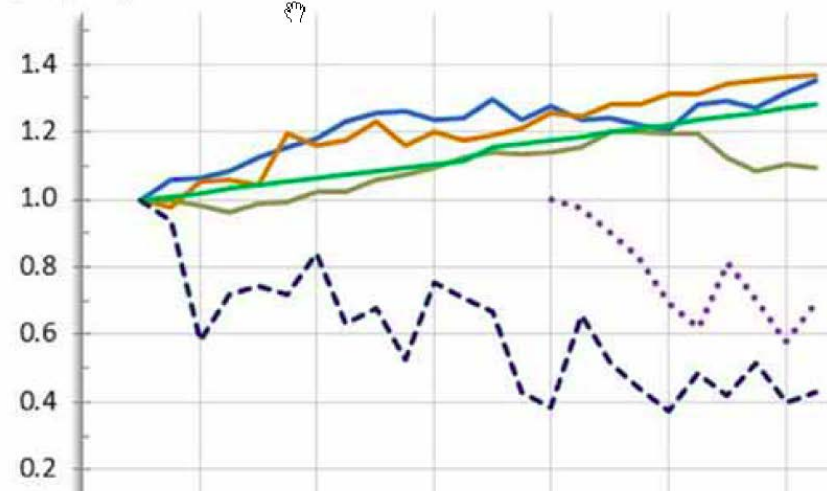
Hazmat Safety with Context Measures (1988-2011)

Change from 1988 (Index = 1)



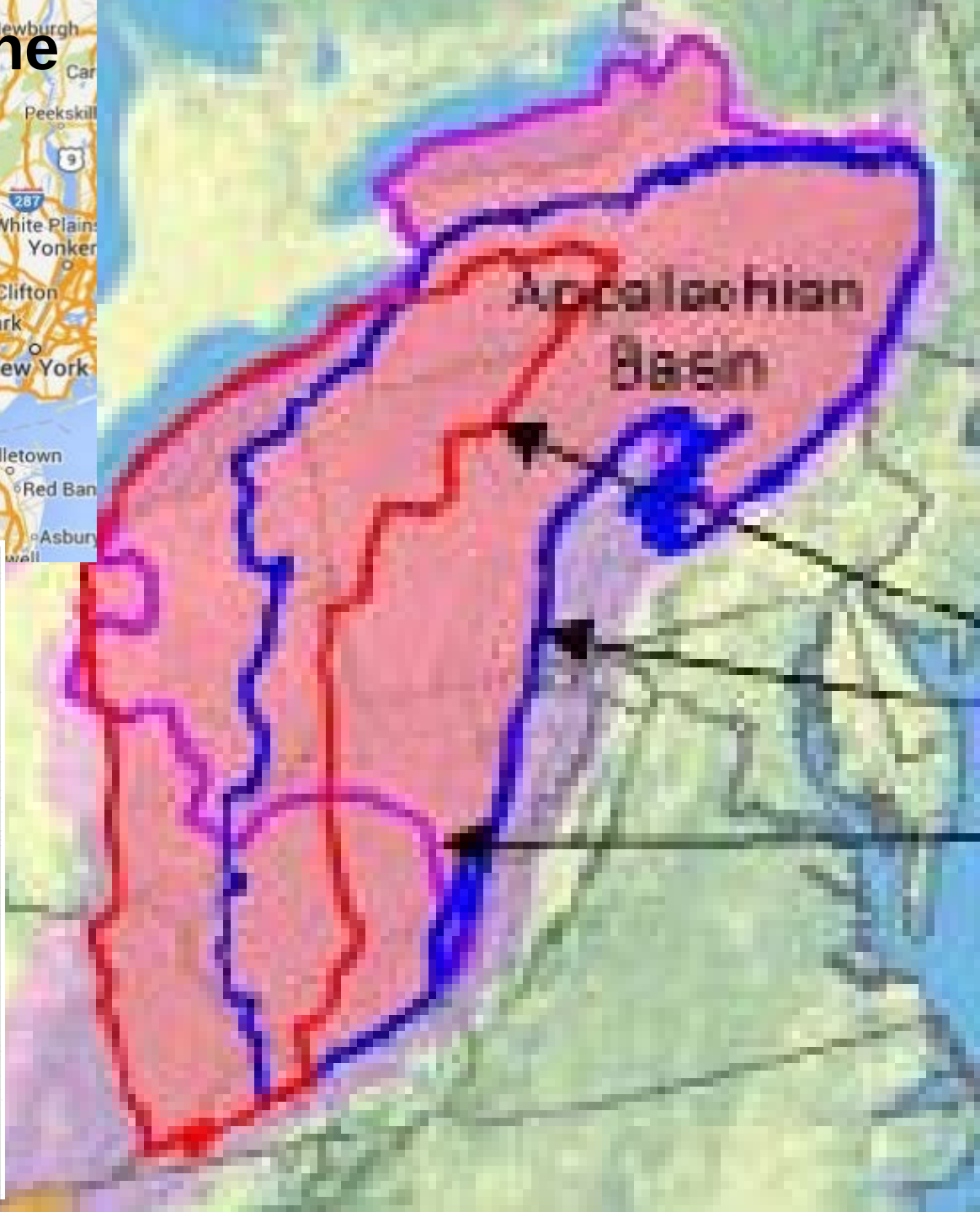
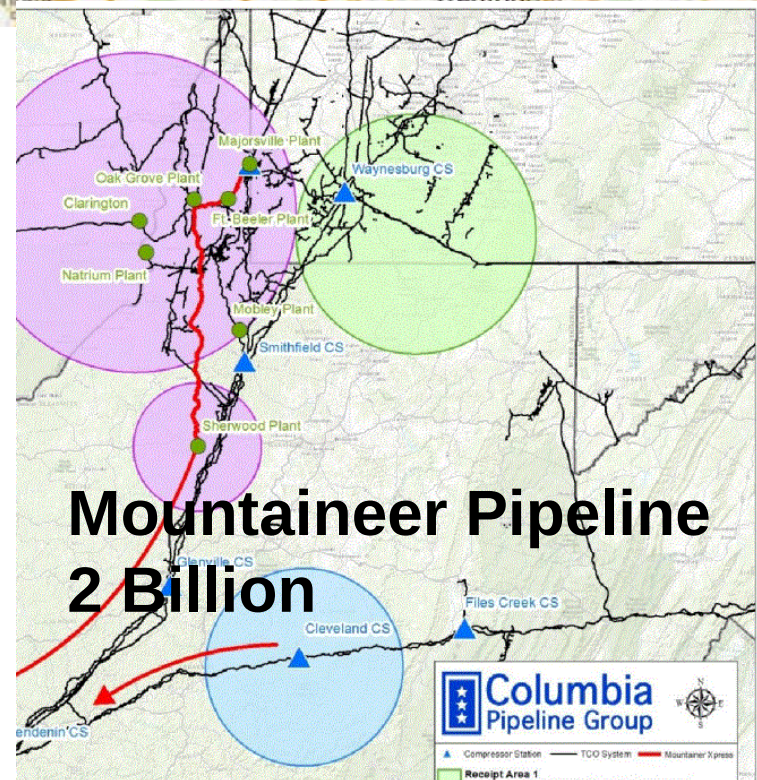
Pipeline Safety with Context Measures (1988-2011)

Index (1988 = 1)



PennEast Pipeline

1 Billion



Why is infrastructure investment so difficult?

(complex and complicated issue – but a few possibilities)

PORK v MUSCLE

What appears to be "pork or fat" from a national point of view can be "steak or muscle" from a local point of view.

INVESTMENT IN HUMAN CAPITAL AND INTERNET MORE ATTRACTIVE & w LOWER PERMITTING COST

"Sooner or later "all of those Dot coms have to take a class in logistics" (ie ship through FedEx). Jim Smith, Pres. of FedEx.

LACK OF POLITICAL WILL & INTEREST TO PAY FOR MAINTENANCE

"If the Spaniards and Australians buy our toll roads with their 50 year horizon pension funds, they can raise the tolls, install "EZpass" (fire toll takers) and "we" won't be accused of raising taxes or displacing workers"

ANY CONSTRUCTION NOW DISADVANTAGES A LARGE NUMBER OF PEOPLE BUT SMALL %

Impact is amplified by internet, increasing sensitivity to disruption, and regulatory considerations.

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Water Is the Next Oil

Water price policy and public perception are not aligned

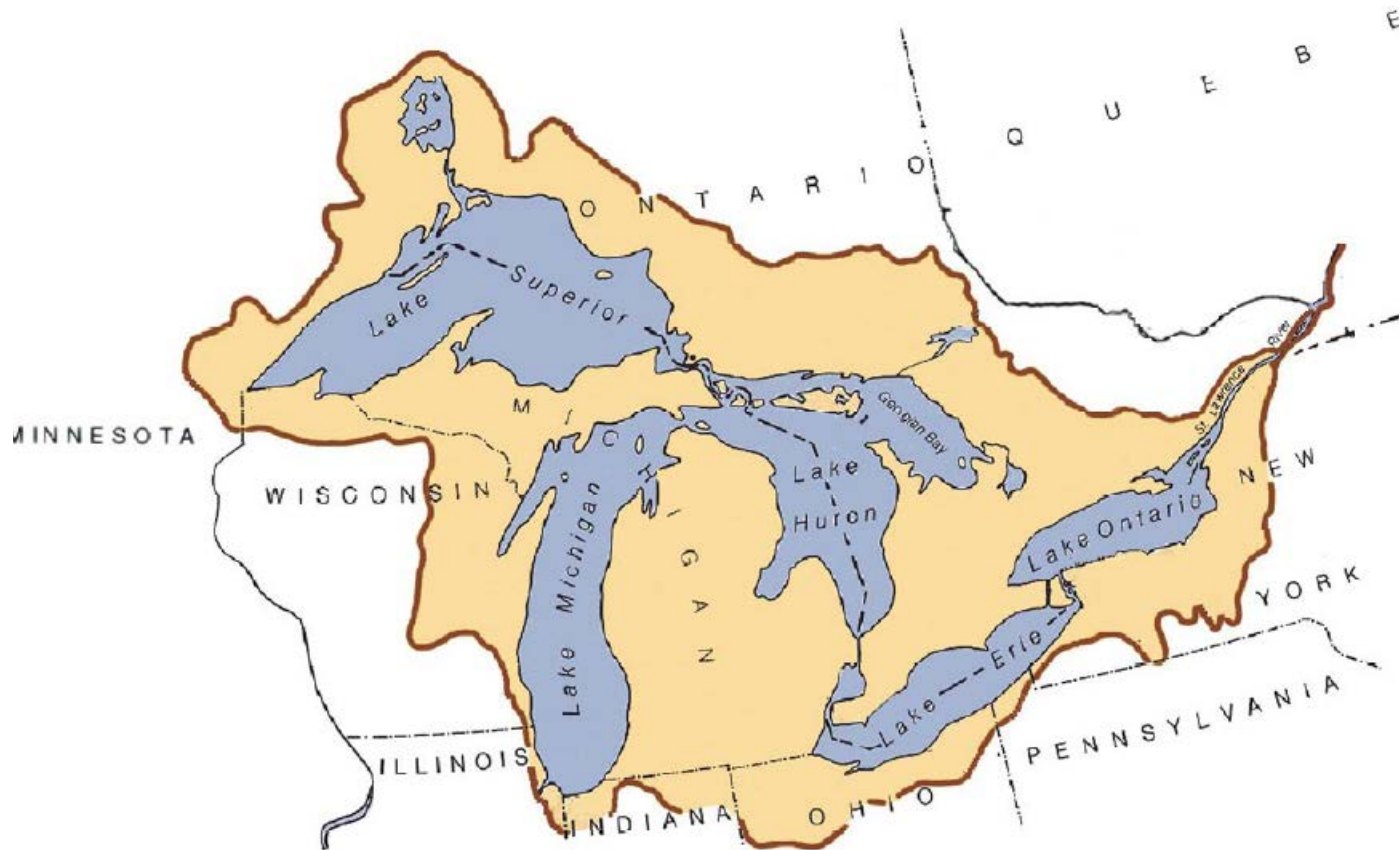
Price of Lake Michigan Water from my tap: \$ 0.002/ gal
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A recent survey of 14 countries indicates that average municipal water prices range from 66¢ per cubic meter (0.002\$/gal) in the United States up to \$2.25 in Denmark and Germany. Yet consumers rarely pay the actual cost of water. In fact, many governments practically (and sometimes literally) give water away for nothing.

"Earth Policy Institute 2007"

Some cities in CA have yet to finish installing water meters; Sacramento is the poster child.

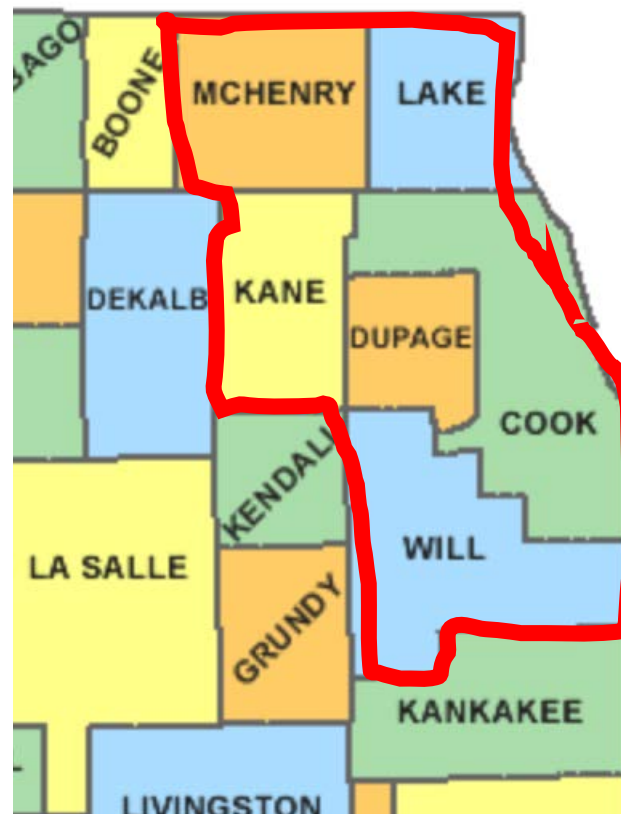
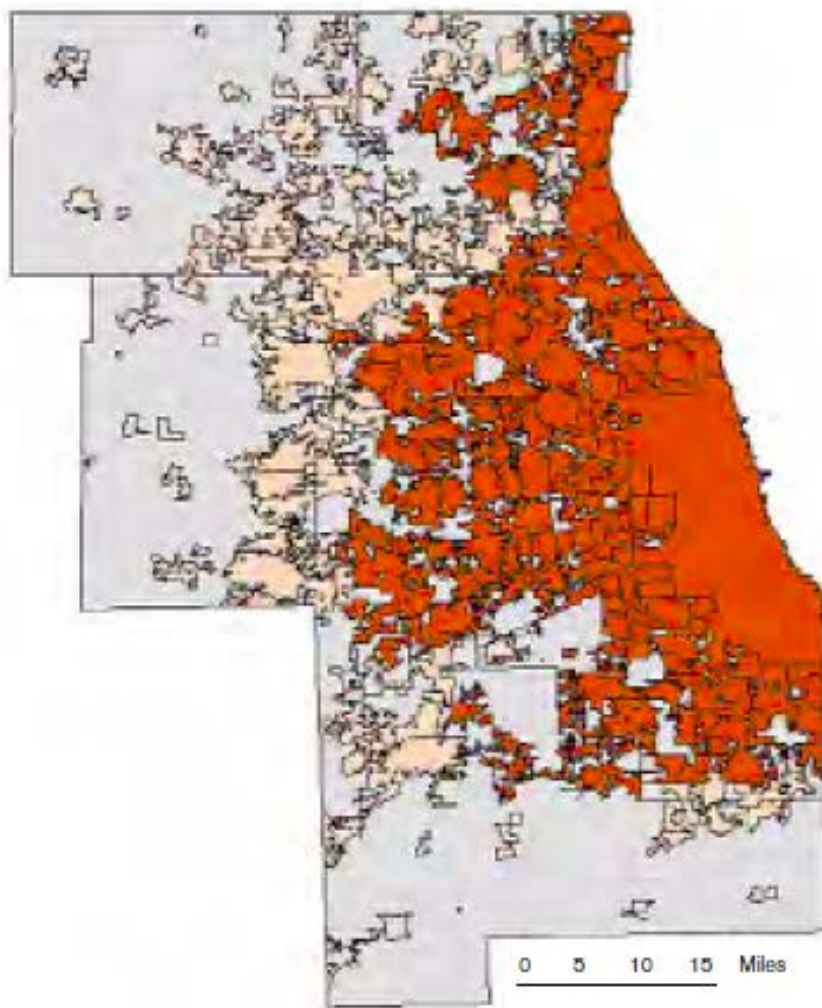
Water rights are complicated, complex, and vary dramatically from state to state.



1985 Great Lakes Charter

Prior notice of any diversion outside of basin that
Exceeds 5,000,000 gal/day average over 30/days
Gather data on diversions > 100,000 gal/day

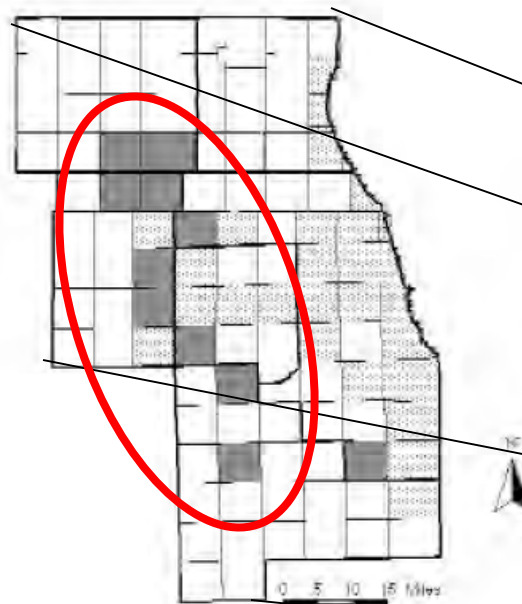
Figure 4:
Primary Drinking Water Sources in the
Northeastern Illinois Region



-  *Municipalities receiving Lake Michigan water*
-  *Municipalities served by other surface or groundwater sources*
-  *Unincorporated areas*

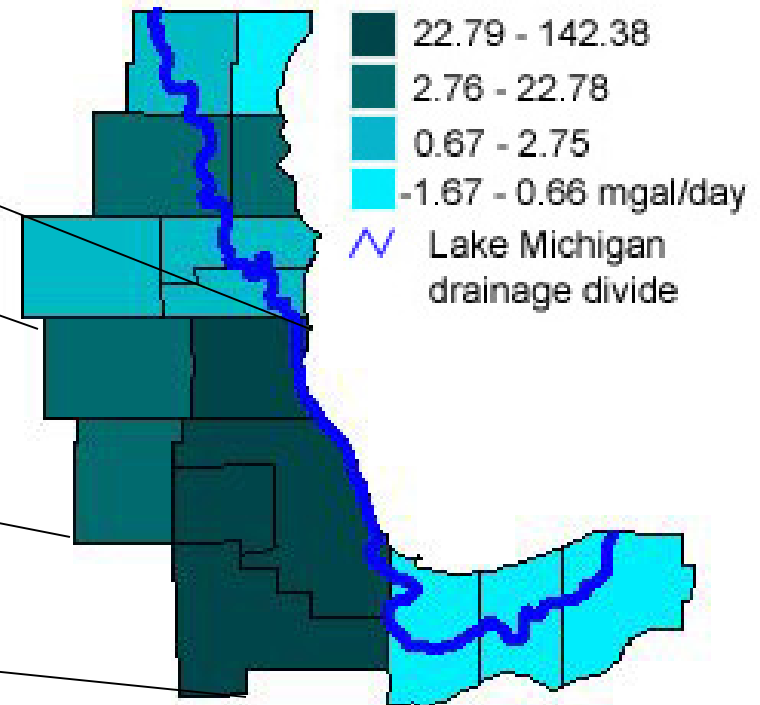
Figure 5:
Potential Water Shortages Predicted
in Northeastern Illinois in 2020

Shortages in collar counties



-  *Potential shortage*
-  *Adequate supply*
-  *Expected surplus*
-  *County boundaries*

Projected Growth in Consumption



Have not discussed maintenance

<http://www.nipc.org/environment/slmrWSC/Overview.htm>

<http://www.growingsensibly.org/cmapdfs/TroubledWaters.pdf>

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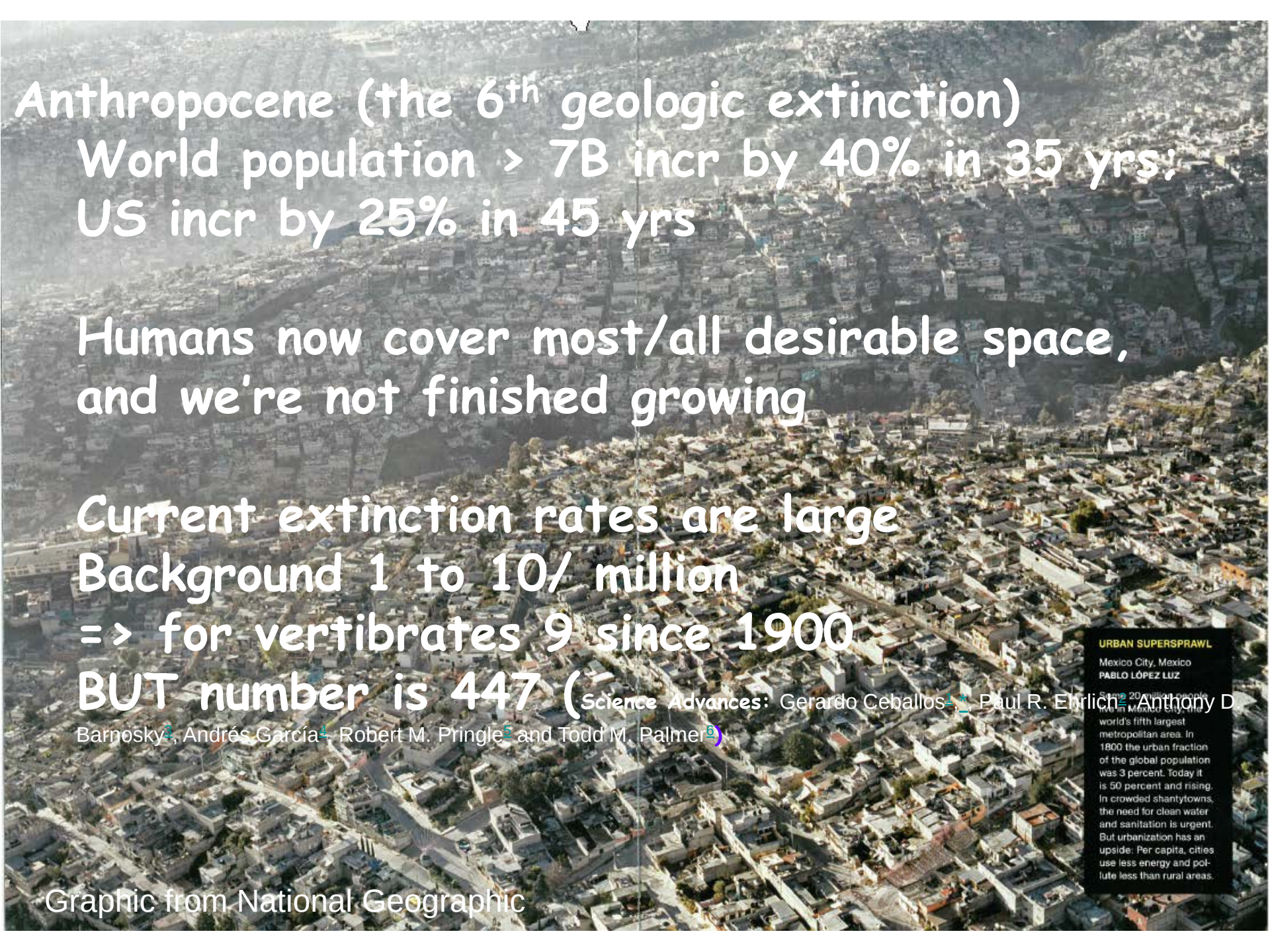
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Humans now cover most/all desirable space,
and we're not finished growing

Current extinction rates are large
Background 1 to 10/ million
=> for vertebrates 9 since 1900

BUT number is 447 (Science Advances: Gerardo Ceballos^{1,2}, Paul R. Ehrlich³, Anthony D. Barnosky², Andrés García⁴, Robert M. Pringle⁵ and Todd M. Palmer⁶)

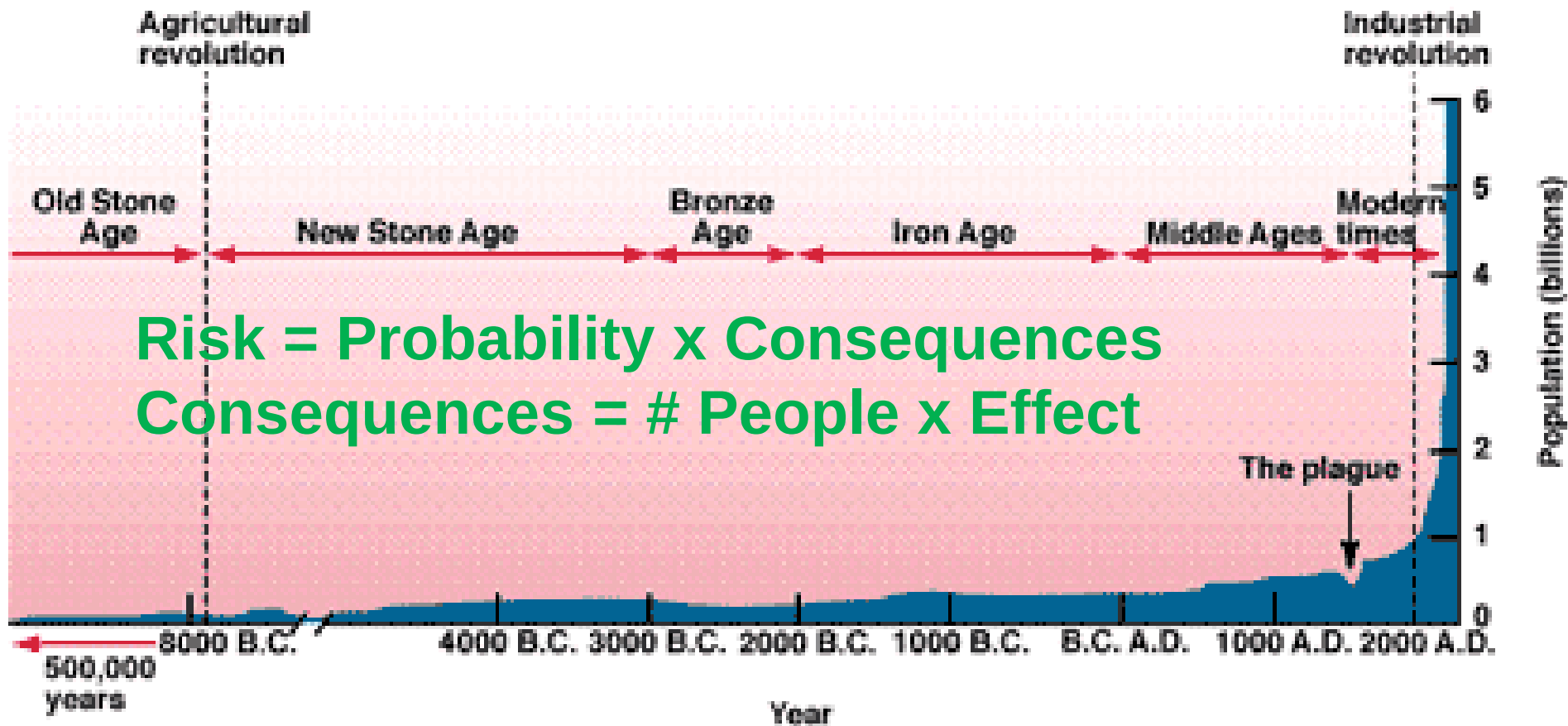
URBAN SUPERSPAWL

Mexico City, Mexico
PABLO LÓPEZ LUZ

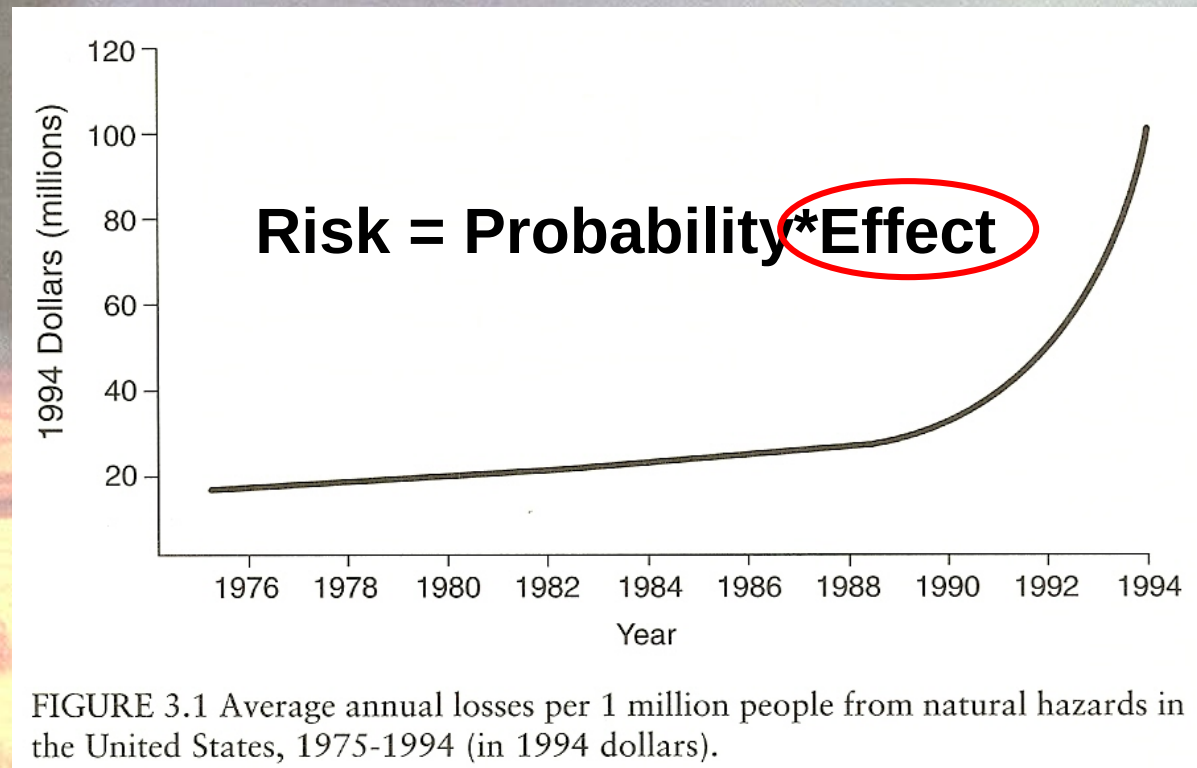
Some 20 million people live in Mexico City, the world's fifth largest metropolitan area. In 1800 the urban fraction of the global population was 3 percent. Today it is 50 percent and rising. In crowded shantytowns, the need for clean water and sanitation is urgent. But urbanization has an upside: Per capita, cities use less energy and pollute less than rural areas.

Graphic from National Geographic

Human population levels through history.

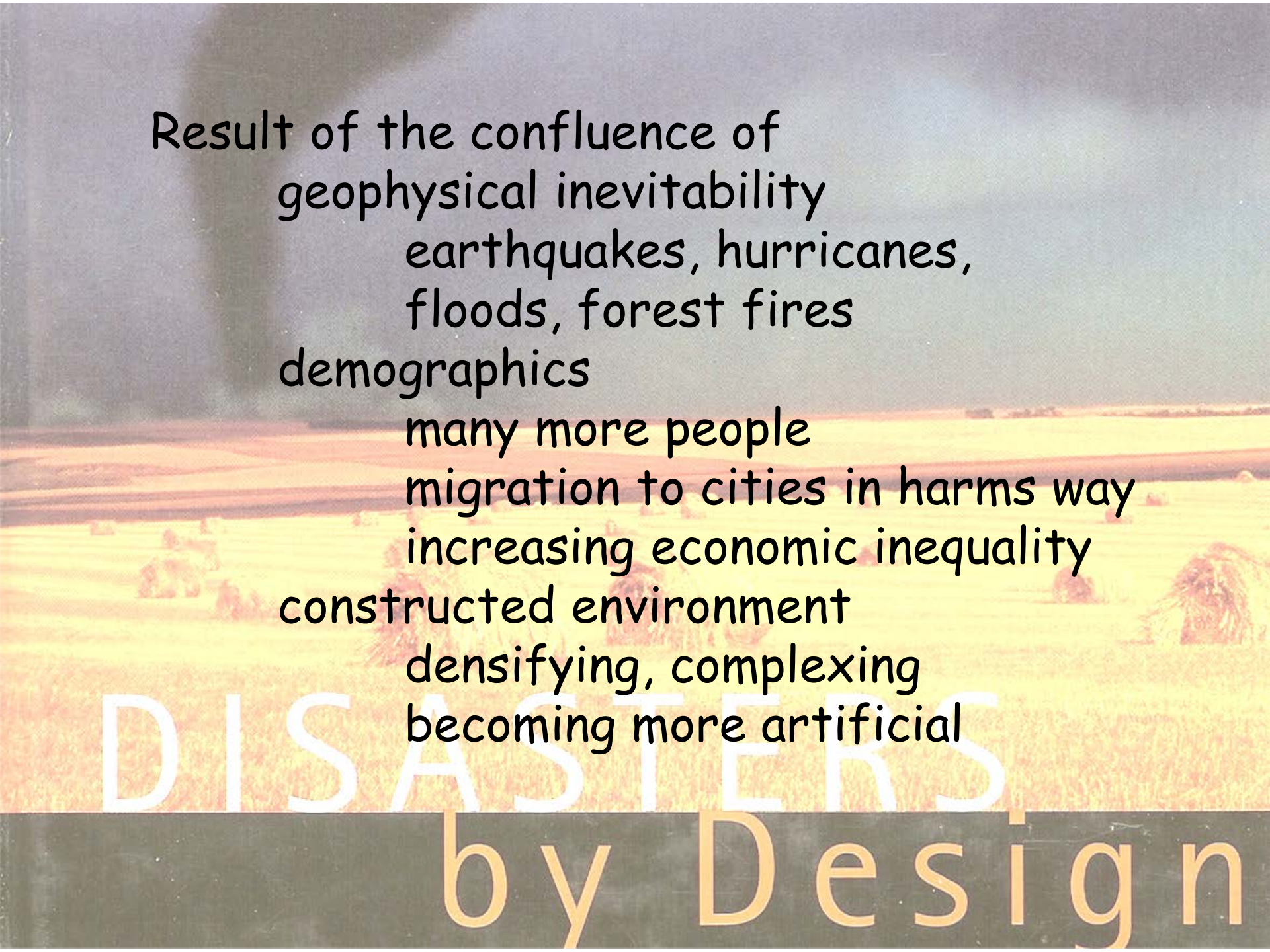


Katrina is a Mega-Example of A Growing Trend



Graphic from Disasters by Design, Dennis Meliti (1999)

DISASTERS
by Design



Result of the confluence of
geophysical inevitability
earthquakes, hurricanes,
floods, forest fires

demographics

many more people

migration to cities in harms way

increasing economic inequality

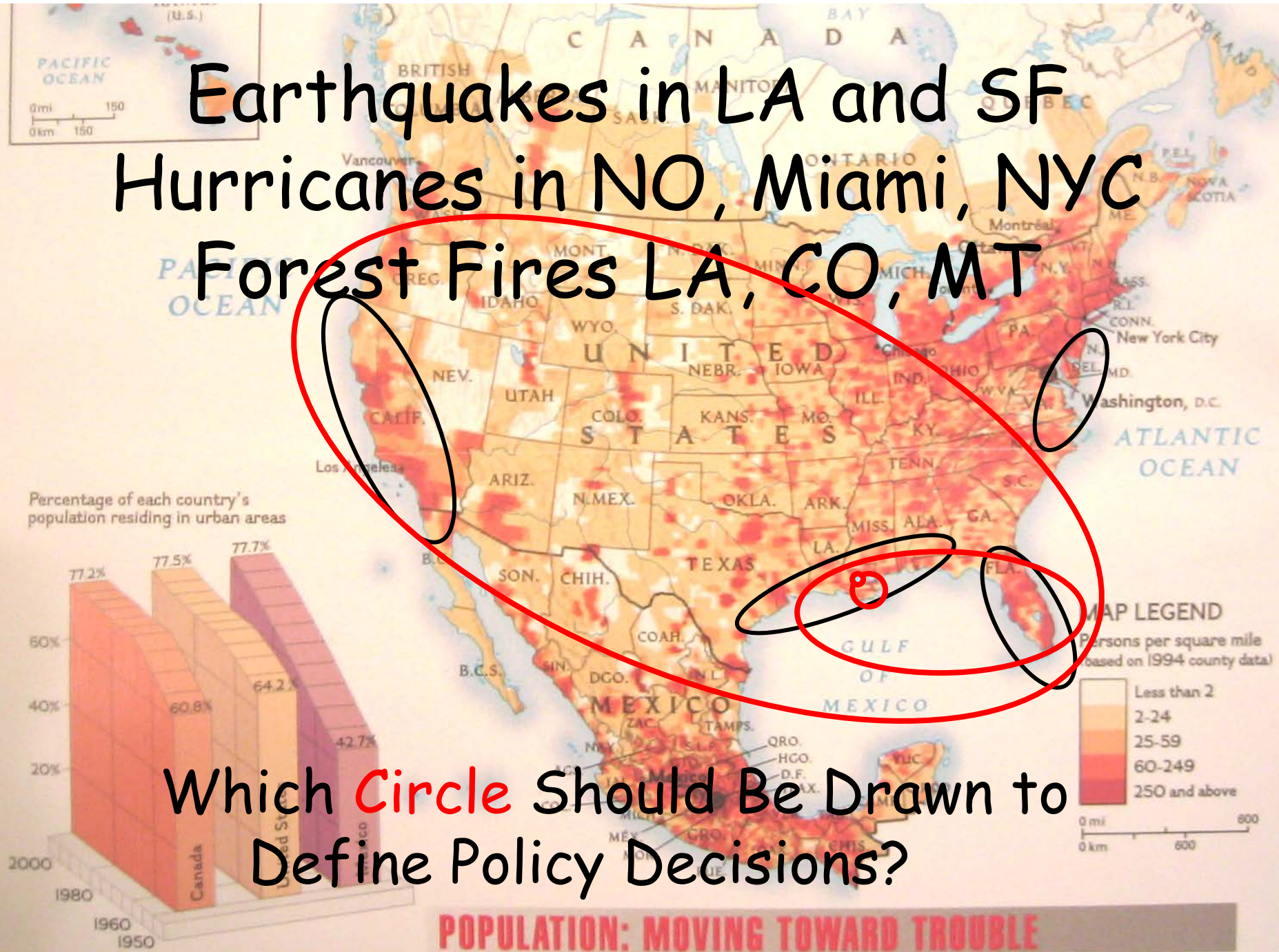
constructed environment

densifying, complexing

becoming more artificial

DISASTERS by Design

Earthquakes in LA and SF
Hurricanes in NO, Miami, NYC
Forest Fires LA, CO, MT



Oil transformed Dubai in the 1970s. The city now boasts the world's tallest building, giant malls, and some two million residents, who depend on desalinated seawater and air-conditioning—and thus on cheap energy—to live in the Arabian desert.

JENS NEUMANN / EDSAR ROTHMANN

Graphic from National Geographic

ENTER THE ANTHROPOCENE AGE OF MAN

It's a new name for a new geologic epoch—one defined by our own massive impact on the planet. That mark will endure in the geologic record long after our cities have crumbled.

World population > 7B incr by 40% in 35 yrs; US incr by 25% in 45 yrs

Are all the reasonably sustainable habitable locations fully occupied?
Could cars be built in Alabama without air conditioning?

Any- even well conceived -- construction will disadvantage a small %
BUT large number of people.

To maintain current life styles, in the next 45 years the United States must INCREASE its core infrastructure by 25%, maintain/replace what took 175 years to build, WHILE employing it full time.

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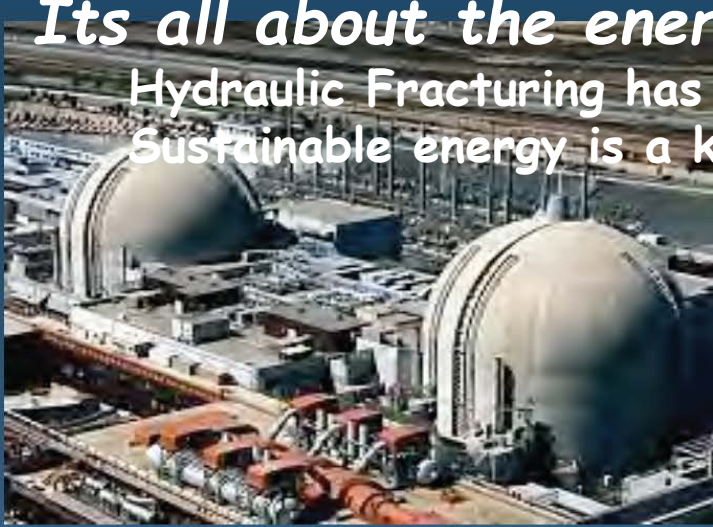
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Powering the Planet

Nathan S. Lewis, California Institute of Technology

<https://www.youtube.com/watch?v=EUKqx2uk-Gs>



Perspective

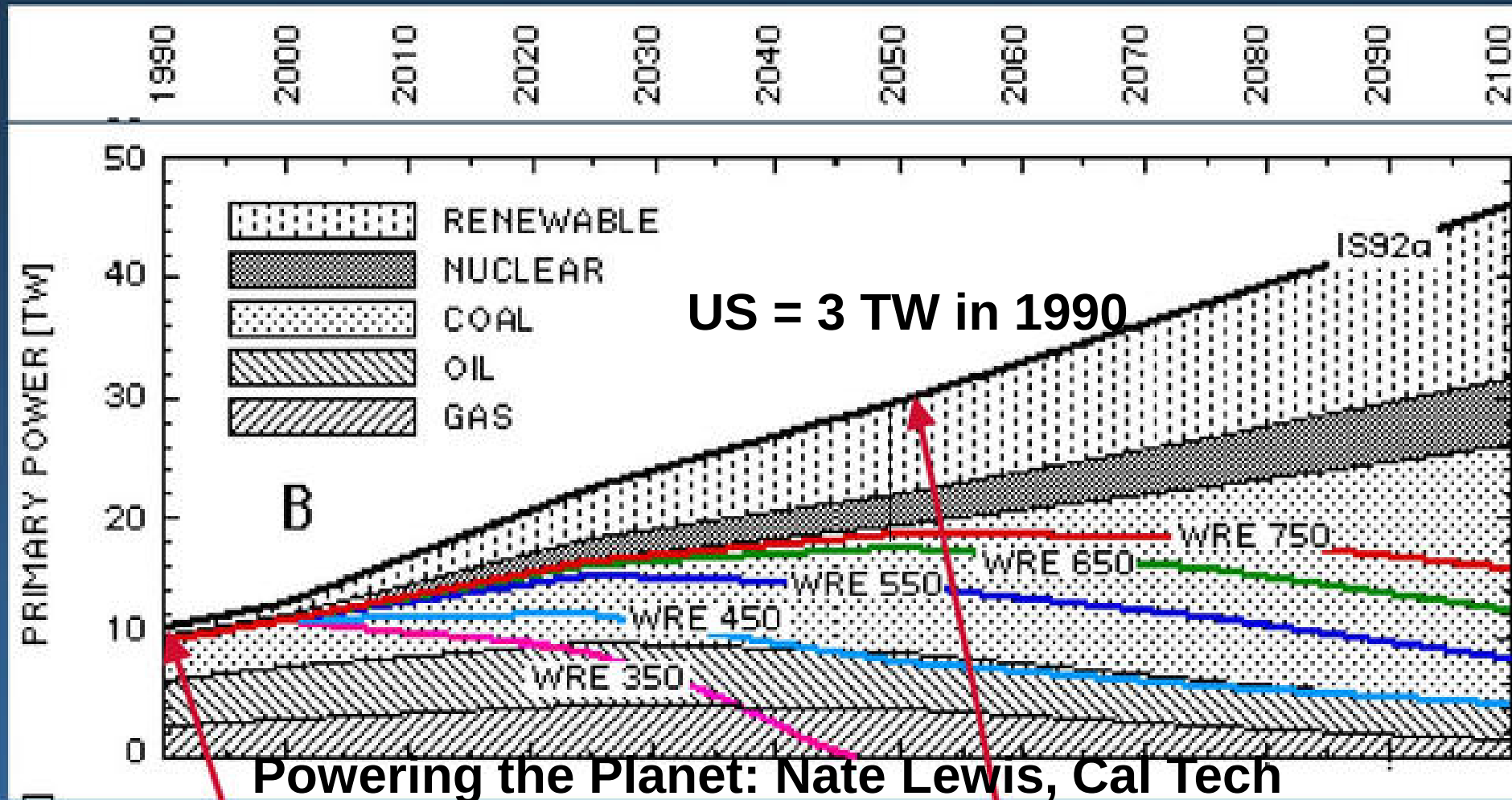
“Energy is the single most important challenge facing humanity today.”
Nobel Laureate Rick Smalley, April 2004, Testimony to U.S. Senate

“..energy is the single most important scientific and technological challenge facing humanity in the 21st century..”: Chemical and Engineering News, August 22, 2005.

“What should be the centerpiece of a policy of American renewal is blindingly obvious: making a quest for energy independence the moon shot of our generation“, Thomas L. Friedman, New York Times, Sept. 23, 2005.

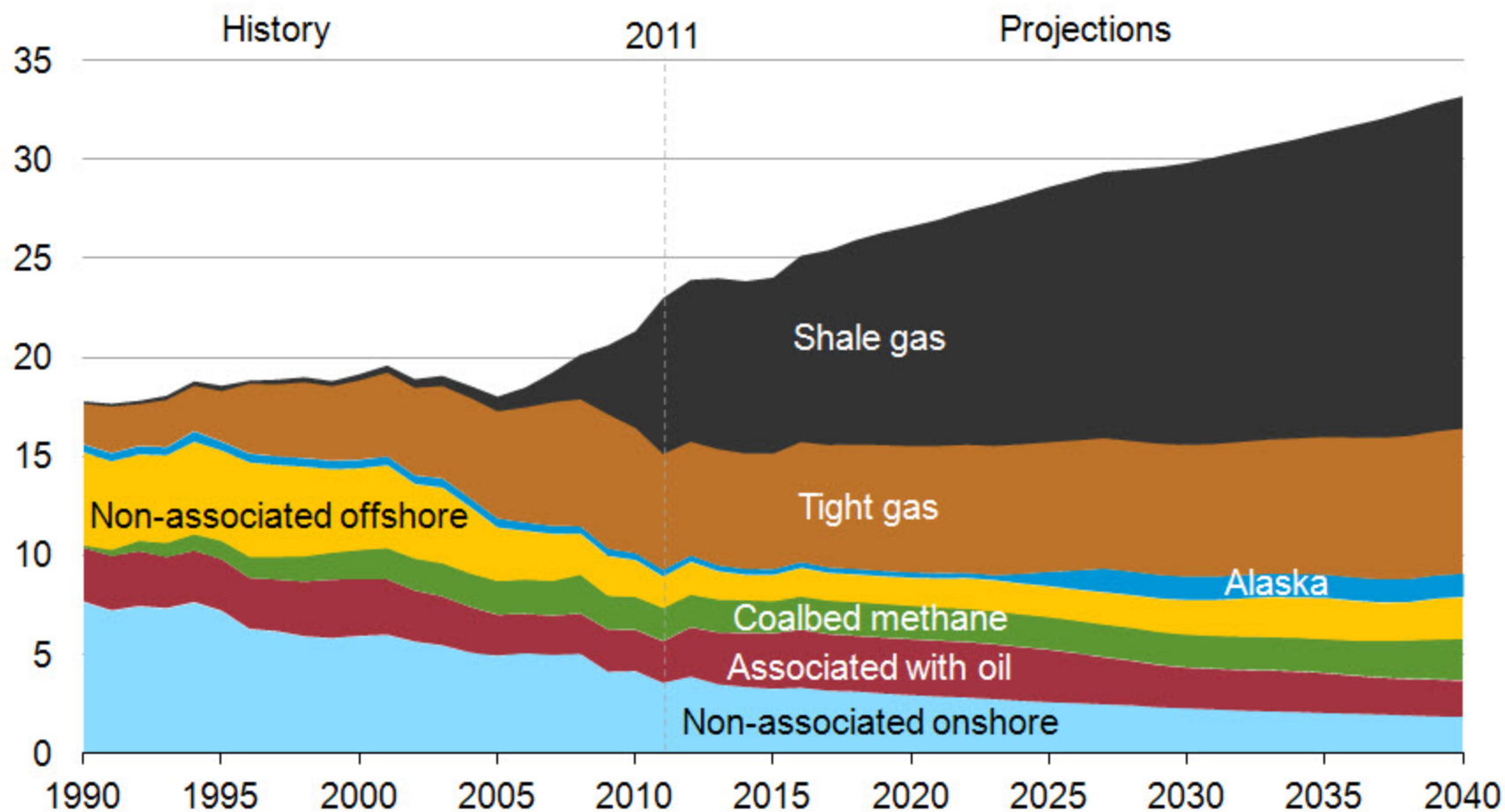
“The time for progress is now. .. it is our responsibility to *lead* in this mission”, Susan Hockfield, on energy, in her MIT Inauguration speech.

Total Primary Power vs Year



1990: 12 TW 2050: 28 TW

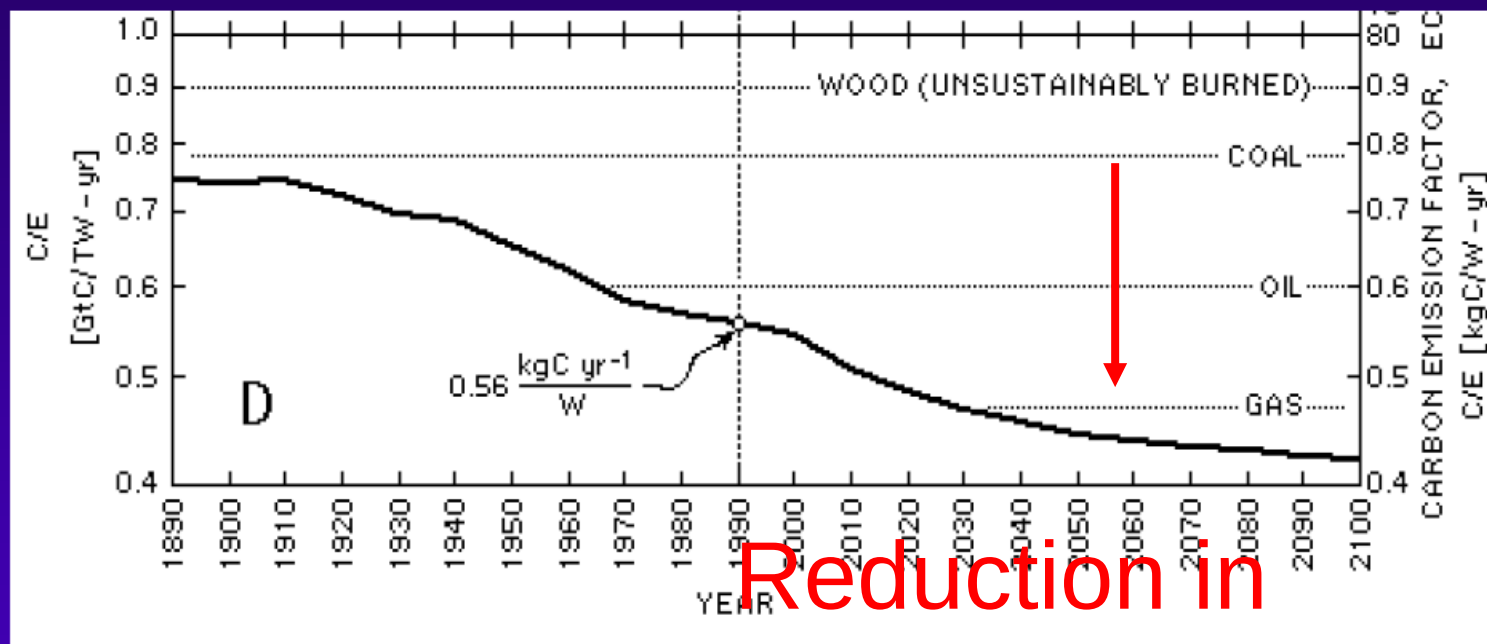
U.S. dry natural gas production trillion cubic feet



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

Domestic production of shale gas is projected to double between 2011 and 2040

Carbon Intensity of Energy Mix



Reduction in
CO₂ emissions by
shifting to Nat Gas

M. I. Hoffert et. al., Nature 1998, 395, 881

Possible Approach to Hazards/Infrastructure

Adopt systems approach:

facilities must leverage & support complimentary systems

Accept responsibility

humans - and nature - over stress infrastructure

Anticipate ambiguity and change

design for modification and ease of maintenance

Reject short-term thinking

how will today's facility serve future generations

Account for social forces

facilities must reflect a shared social value & aspiration

Develop SUSTAINABLY

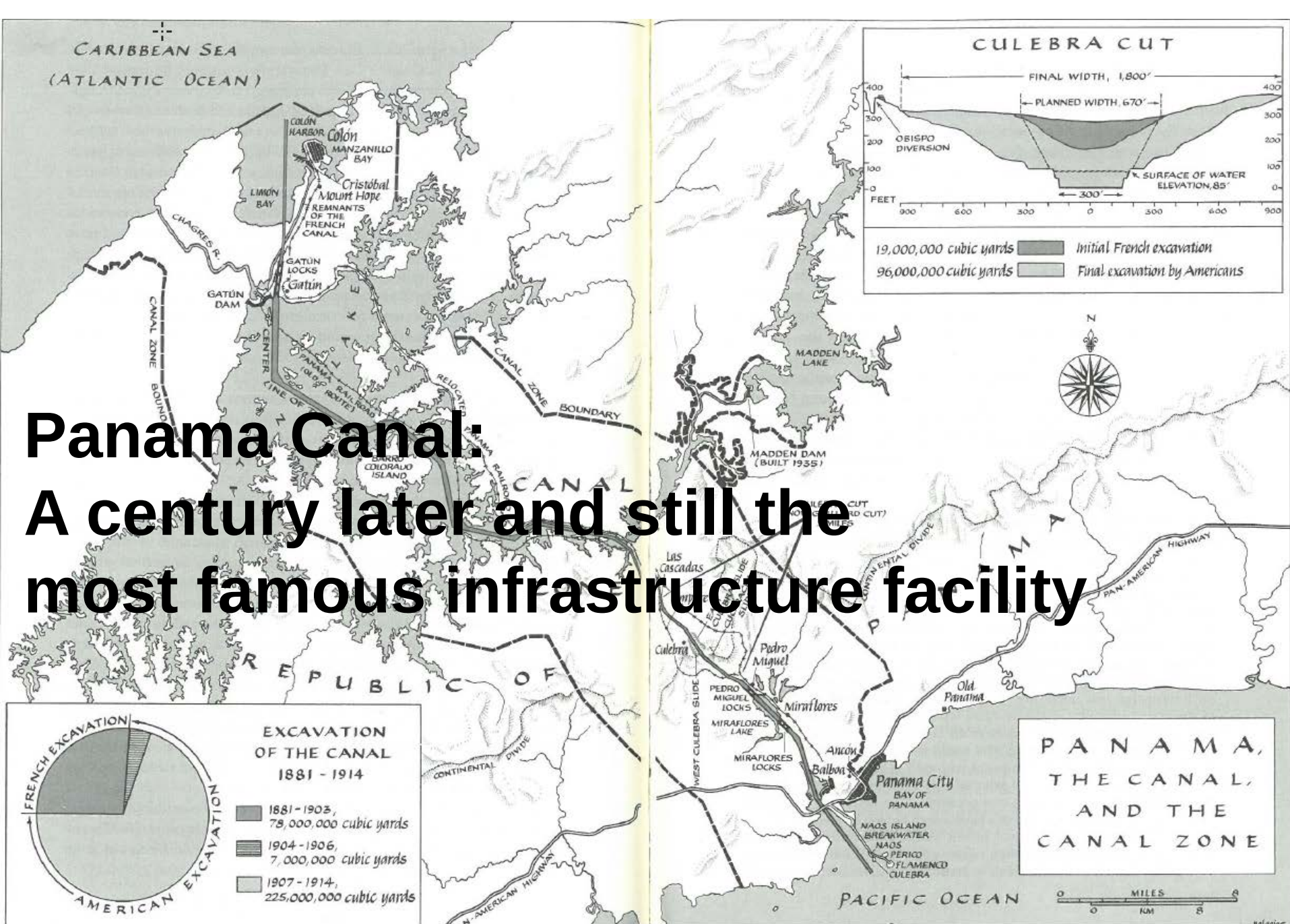
facilities should strengthen resiliency

DISASTERS
by Design

ASCE'S SOLUTIONS FOR RAISING THE GRADE

- promote sustainability and resilience;
- develop federal, regional,& state infrastructure plans;
- address life cycle costs and ongoing maintenance;
- increase federal leadership in infrastructure;
- increase and improve infrastructure investment from all stakeholders.





How much would be spent today to match the Construction of the Panama Canal

Country	France	US
1) Canal Const. (millions)	250	350
per year	50	35
2) Population (millions)		
1890	40 ~ 10 families	63
	800,000 investors ~ 8% of families in France lost money	
1904	40	82
3) GDP (~billions)		
1890	95	214
1904	116	363
2016		18,000
4) US Federal Budget (~billions)		
1904 (~ 2% GDP)		7
2016 (~18% GDP)		3,240
5) Canal Expenditure (% yearly Fed Budget)		$35/7,000 = \frac{1}{2}\%/yr$

$\frac{1}{2}\%$ of today's yearly budget (.005x3000)

15 billion/yr for 10 yrs

Defense Dept Budget this year ~

54 billion