Water Resource Economics and Finance

(Emphasis on Finance and Risk Management)

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Special thanks to those that made it all possible

- Rachel Baum (Ph.D.), UNC
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NSF Effort to Explore Opportunities and Challenges

Environmental Science & Technology

Published: July 08, 2011

6235 dx.doi.org/10.1021/es202128s | *Environ. Sci. Technol.* 2011, 45, 6235–6236

Increasing the Role of Economics in Environmental Research (or Moving beyond the Mindset That Economics = Accounting)

Gregory W. Characklis,[*,†] Peter Adriaens,[‡] John B. Braden,[§] Jennifer Davis,[∥] Bruce Hamilton,[⊥] Joseph B. Hughes,[¶] Mitchell J. Small,[#] and John Wolfe[%]

- Many opportunities for interdisciplinary environmental research involving economists, scientists and engineers, but they have been poorly exploited
- Increased potential to influence environmental policymaking and make the import of environmental engineering research more apparent
- A primary obstacle is that environmental scientists and engineers have little understanding of what the field of economics has to offer

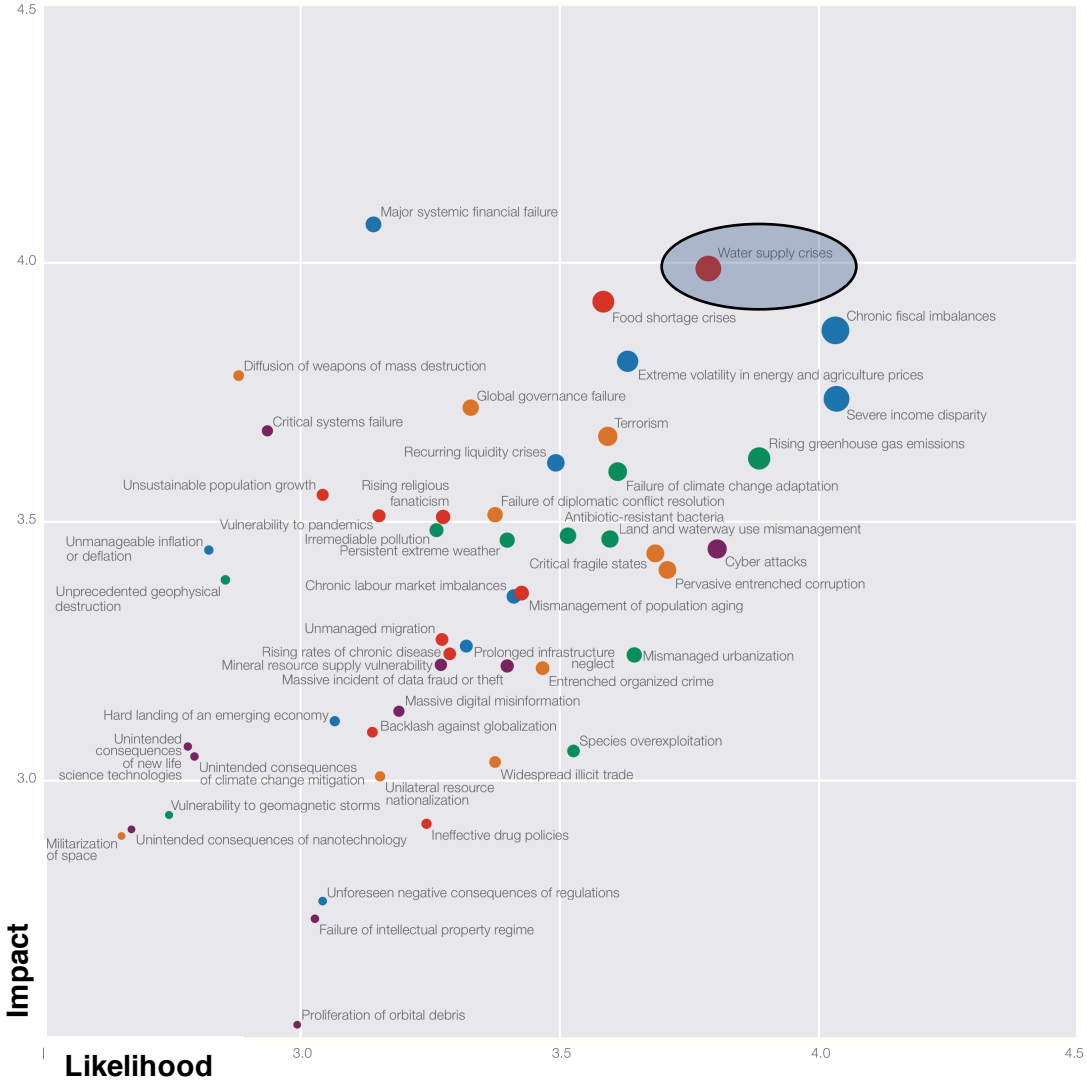
How about Finance?

- Finance is the study of the "management of funds"*
- One of the primary purposes is to examine the ways in which something can be paid for:
  - Cash upfront (almost nobody does this)
  - Payments over time (e.g., home mortgage)
  - Leasing as necessary (e.g., AirBnB, Uber)
- Finance also involves developing strategies for "managing risk" by reducing large fluctuations in costs and/or revenues
  - Insurance (i.e. risk pooling)
  - Hedging (e.g., risk shifting)

* Miriam-Webster (3) 2016

Ranking of Global Risks

(as ranked by participants at the World Economic Forum in Davos)



Source: World Economic Forum

Source: Global Risks 2012, World Economic Forum

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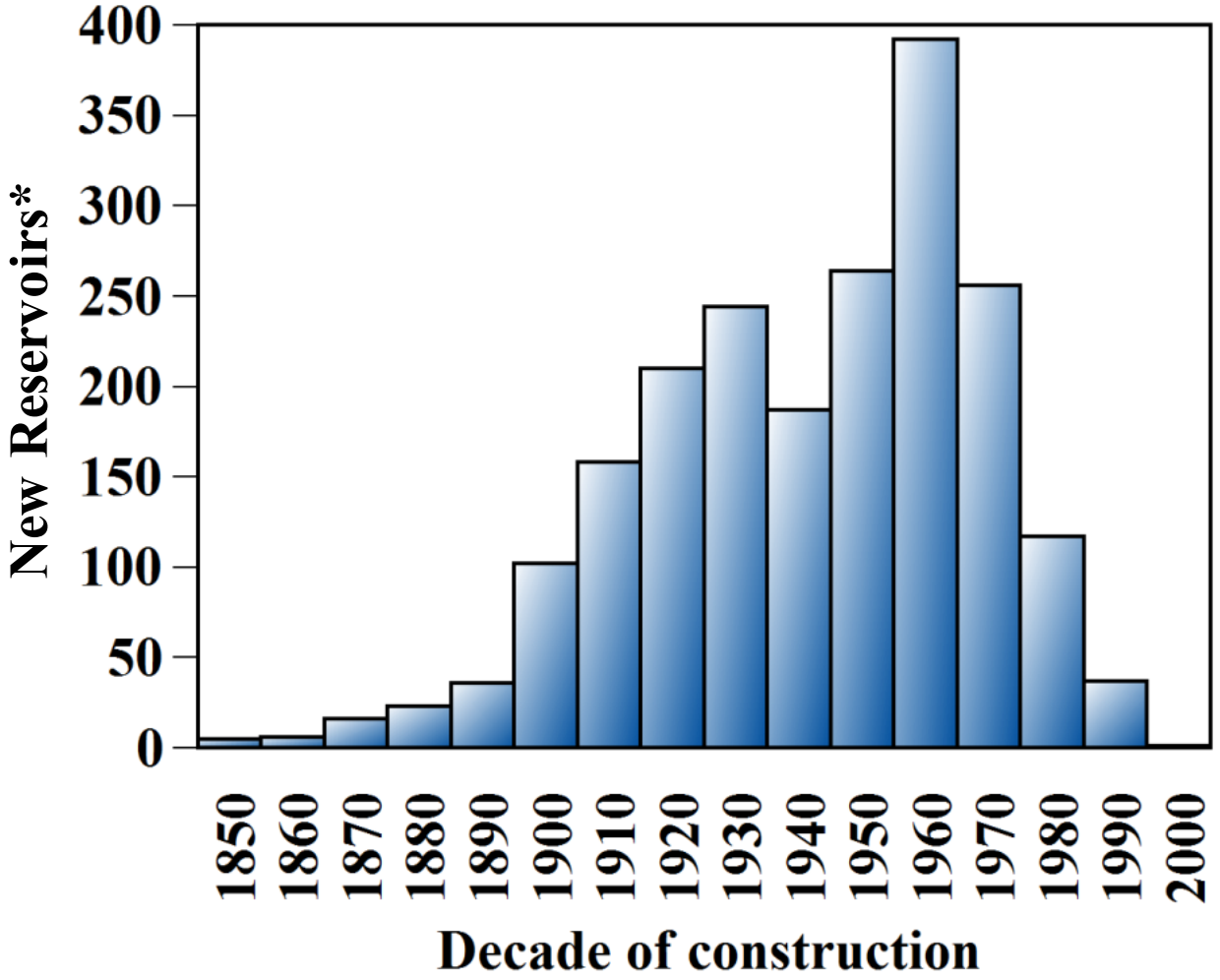
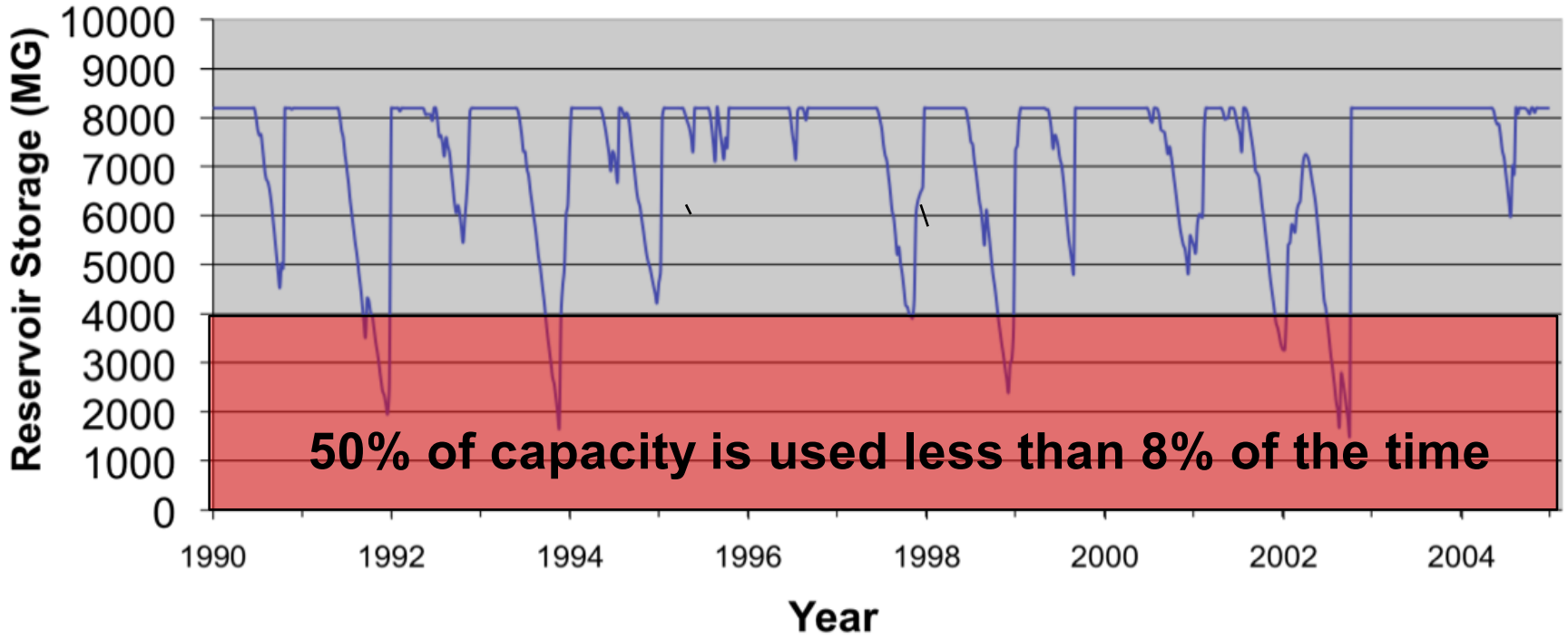
Pace of US reservoir construction has declined



* Capacity > 0.1 km^3

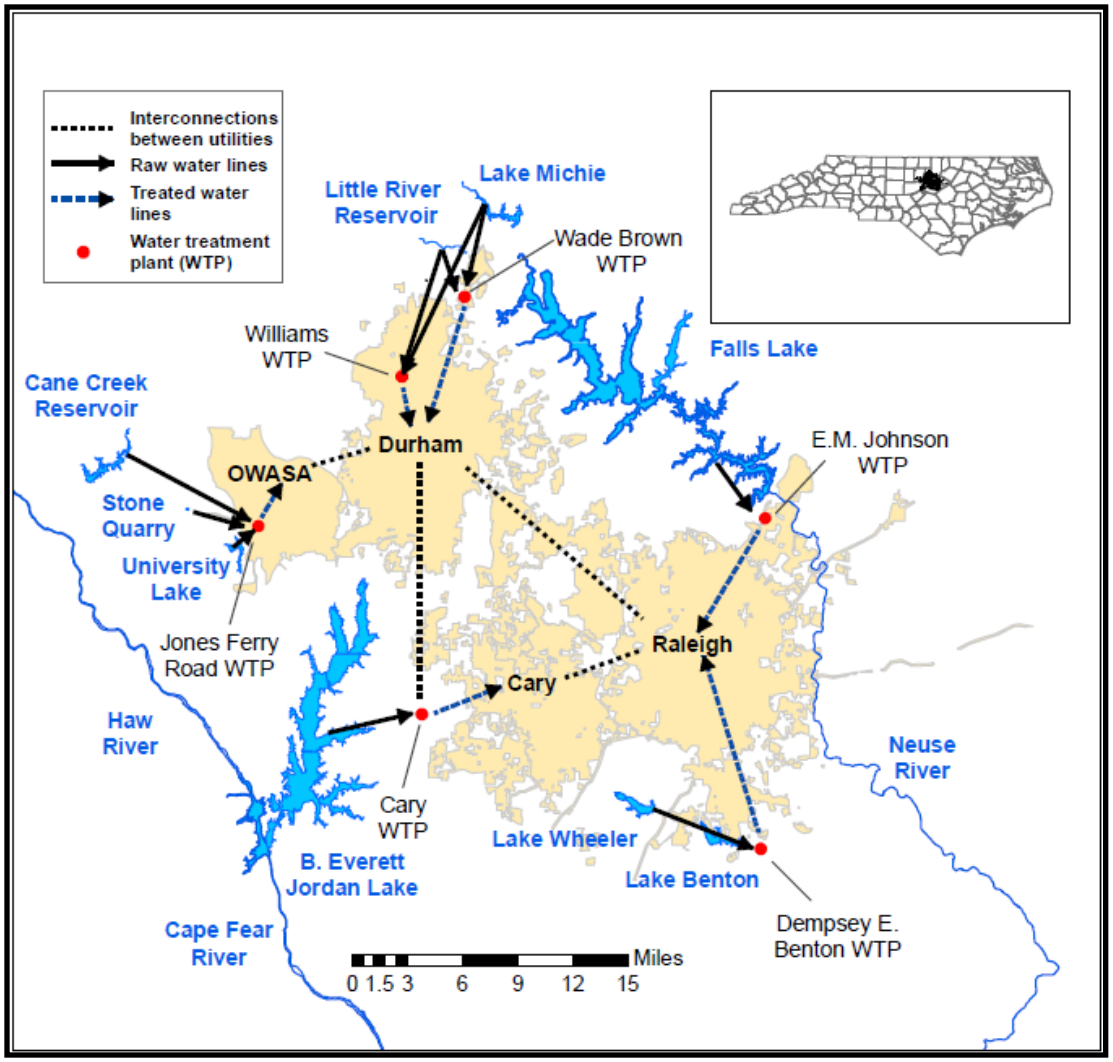
Source: GRanD database, at http://atlas.gwsp.org/

Surplus capacity has traditionally ensured reliability



- Maintaining rarely used capacity is costly and environmentally burdensome
- Both capacity requirements and long-term costs can be reduced by
  - Conservation measures (reduces revenues)
  - Acquiring additional water (increases costs)

Research Triangle of North Carolina, USA



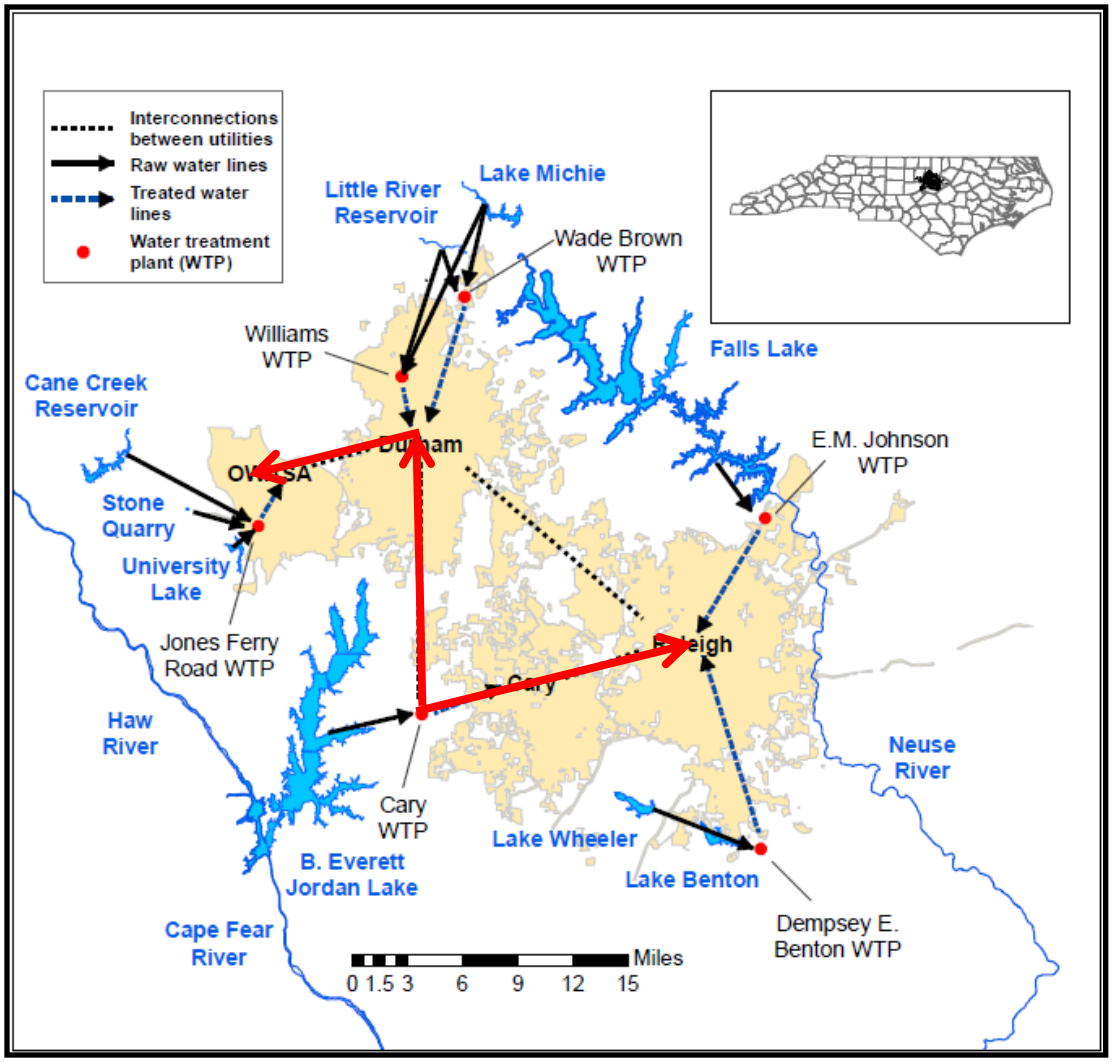
Rapidly growing population of ~1.5M

4 major utilities, each independently run

- **9 reservoirs**
- **5 treatment plants**
- **interconnections**

Serious droughts in 2002 and 2008

Research Triangle of North Carolina, USA



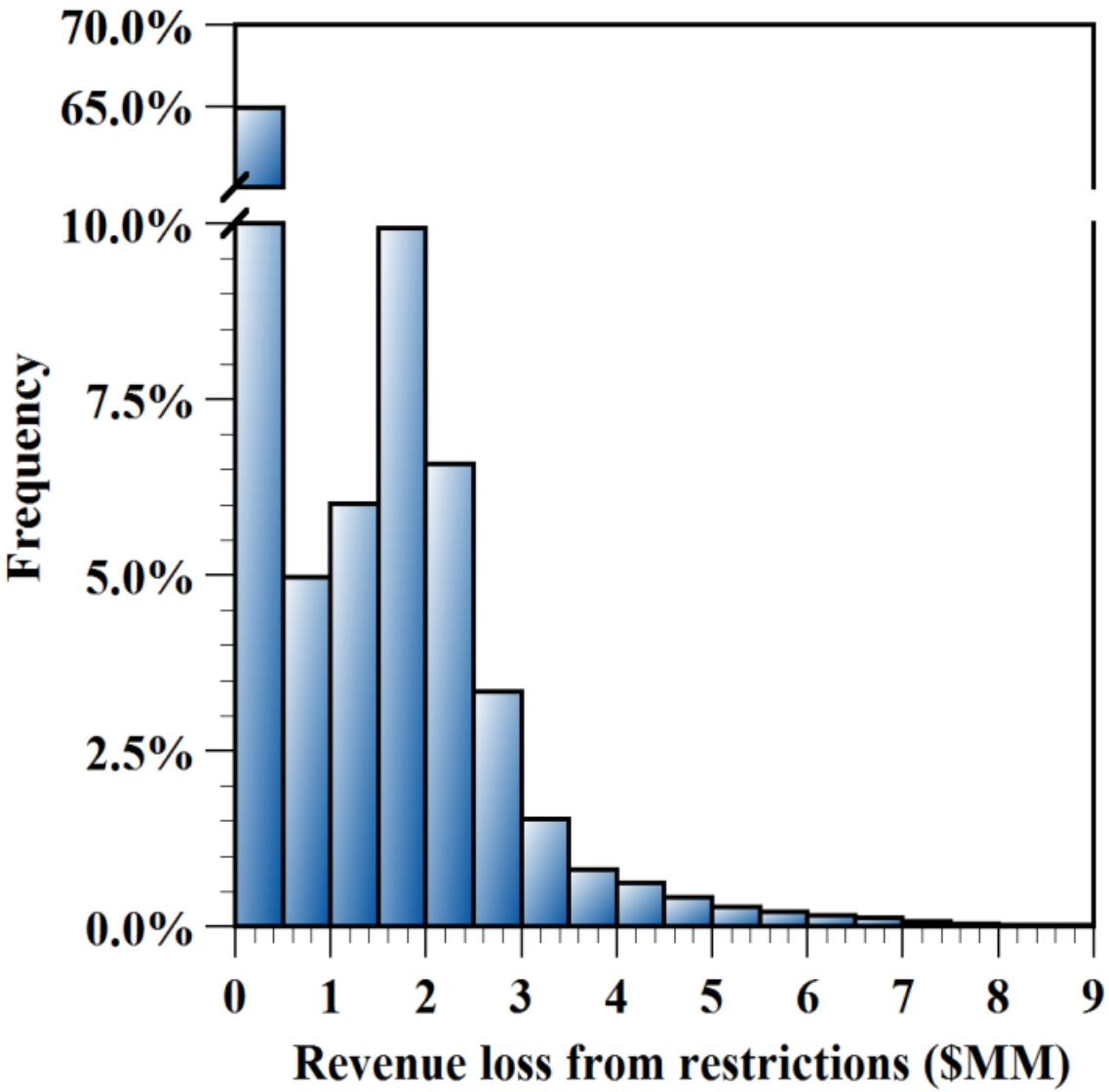
Utilities have 3 options to deal with growing demands:

- **New sources**
- **Conservation**
- **Transfers**

But, there are many financial concerns

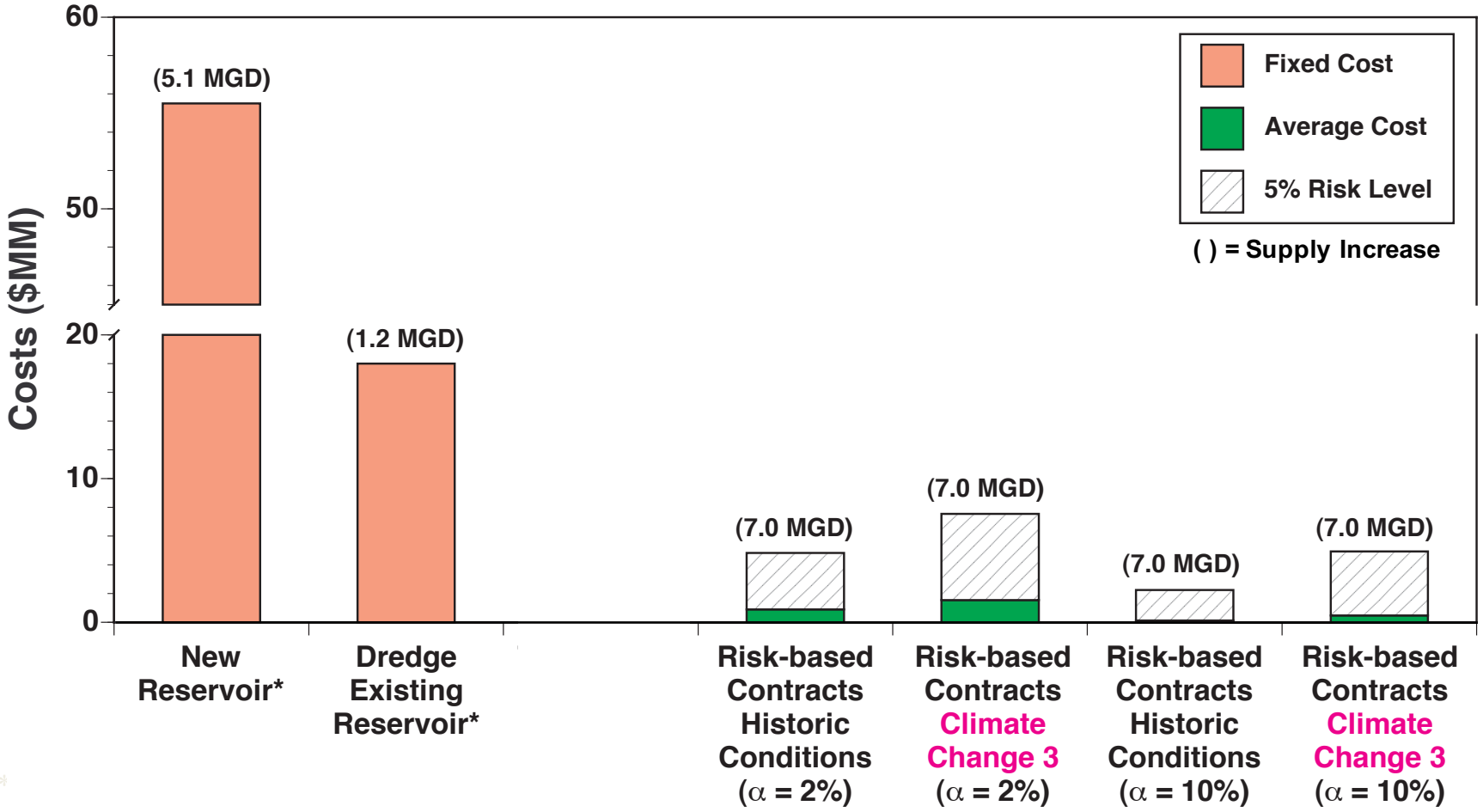
Unless managed, these concerns will limit implementation

Conservation Reduces Revenues



Comparison of Transfers vs. New Supplies

(Costs for OWASA 2010-2025)



- Risk-based contracts are substantially less expensive than infrastructure
- Transfers lower average costs, but cost variability remains a challenge

Caldwell, C. and G. W. Characklis (2014). "Impact of Contract Structure and Risk Aversion on Inter-utility Water Transfer Agreements," *Journal of Water Resources Planning and Management*, 140(1), pp. 100-111.

Cost/Revenue swings can affect utility credit ratings

'*We have observed that one of the most common … reasons for a utility to miss its financial targets is weather*'

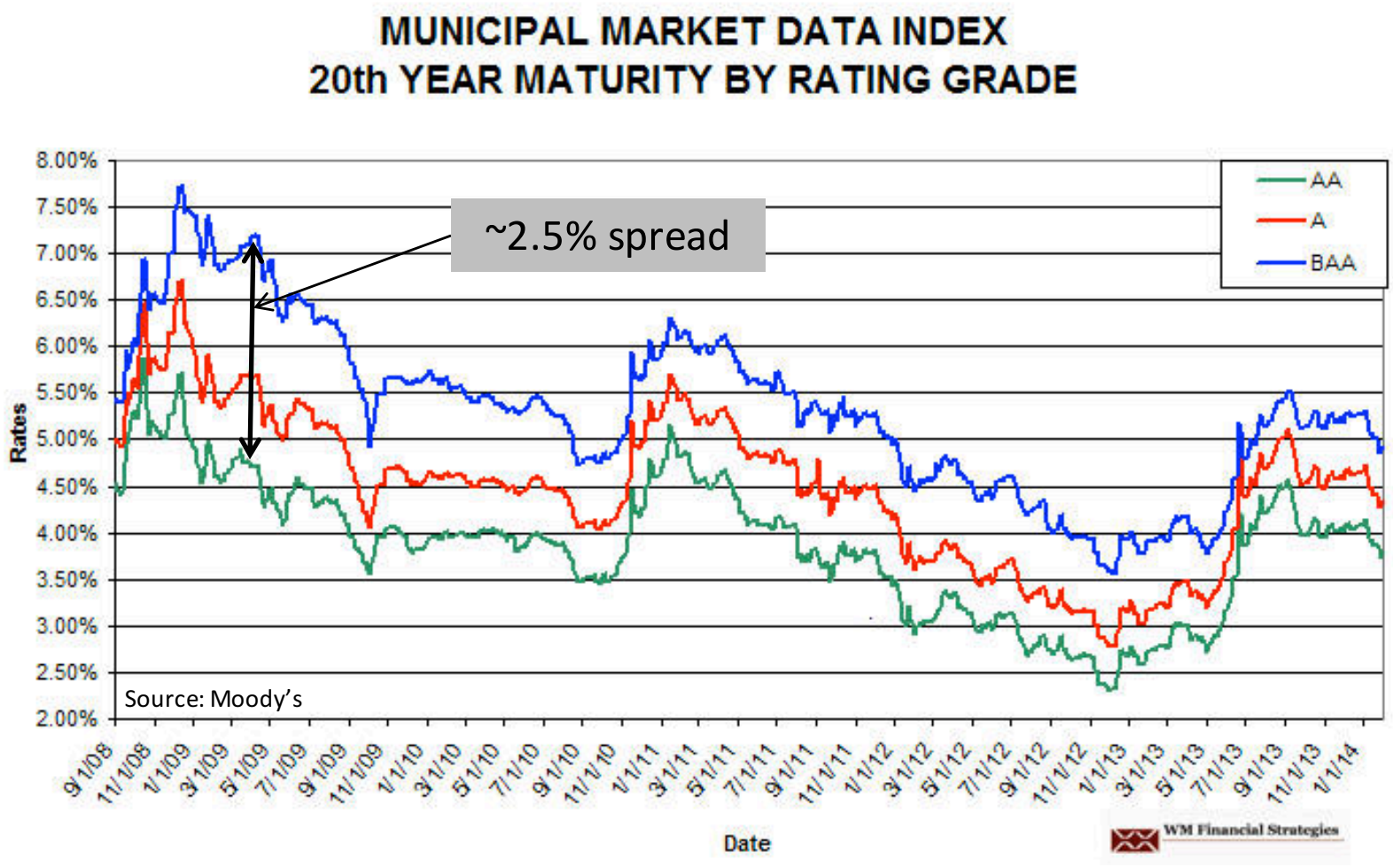
- 2012 Standard & Poors

[*Commenting on new evaluation criteria related to hydrologic variability*]:

'We estimate that about 25% of total ratings [of water utilities] will change as a result of these criteria'

- 2016 Standard & Poors

Water Business is capital intensive (interest rates matter … a lot)



- Debt service payments often make up 25-50% of a utility's operating costs
- A significant rating downgrade can increase utility costs significantly

Utility attitudes toward financial uncertainty

Expected rate increase: 20%

Survey of Utility Personnel

(Sample question) Would you prefer a water supply option* with:

(A) costs that will raise rates 30% in all years

(B) costs that will raise rates 40% in 50% of years and 0% otherwise

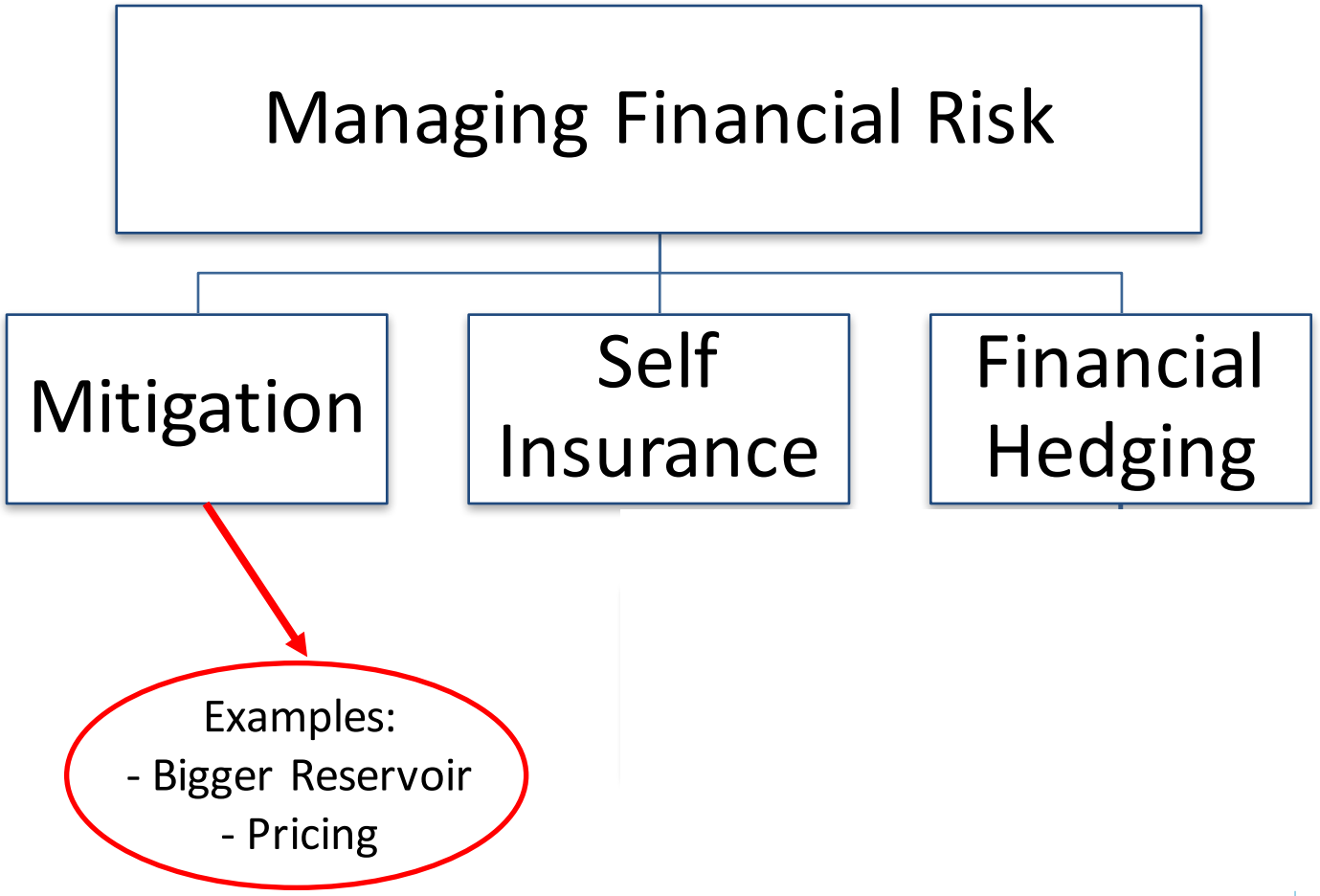
*** Similar with respect to quality, reliability, etc.**

- Utility personnel are highly risk averse, and this impacts their decisions
- Transfers and Conservation options will be more fully integrated if financial risk can be mitigated

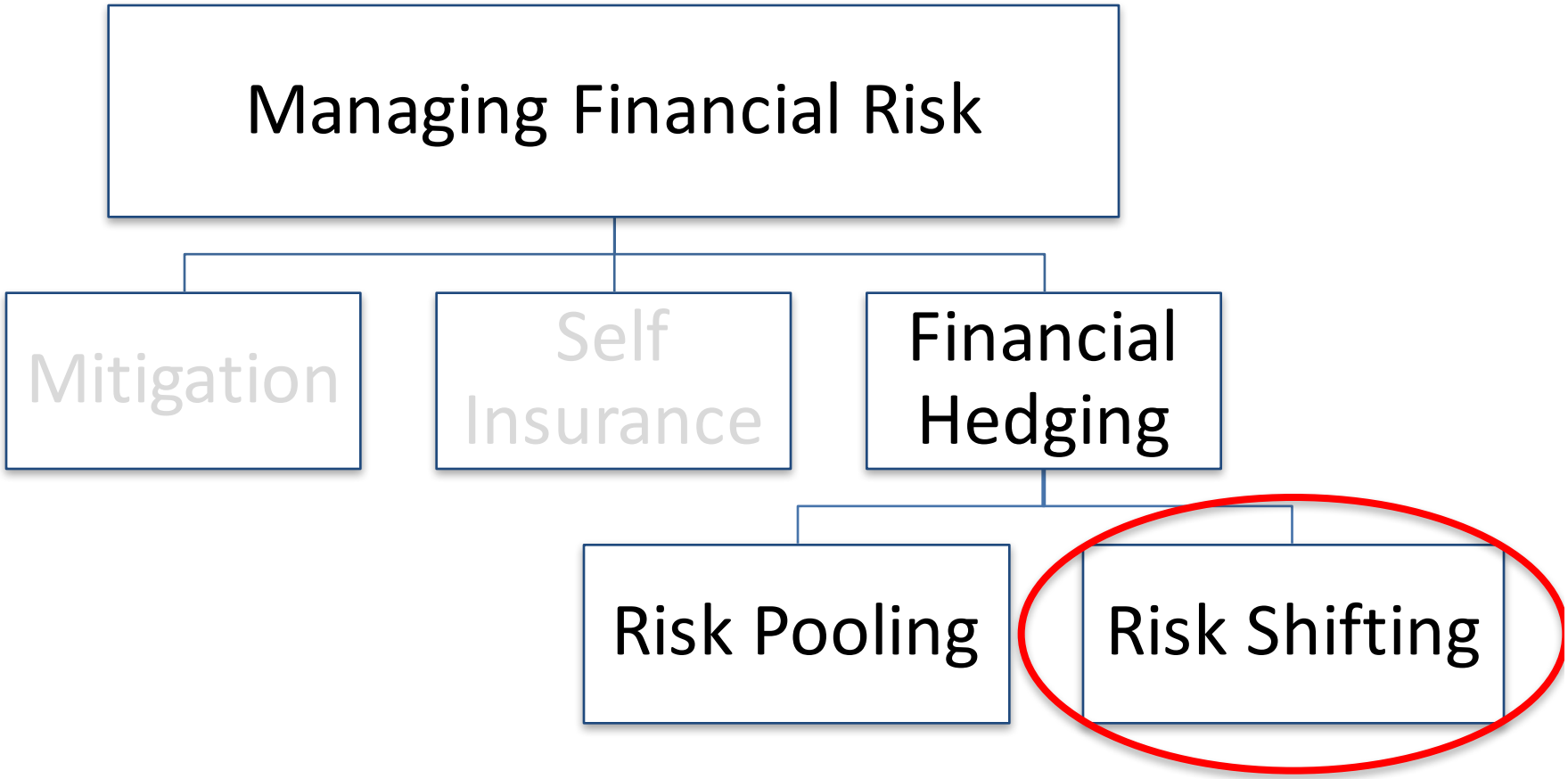
Managing Environmental Financial Risk

1. Identify linkages between financial conditions and environmental conditions (in our case, mostly hydrologic)
2. Model the hydrologic and economic systems as a coupled system, assessing their interdependencies
3. Characterize the financial risk
   i.e. how severe are the losses and how often do they occur?
4. Develop new tools and strategies to manage that risk

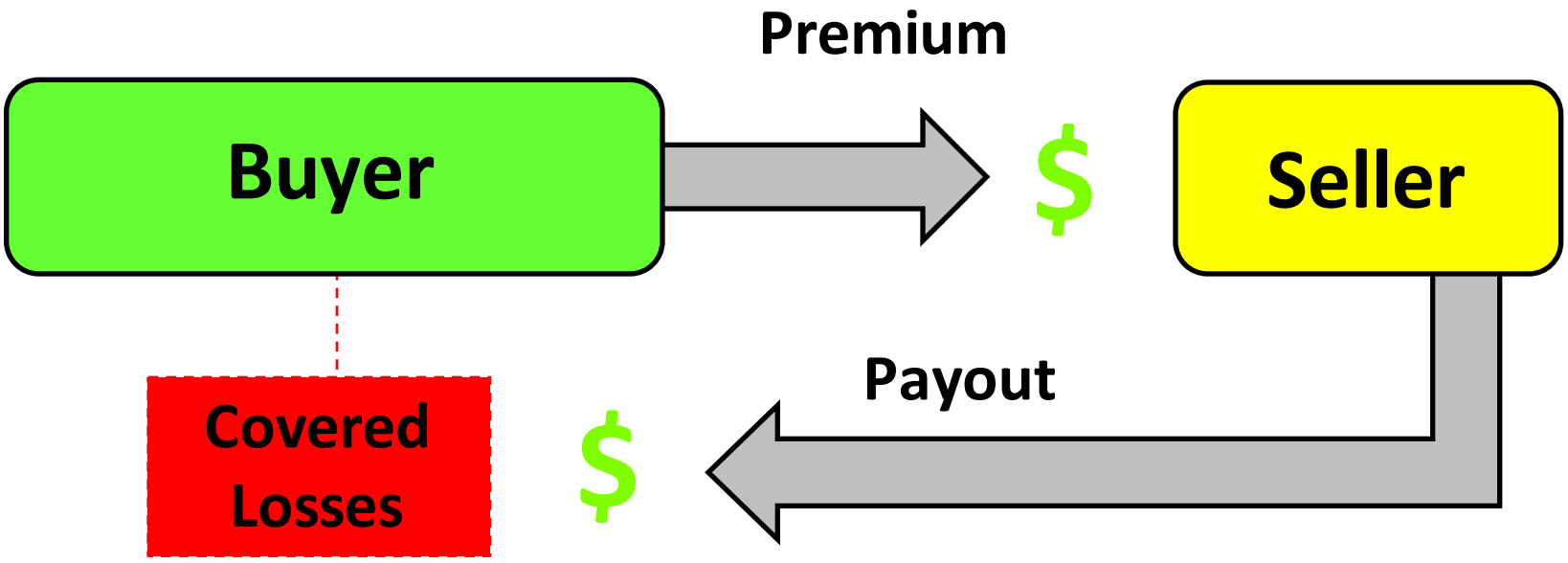
Financial Risk Mitigation



Financial Risk Mitigation

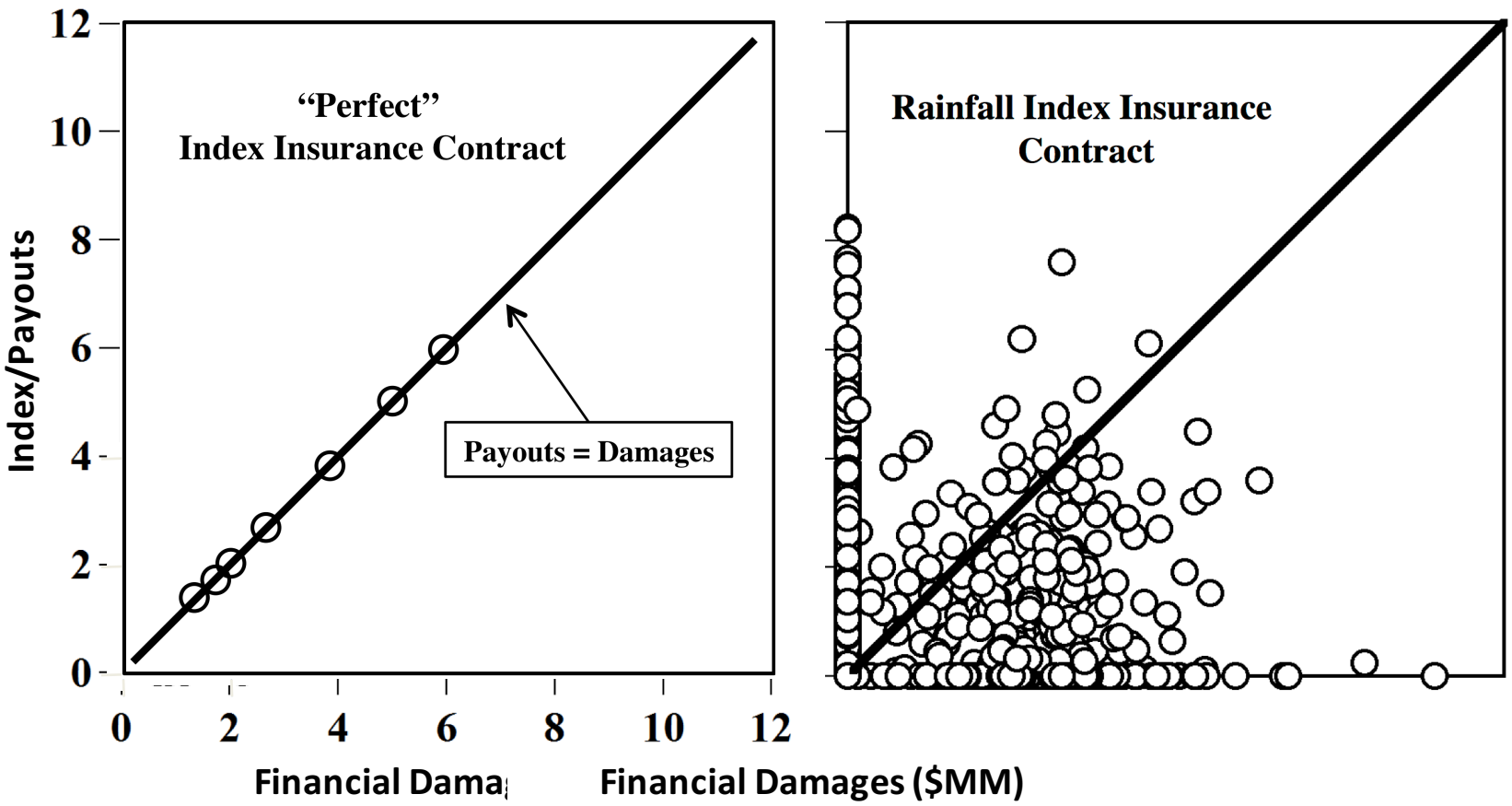


Index-based Financial Instruments



- Index products have some advantages over traditional insurance
  - Lower transaction costs (less subjectivity, no adjustors)
  - Fewer "moral hazard" concerns
  - Quick resolution of claims/payouts
- But, developing an effective index is often difficult

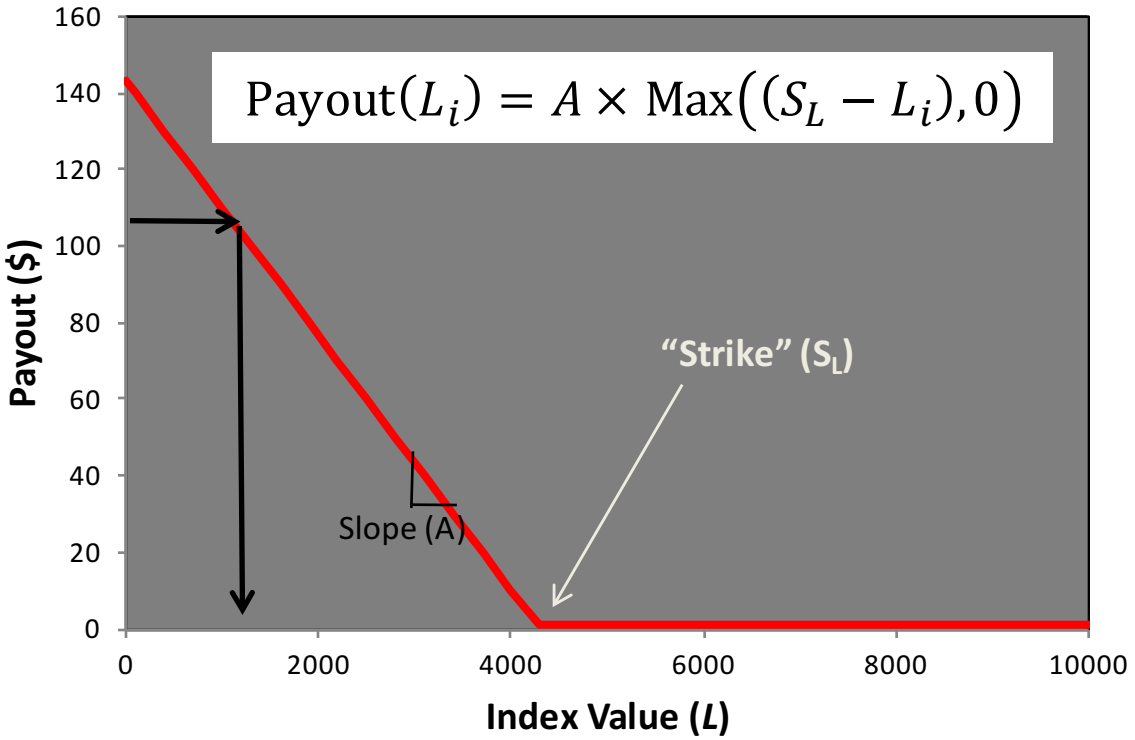
Financial Index Insurance



- Index must correlate well with financial losses
- Transparent, reliable and free from moral hazard concerns

Contract Structure

(standard index insurance)



- Single contract scaled to increase payout as index value declines
- Similar to a "call" option
- Contracts can be structured to protect against high or low index values

Pricing a hedging instrument

Price = Expected payouts + Loading

(or "premium")

- Loading accounts for a number of factors
  - Return on investment
  - Risk premium
  - Administrative and marketing costs
- Loading also represents the "cost" of hedging to the buyer (i.e. this part of the premium doesn't come back in payouts)
- Computing an appropriate loading is the subject of considerable research

Pricing a hedging instrument

Wang Transform

- Transforms a payout probability distribution to be "risk-neutral" using assumptions about the "market price of risk" (γ)
- Infrequent, high consequence, events are assigned higher loadings
  - Higher capital and liquidity requirements have opportunity costs
  - Less frequent, more unpredictable, payouts are more costly

$$F^*(x) = \Phi[\Phi^{-1}(F(x)) + \gamma]$$

where,

x = Payouts

Φ = Standard normal cumulative distribution

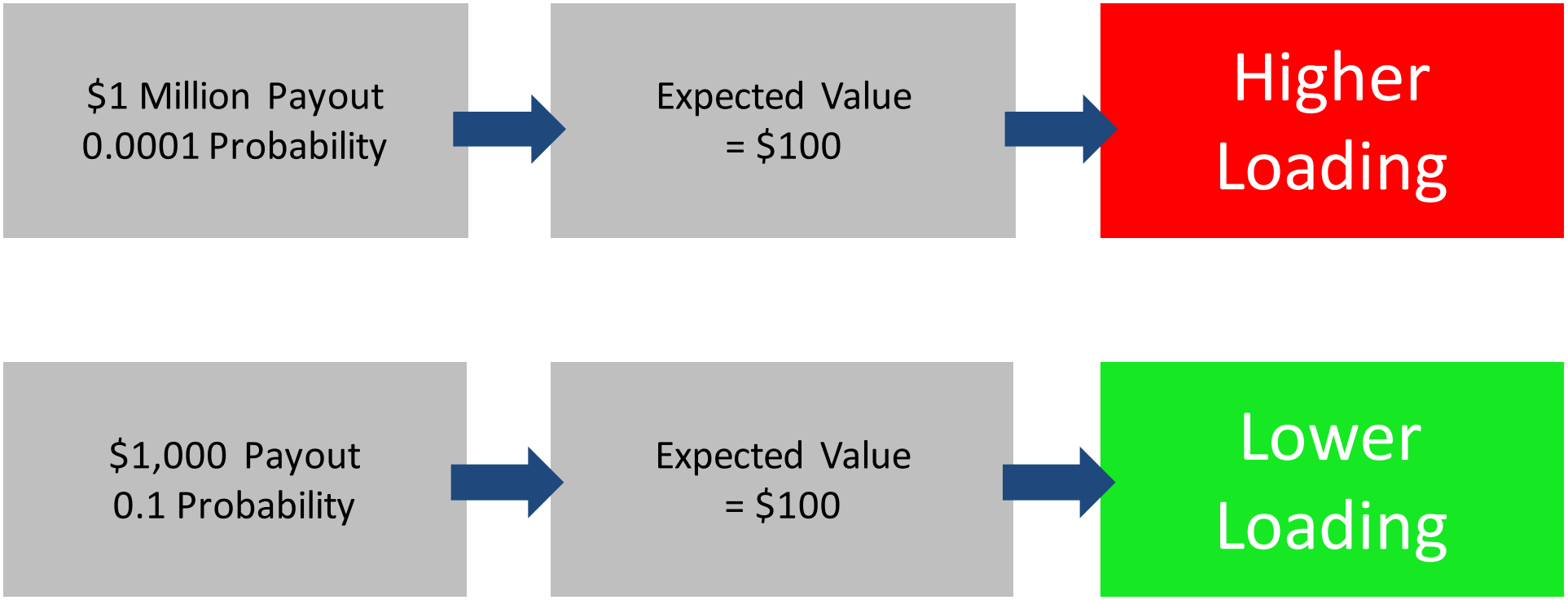
γ = Sharpe ratio of "market price of risk"

$F^*(x)$ = Risk adjusted cdf of payouts

$F(x)$ = Cdf of payouts

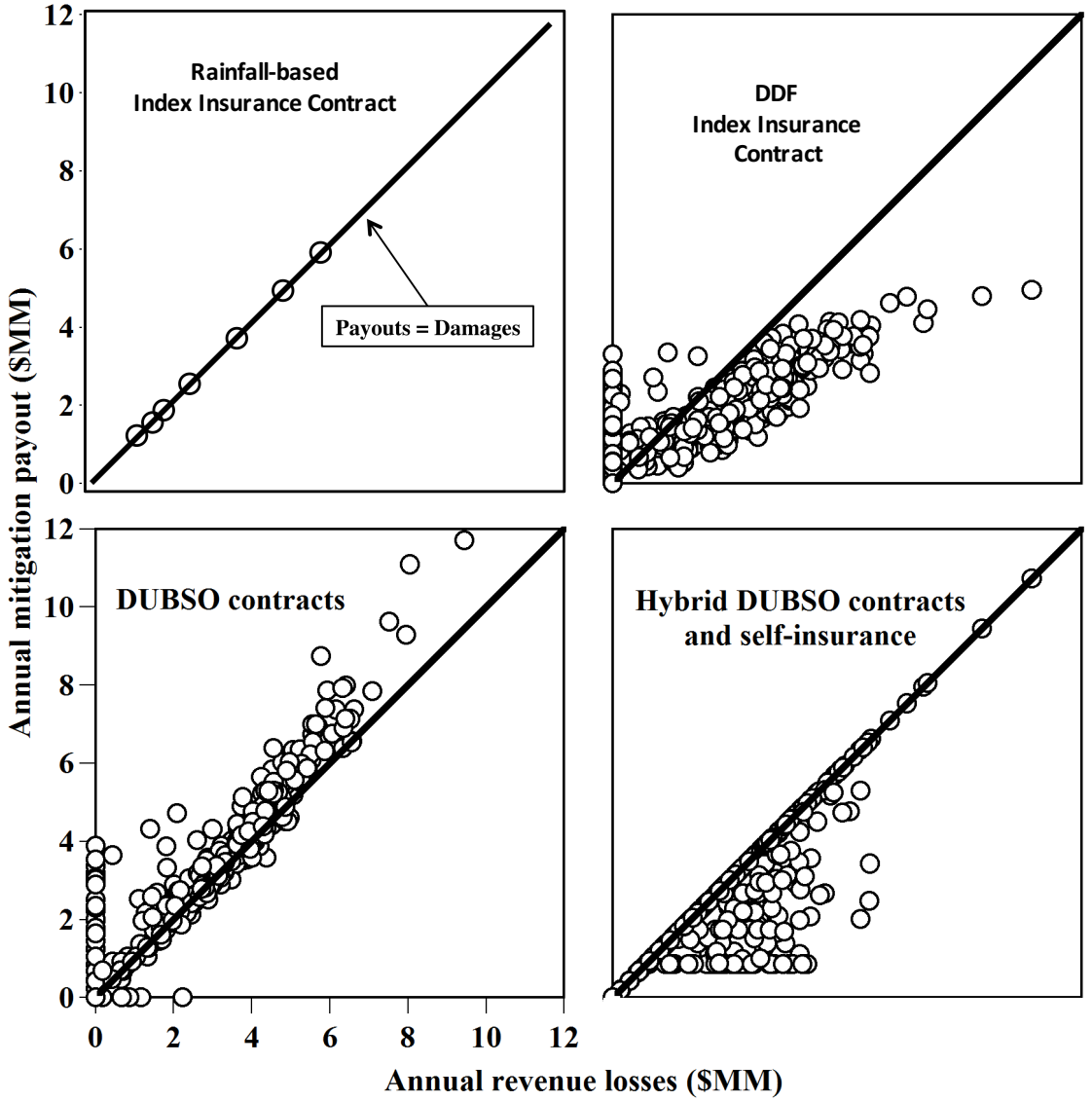
Pricing Intuition

(for Wang Transform or any other pricing method)



LESSON: sitting on big sums of "liquid" reserves (e.g., savings account) has "opportunity costs"

Finding an Effective Index (lowering basis risk)



Zeff and Characklis (2013), "Managing Water Utility Financial Risks through Third-Party Index Insurance Contracts," *Water Resources Research*, 49, doi:10.1002/wrcr.20364.

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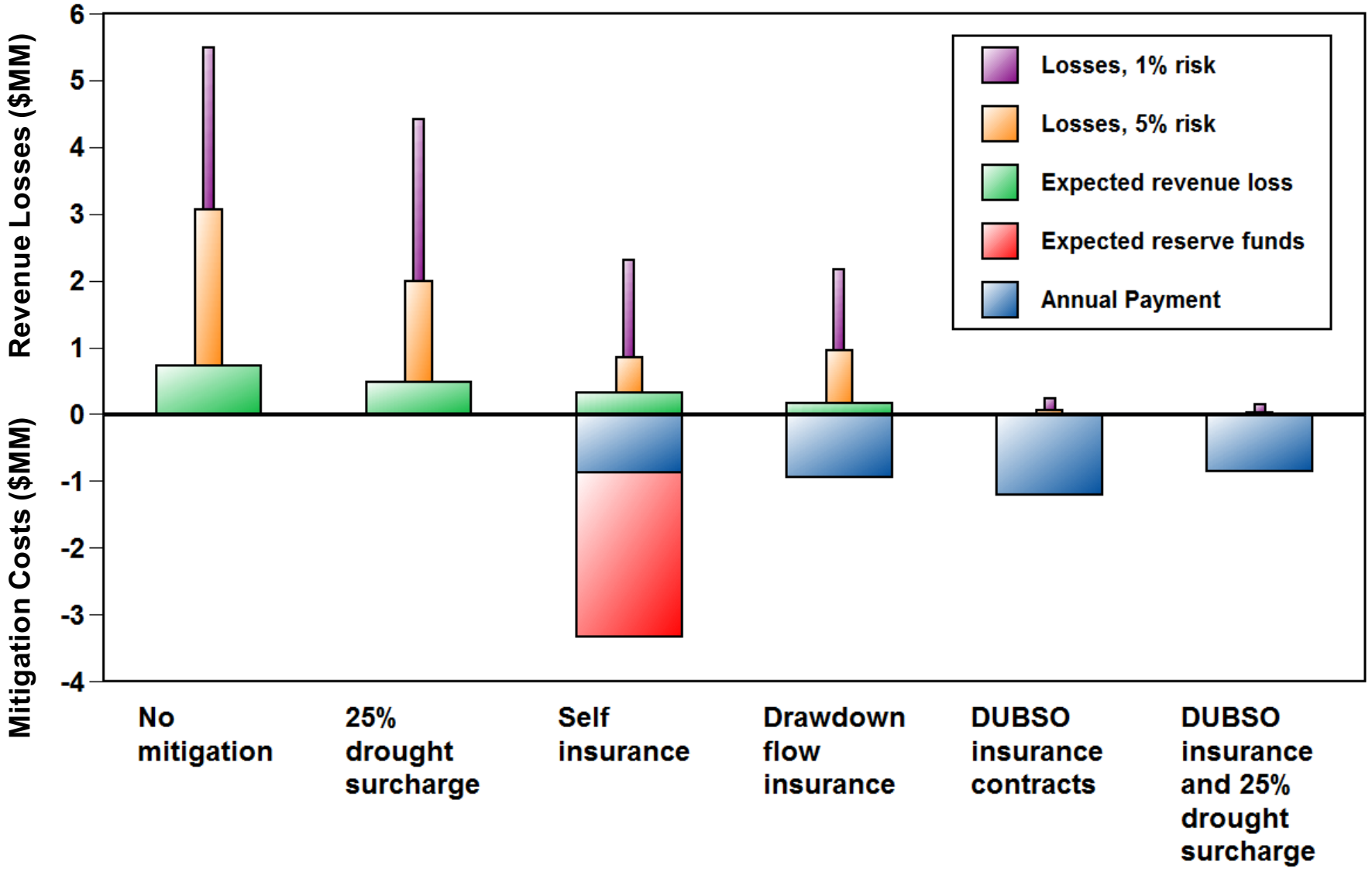
Financial Risk Mitigation Measures



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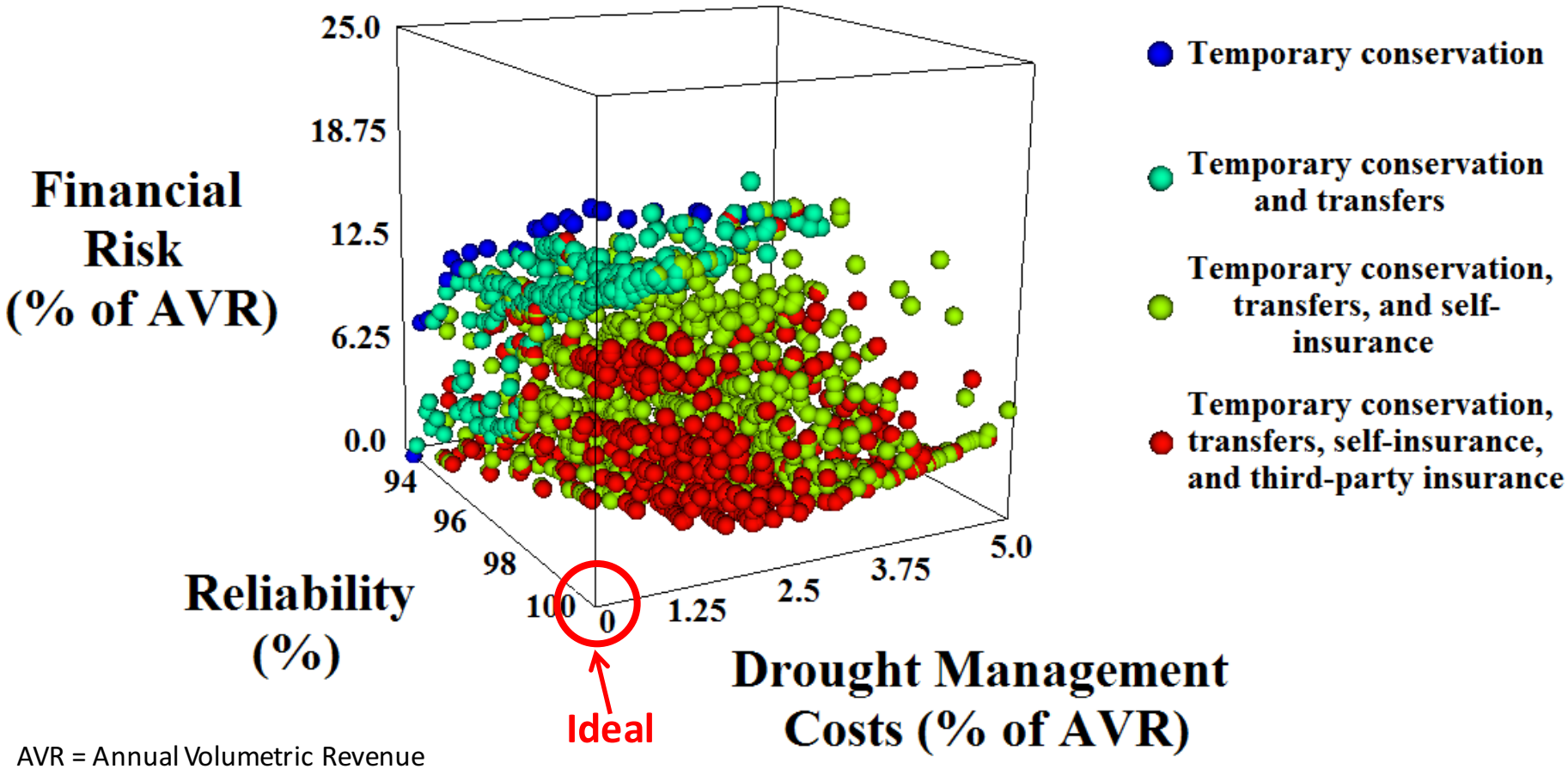
Designing a Drought Management Portfolio



AVR = Annual Volumetric Revenue

Zeff, H.B., Kasprzyk, J. R., Herman, J. D., Reed, P. M. and G. W. Characklis (2014). "Navigating Financial and Supply Reliability Tradeoffs in Regional Drought Portfolios," *Water Resources Research*, 50, doi:10.1002/2013WR015126.

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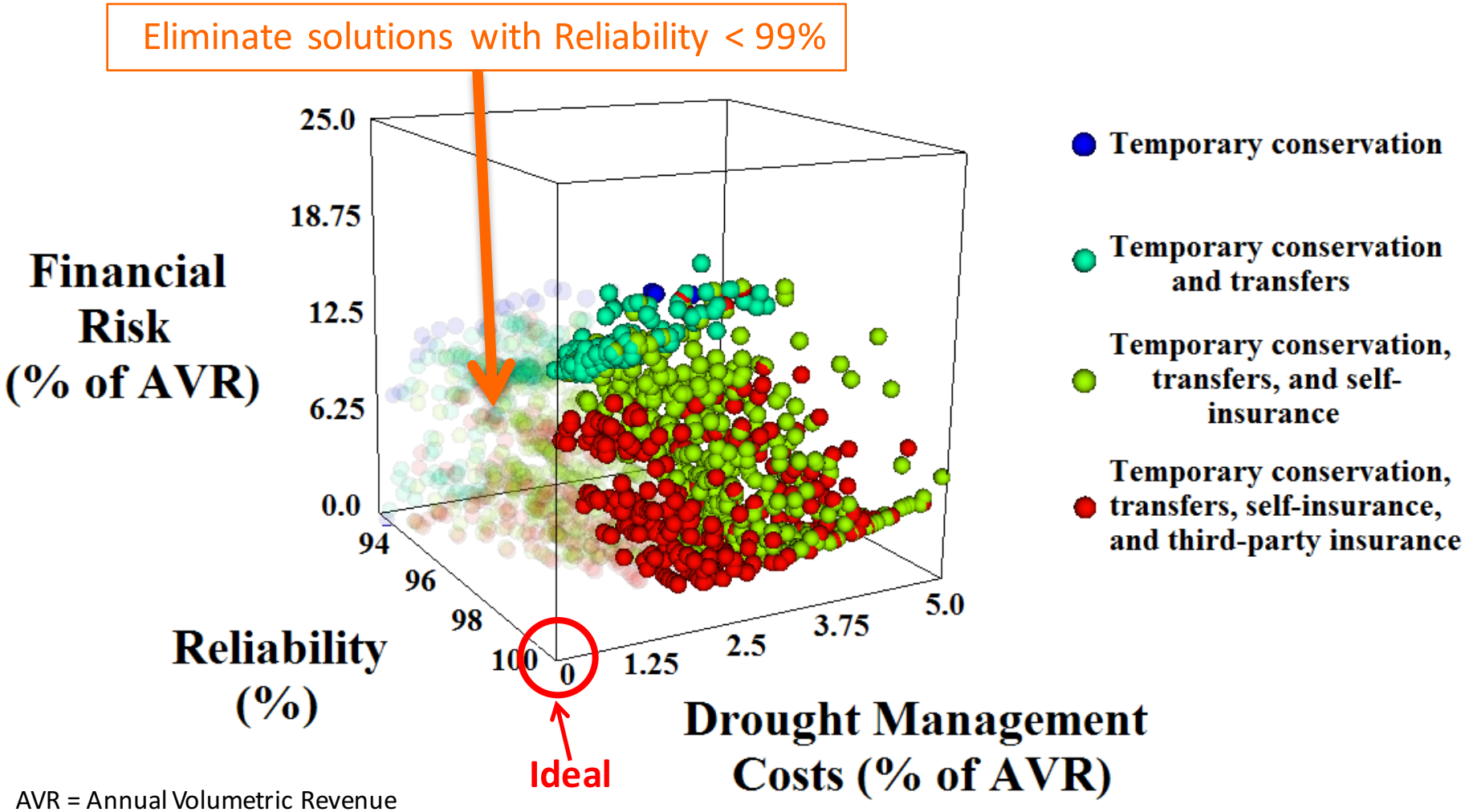

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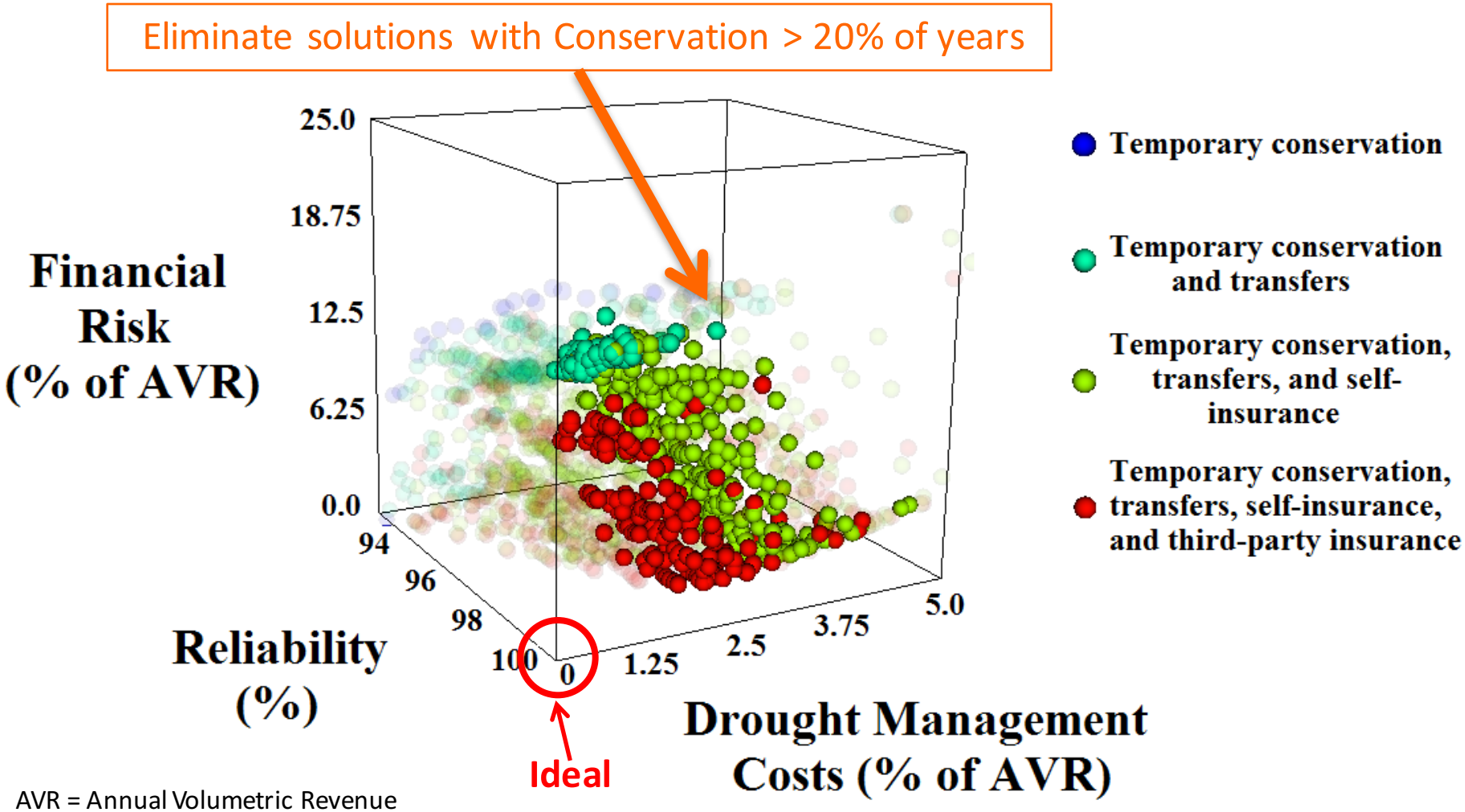

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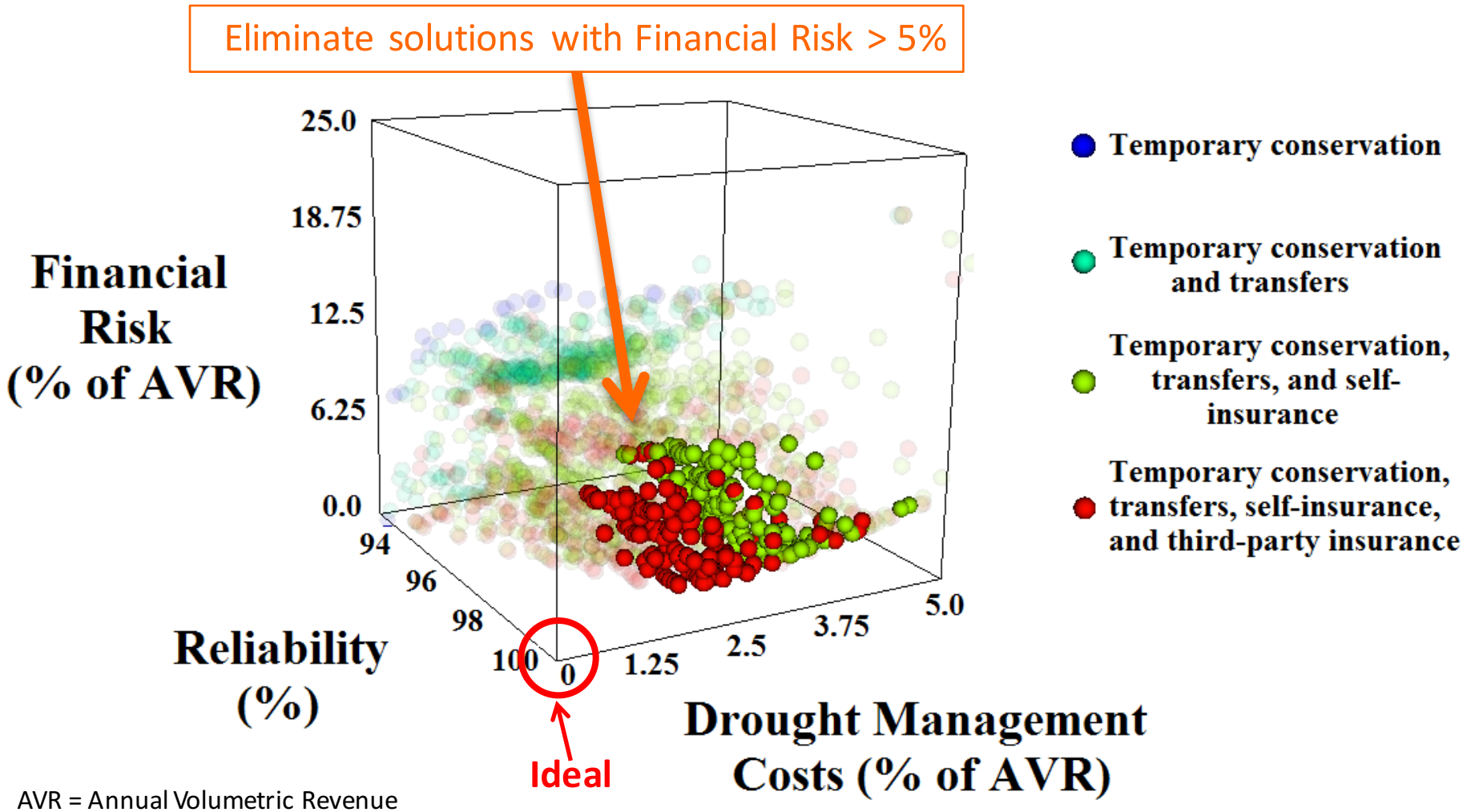

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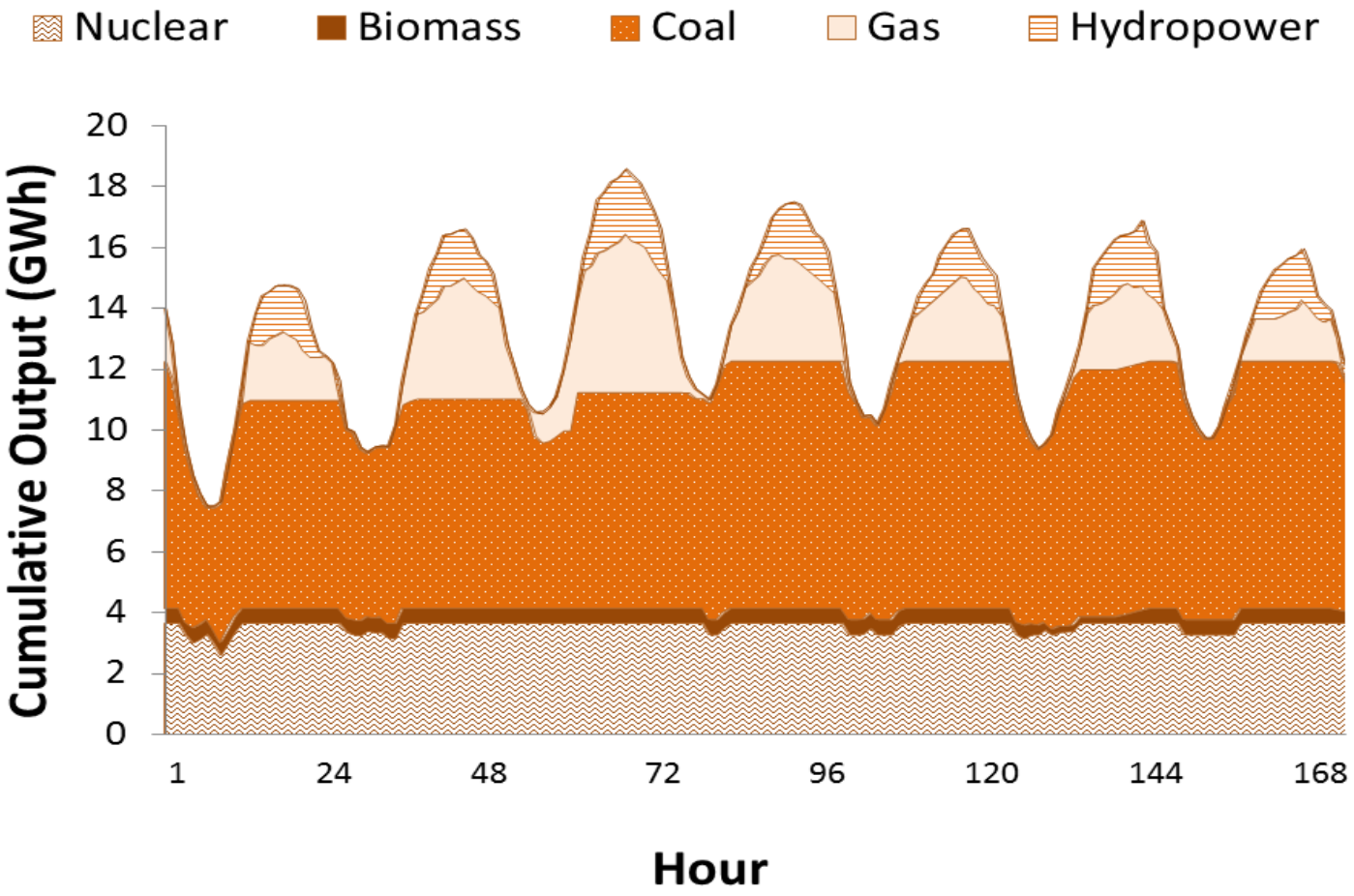
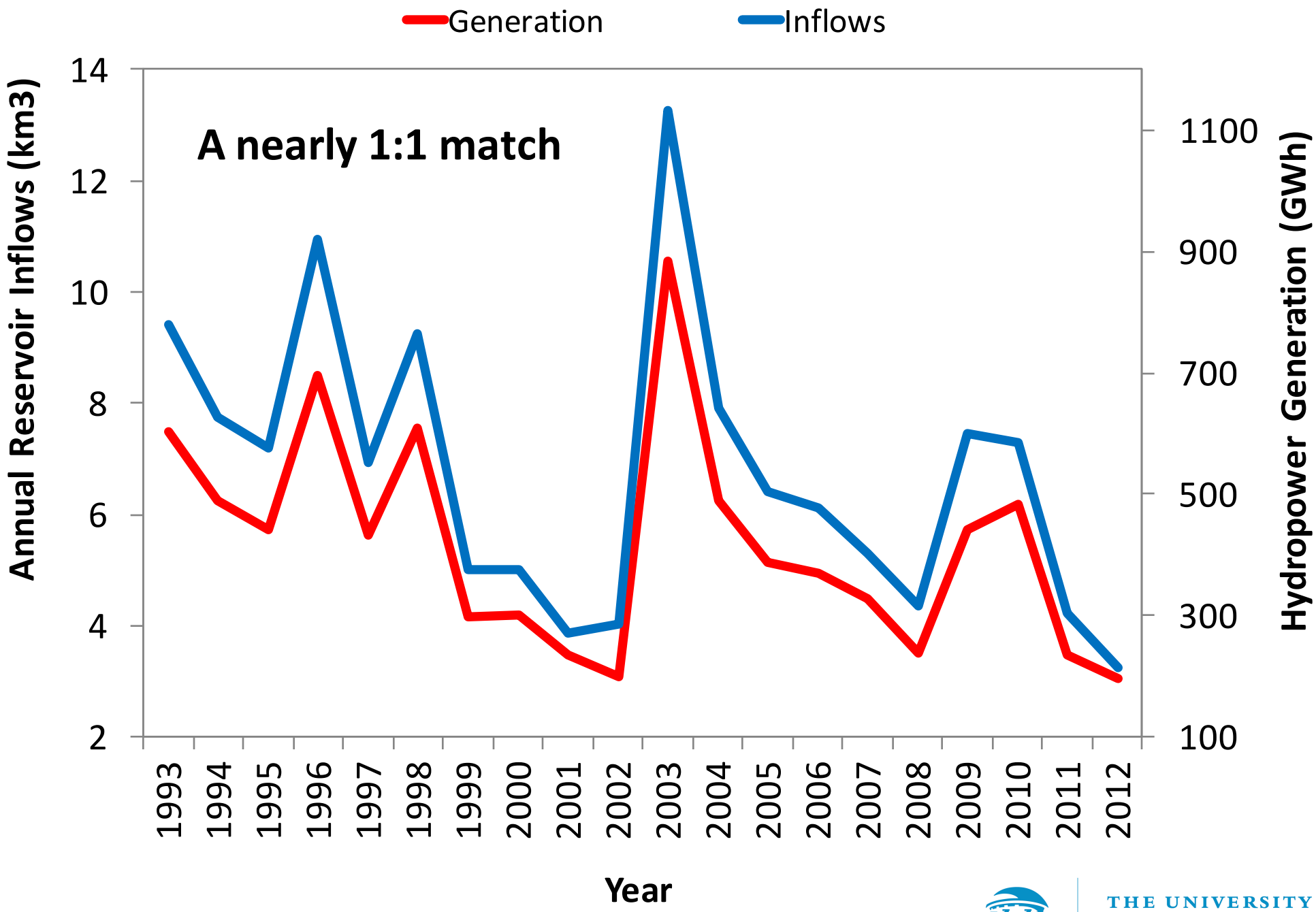
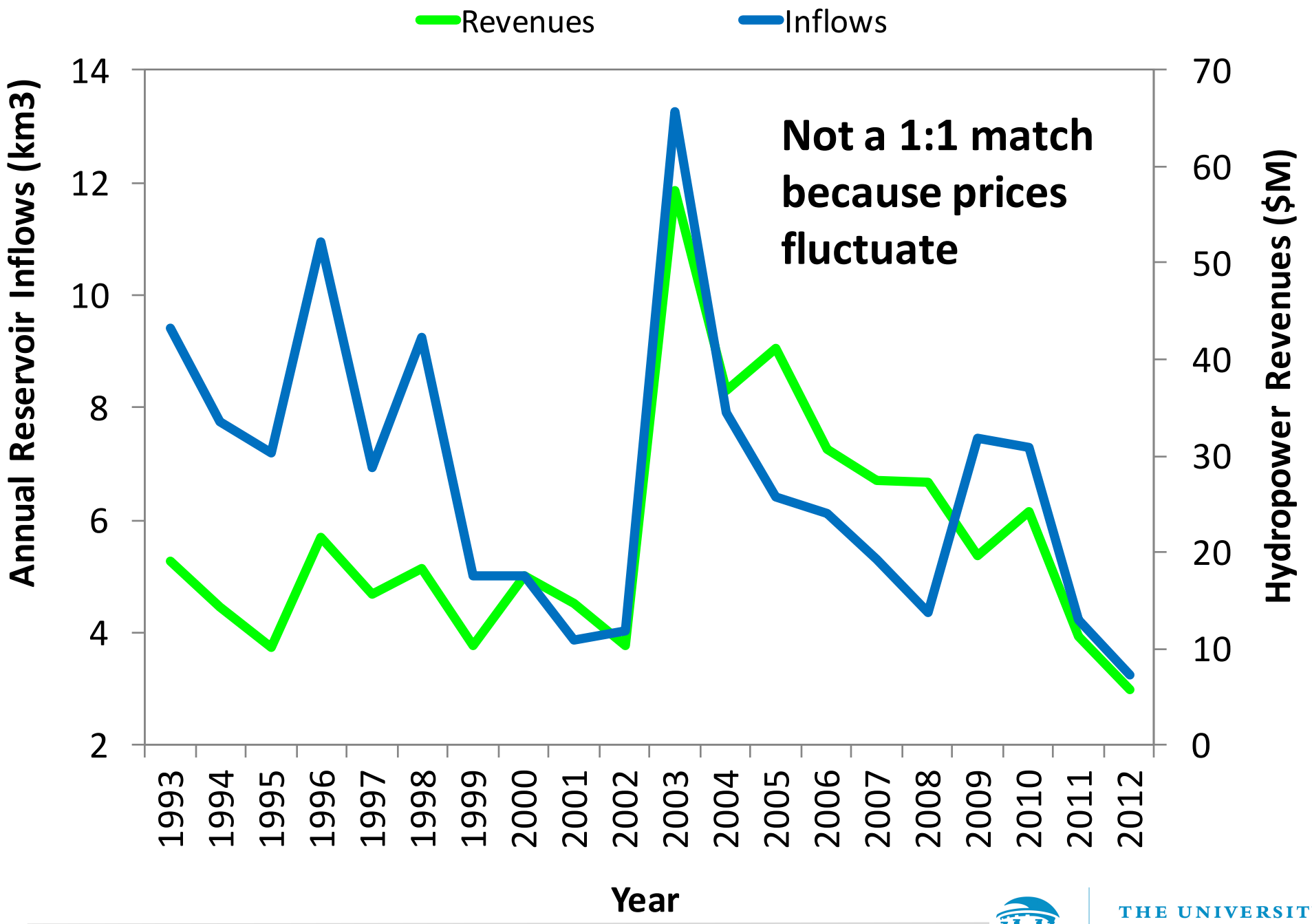
Hydropower

Peaking resources are critically important

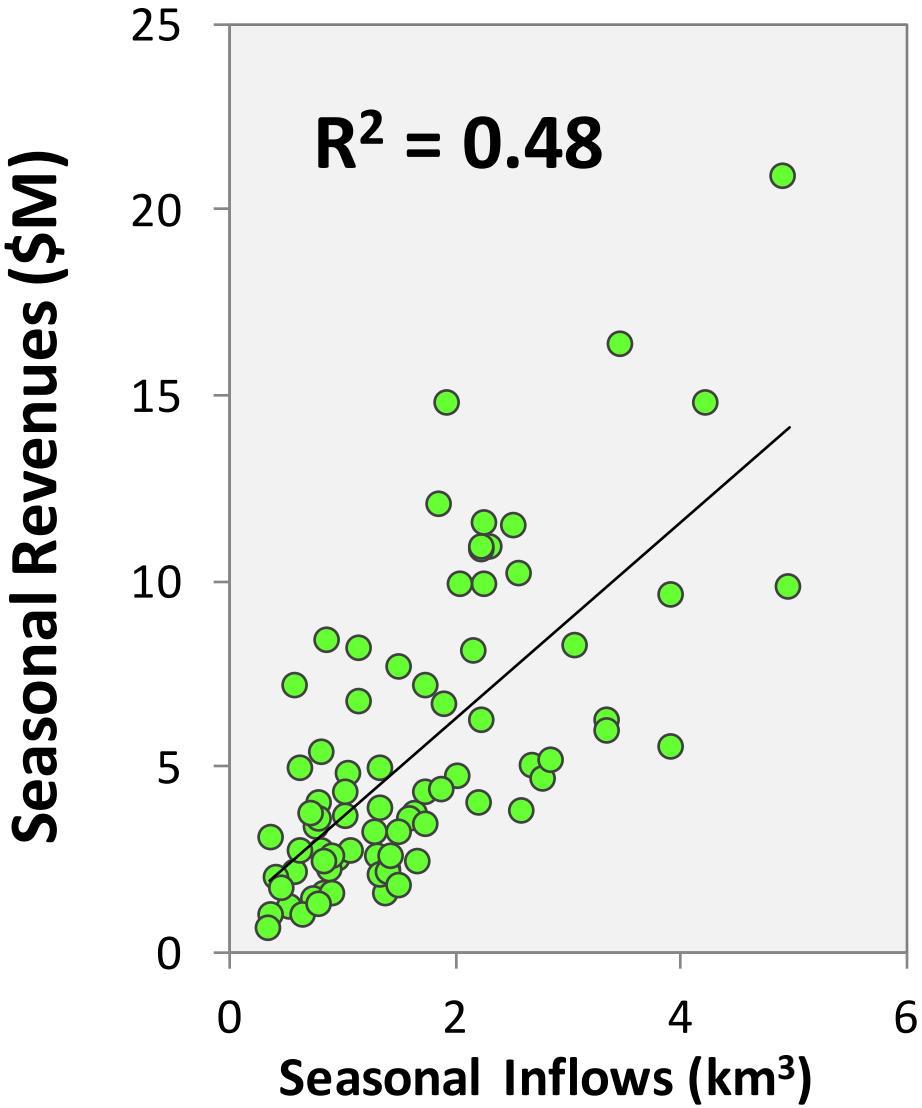


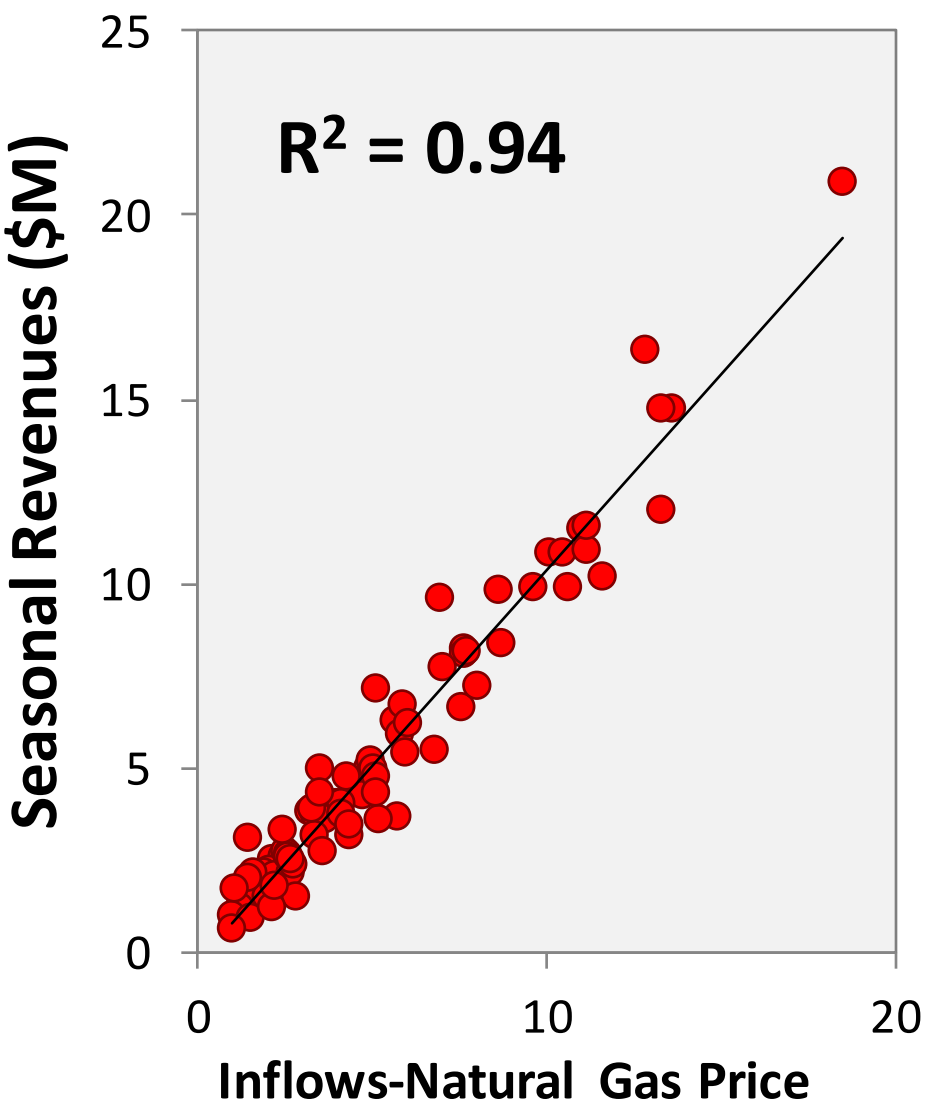
- Hydropower and natural gas are the typical choices, but hydro is cheaper
- "On demand" sources will become more important with increased use of renewables (e.g., wind, solar)


Generation
Inflows
A nearly 1:1 match
Annual Reservoir Inflows (km3)
Hydropower Generation (GWh)
14
12
10
8
6
4
2
1100
900
700
500
300
100
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year

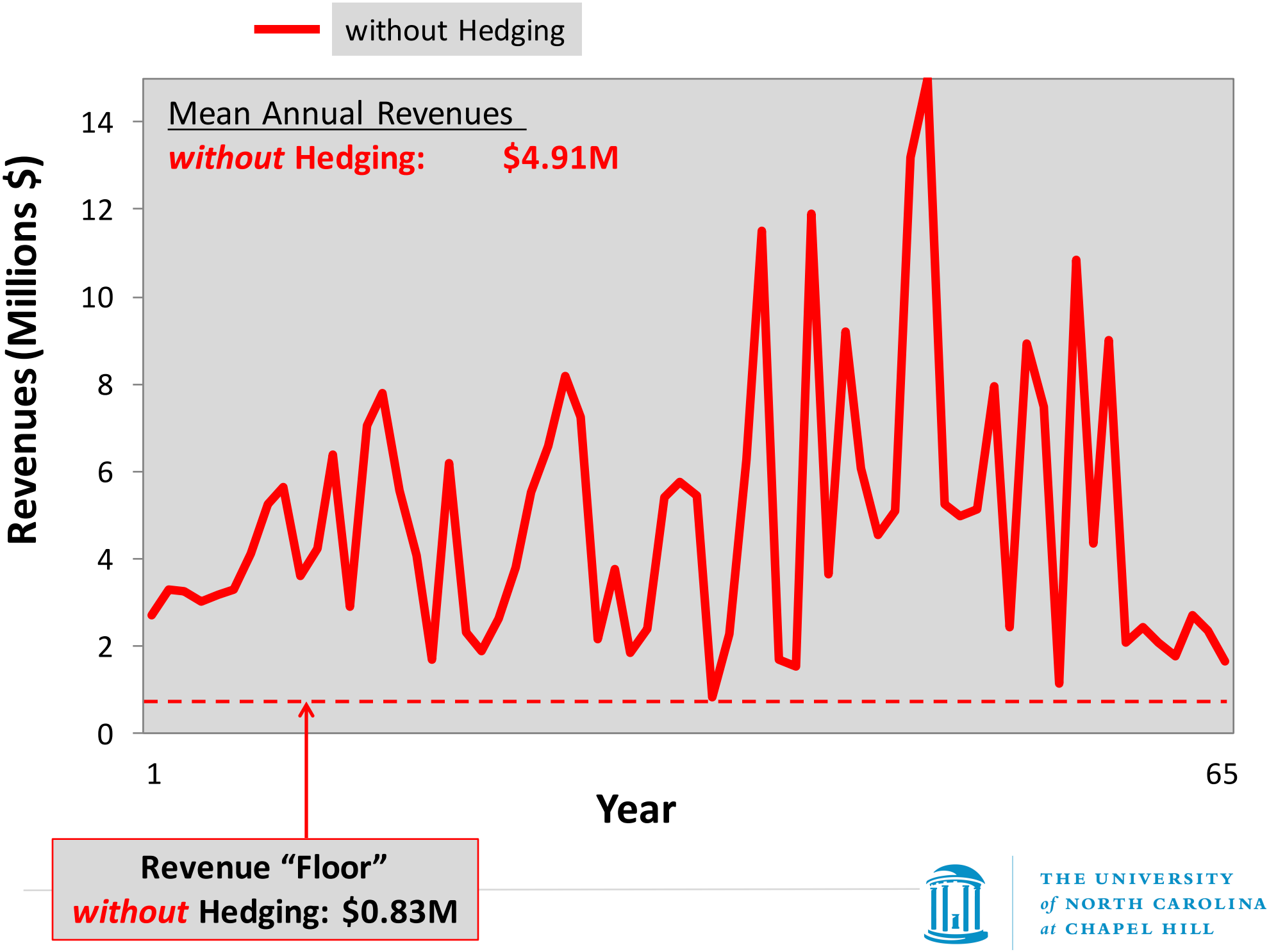

Revenues
Inflows
Annual Reservoir Inflows (km3)
Hydropower Revenues ($M)
Year
Not a 1:1 match because prices fluctuate
14
12
10
8
6
4
2
70
60
50
40
30
20
10
0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

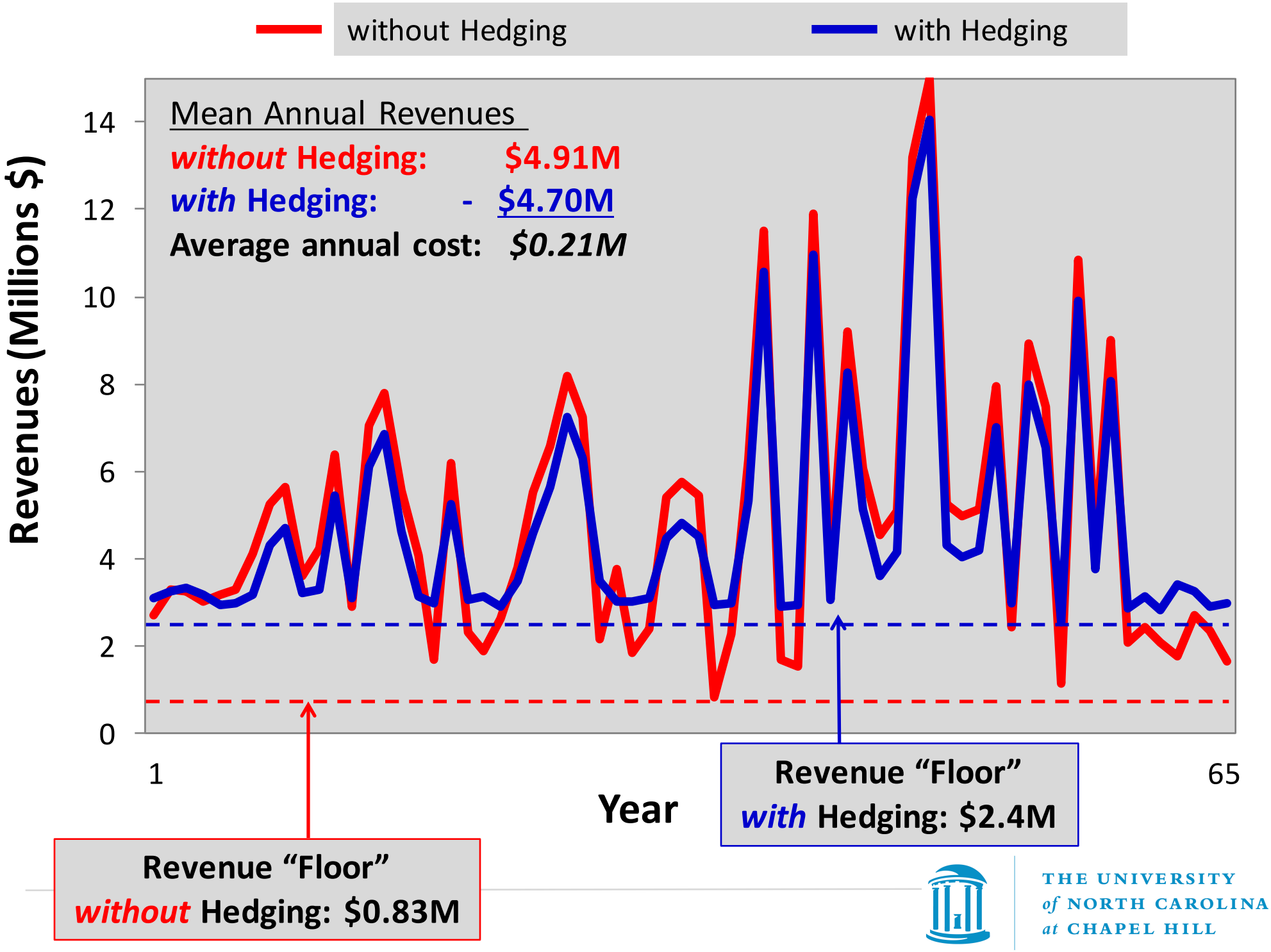
Identifying the "right" index





Kern, J. D. , Characklis, G. W. and B. F. Foster (2015) "Natural Gas Price Uncertainty and the Cost Effectiveness of Hedging Against Low Hydropower Revenues Caused by Drought," *Water Resources Research*, 51, doi:10.1002/2014WR016533.


without Hedging
Mean Annual Revenues
without Hedging: $4.91M
Revenues (Millions $)
14
12
10
8
6
4
2
0
1
65
Year
Revenue "Floor"
without Hedging: $0.83M



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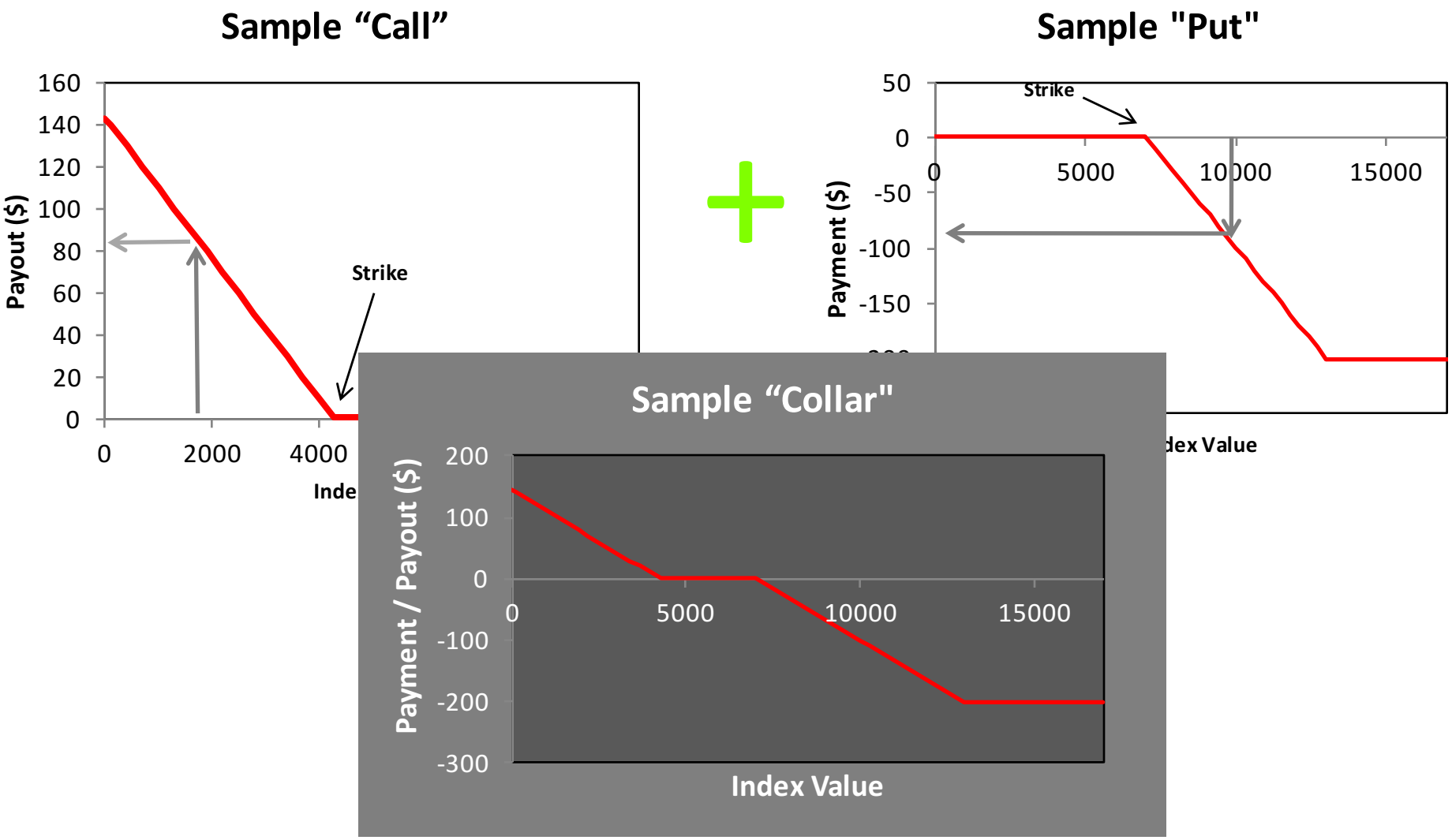
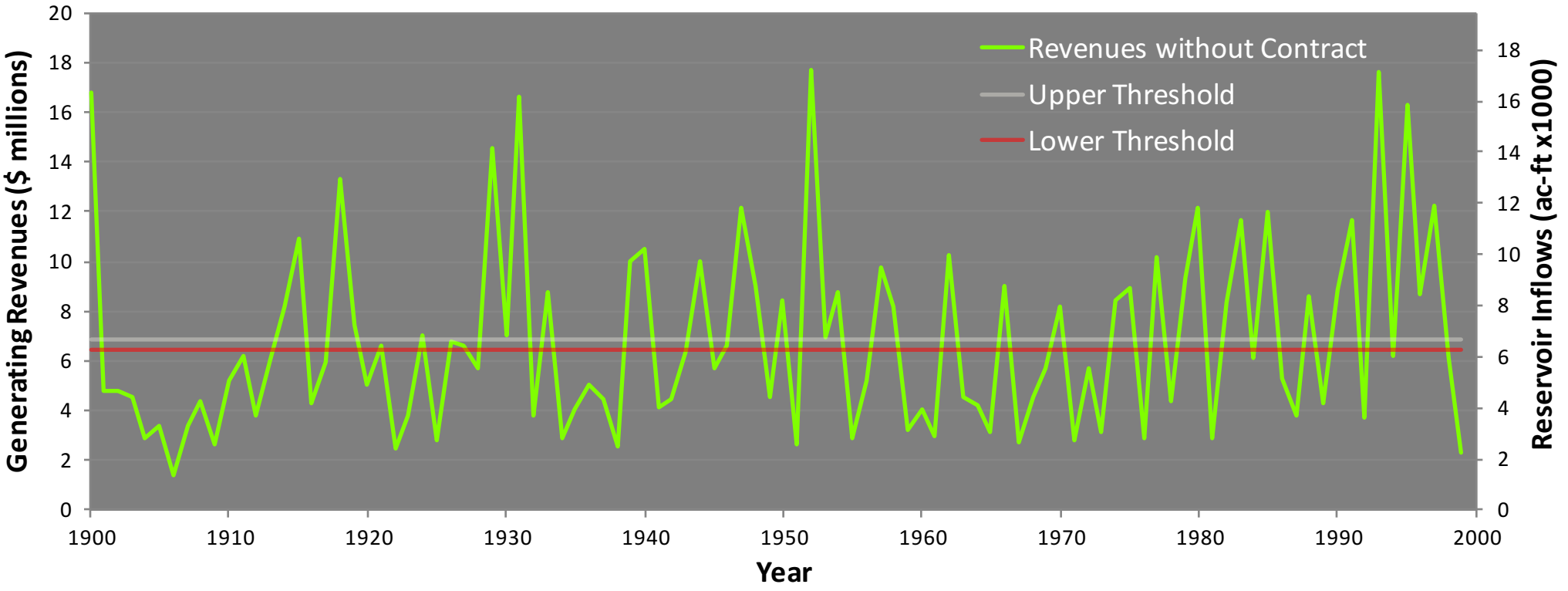
Contract Structure



Collar Contract



- If revenue stability is critical, a "collar" structure might be useful
- Generator buys protection against low revenue periods with proceeds made by selling rights to high revenue periods

Foster, B. F., Kern, J. D. and G. W. Characklis (2015). "Mitigating Hydrologic Financial Risk in Hydropower Generation Using Index-Based Financial Instruments," *Water Resources and Economics*, 10, pp. 45-67, doi:10.1016/j.wre.2015.04.001

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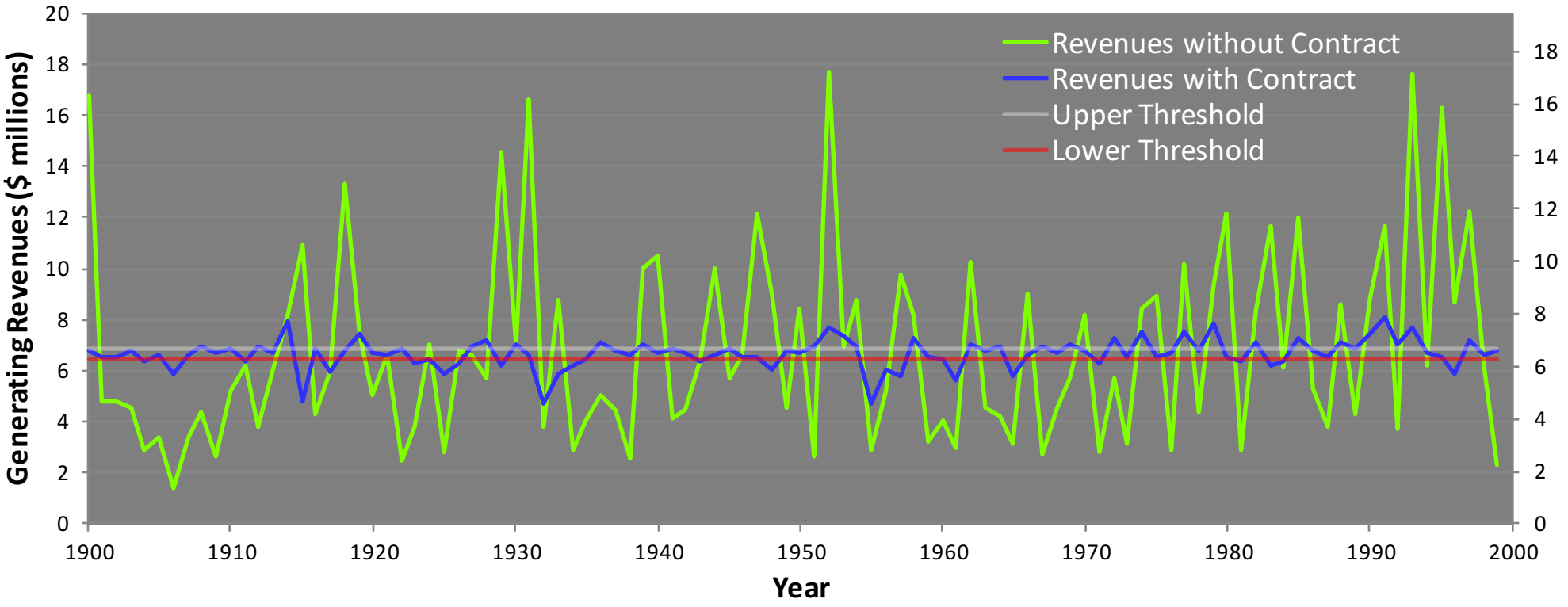

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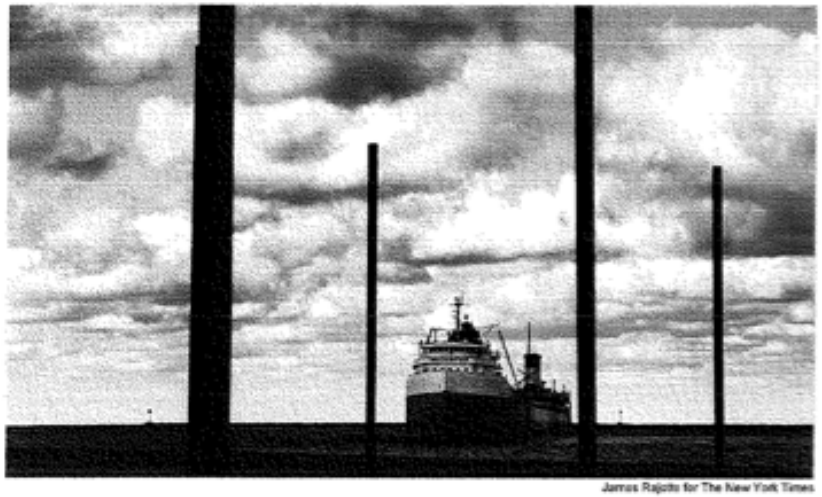
Impacts of Water Scarcity on Inland Navigation

The New York Times

Inch by Inch, Great Lakes Shrink, and Cargo Carriers Face Losses



James Rajotte for The New York Times

A ship carrying road salt pulls into the Port of Oswego, N.Y., on Lake Ontario. The lake's water level has dropped three inches during this month alone.

By FERNANDA SANTOS
Published: October 22, 2007

Correction Appended

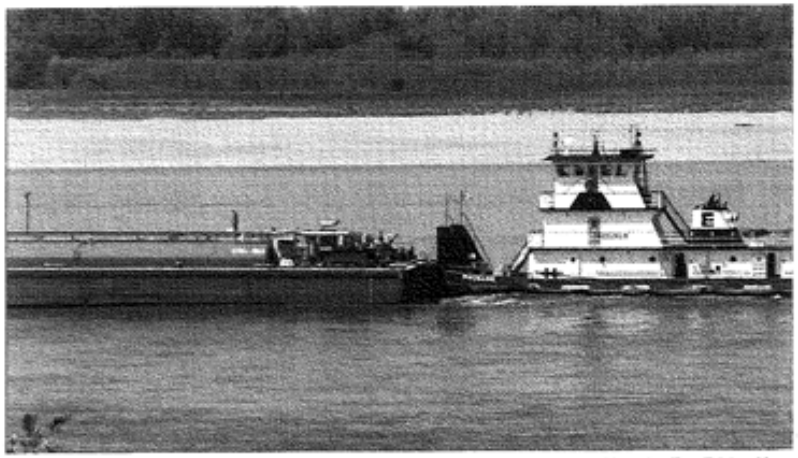
OSWEGO, N.Y. — From his office at the port here, Jonathan Daniels stared at a watermark etched on the rocks that hug one of the commercial piers — a thick dark line several inches above the surface of Lake Ontario — and wondered how much lower the water would dip.

TWITTER
LINKEDIN
E-MAIL
PRINT
REPRINTS
SHARE

CNN U.S.

Coast Guard halts traffic on low-water stretch of Mississippi

From **Joe Sutton**, CNN
updated 9:25 PM EDT, Mon August 20, 2012



The closure was affecting 97 vessels Monday afternoon and was halting both northbound and southbound traffic, officials said.

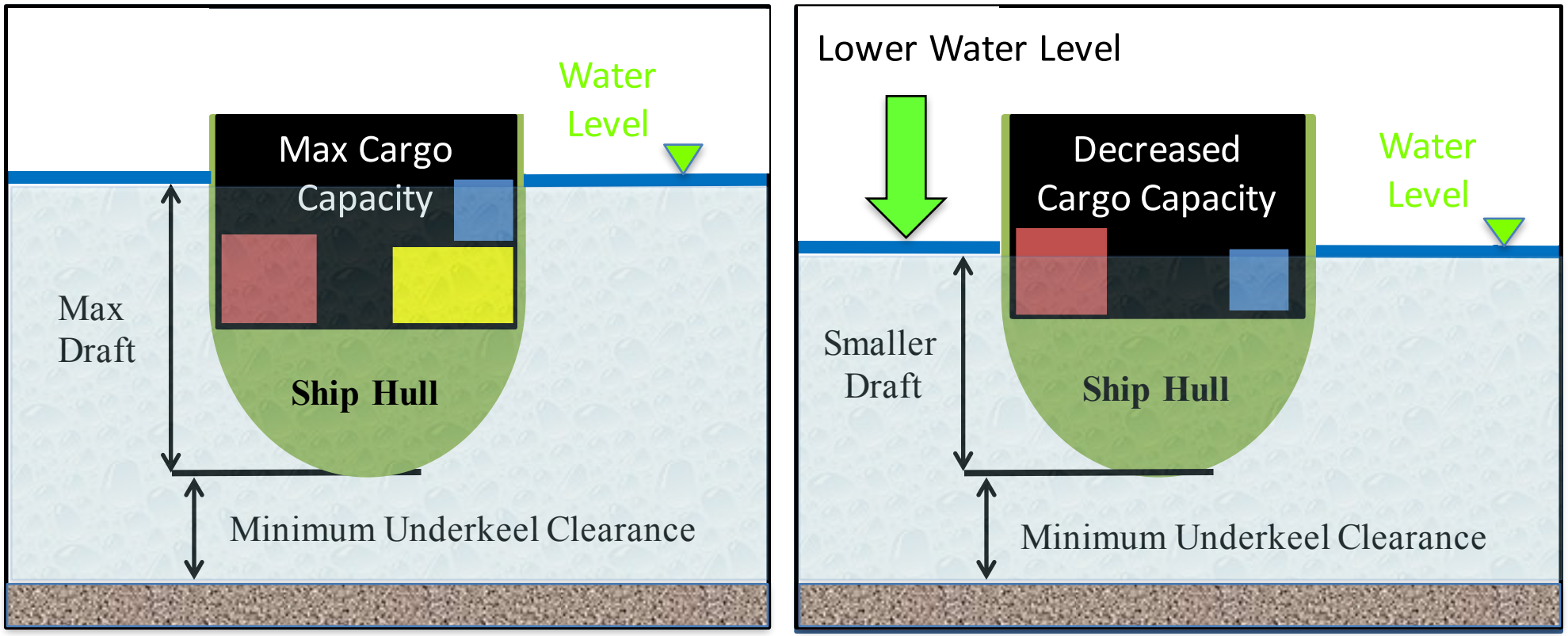
STORY HIGHLIGHTS

- About a hundred vessels were idled by the closure
- A Coast Guard spokesman says he is unsure when the river will reopen

(CNN) -- An 11-mile stretch of the Mississippi River near Greenville, Mississippi, was closed Monday to most vessel traffic because of low water levels, idling nearly a hundred boats and barges in the stream, according to the U.S. Coast Guard.

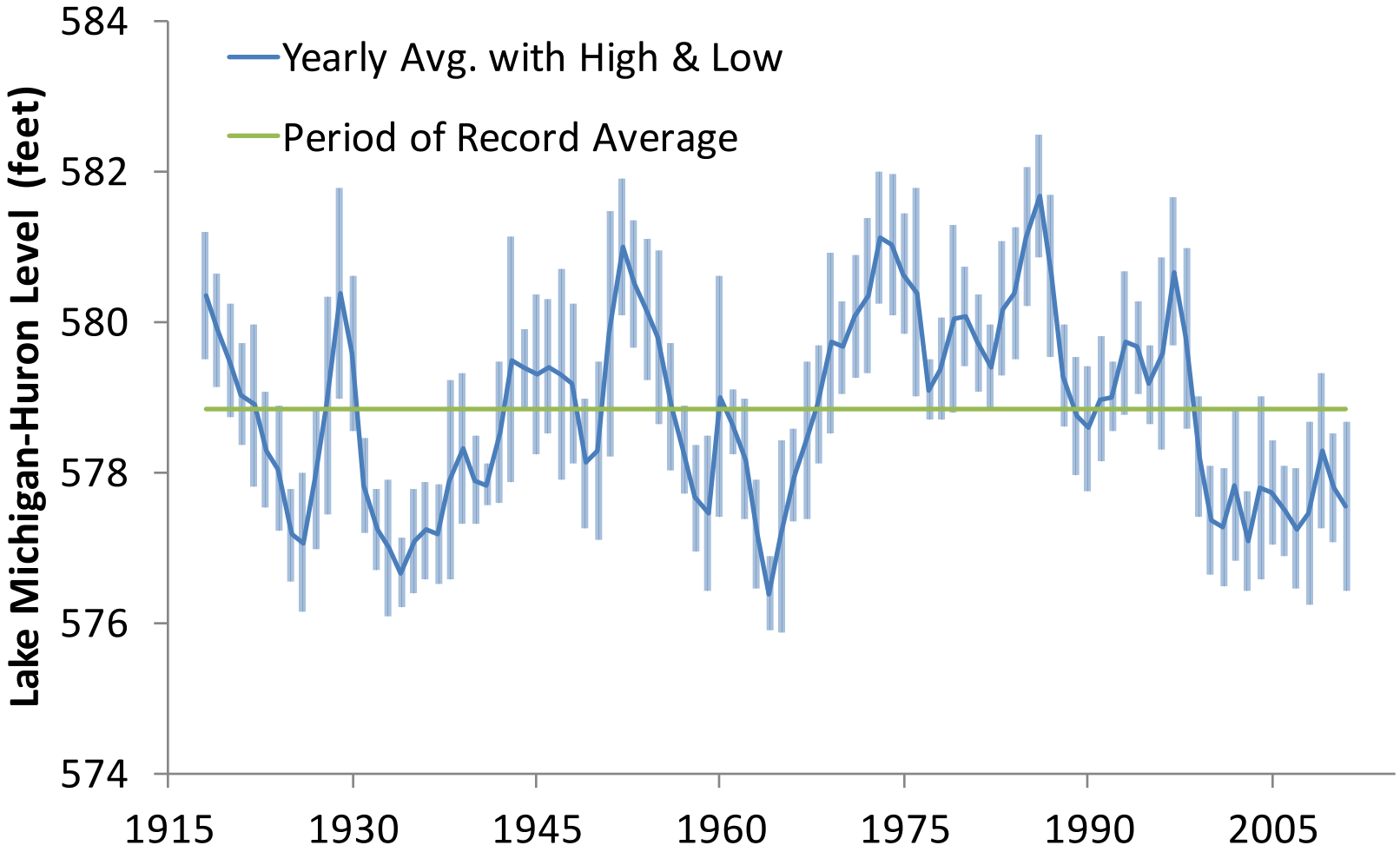
"We are allowing a limited number of vessels based on size" to attempt to pass, said New Orleans-based Coast Guard spokesman Ryan Tippets, adding that the closure was affecting 97 vessels Monday afternoon and was halting both northbound and southbound traffic.

Effect of Low Water Levels on Ships

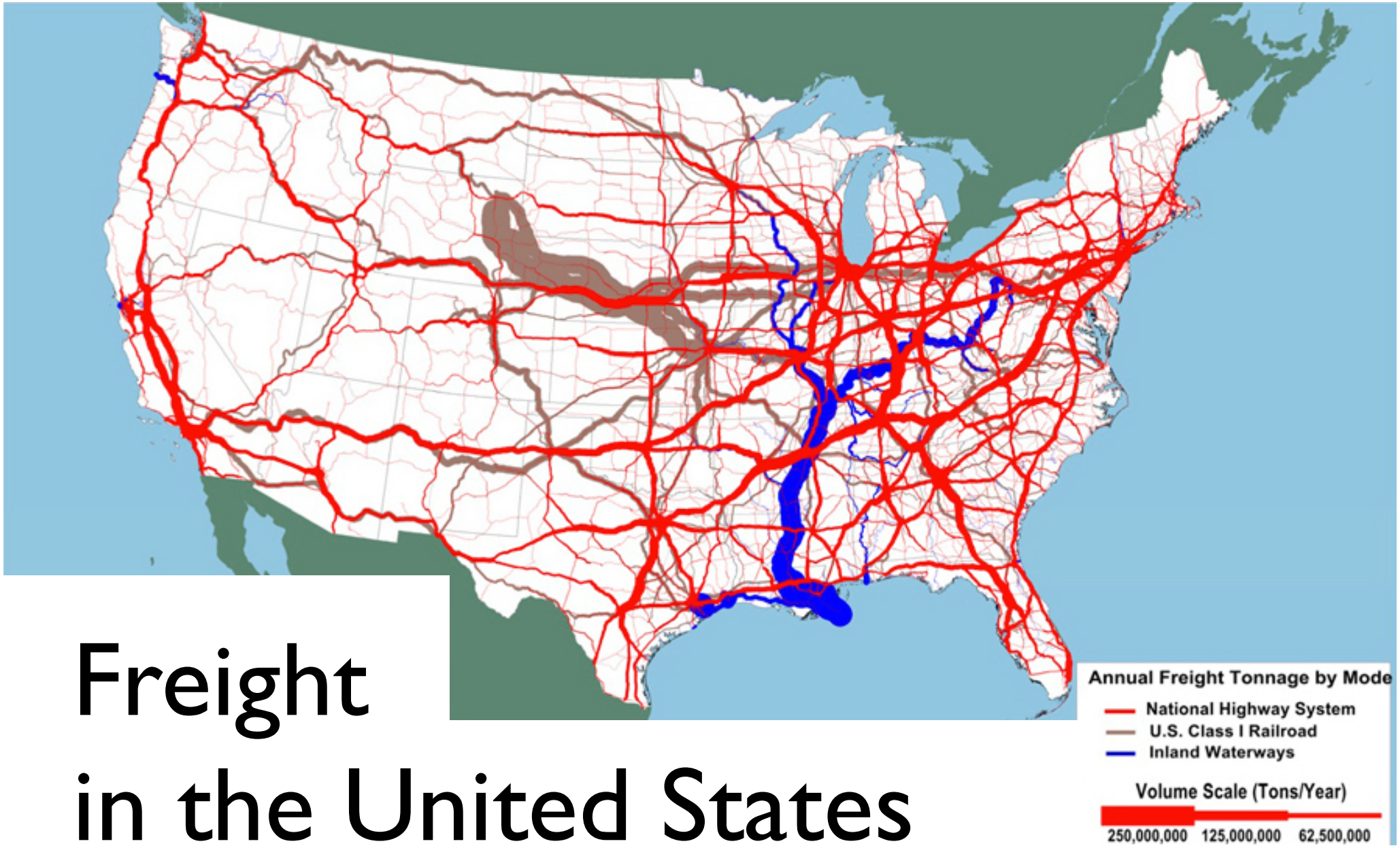


- Low water levels translate to less cargo carrying capacity
- Translates to higher shipping costs for products
- Imposes financial impacts on both shipping firms and their clients

Great Lake Level Variability

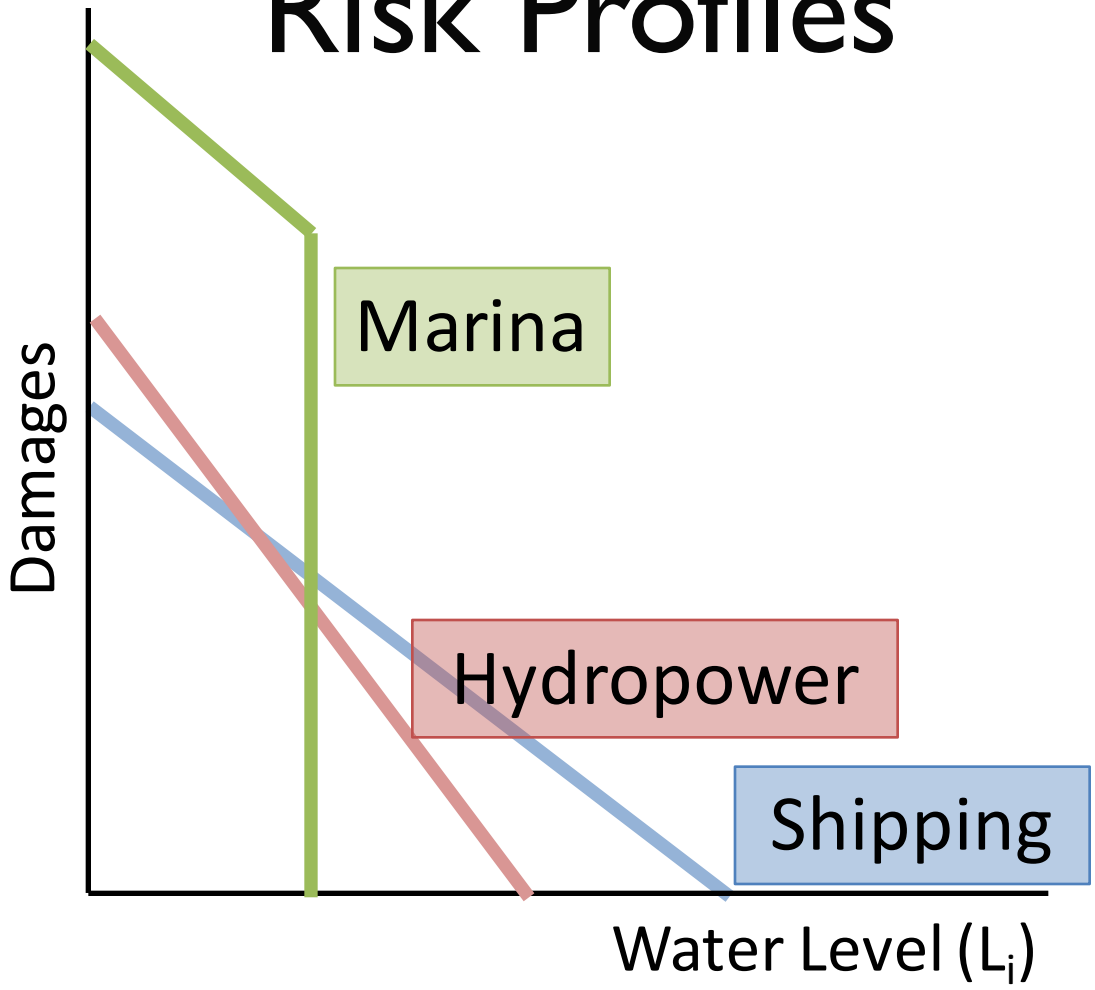


Source: http://www.glerl.noaa.gov/data/now/wlevels/dbd/

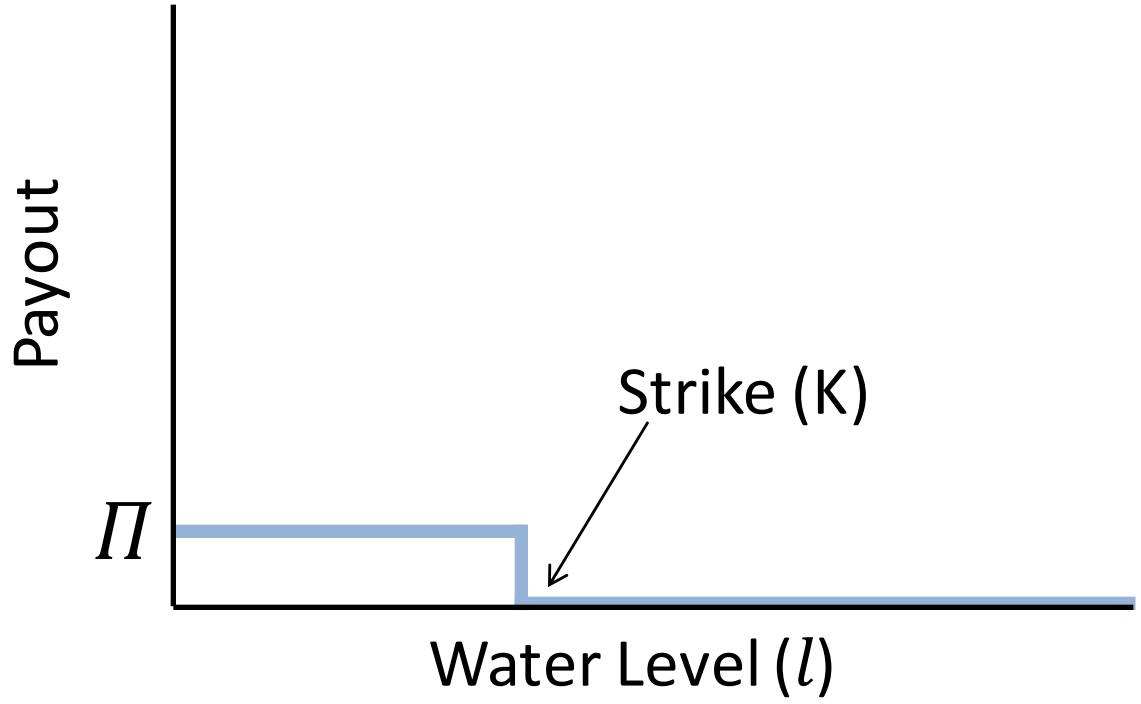


Freight in the United States

Risk Profiles

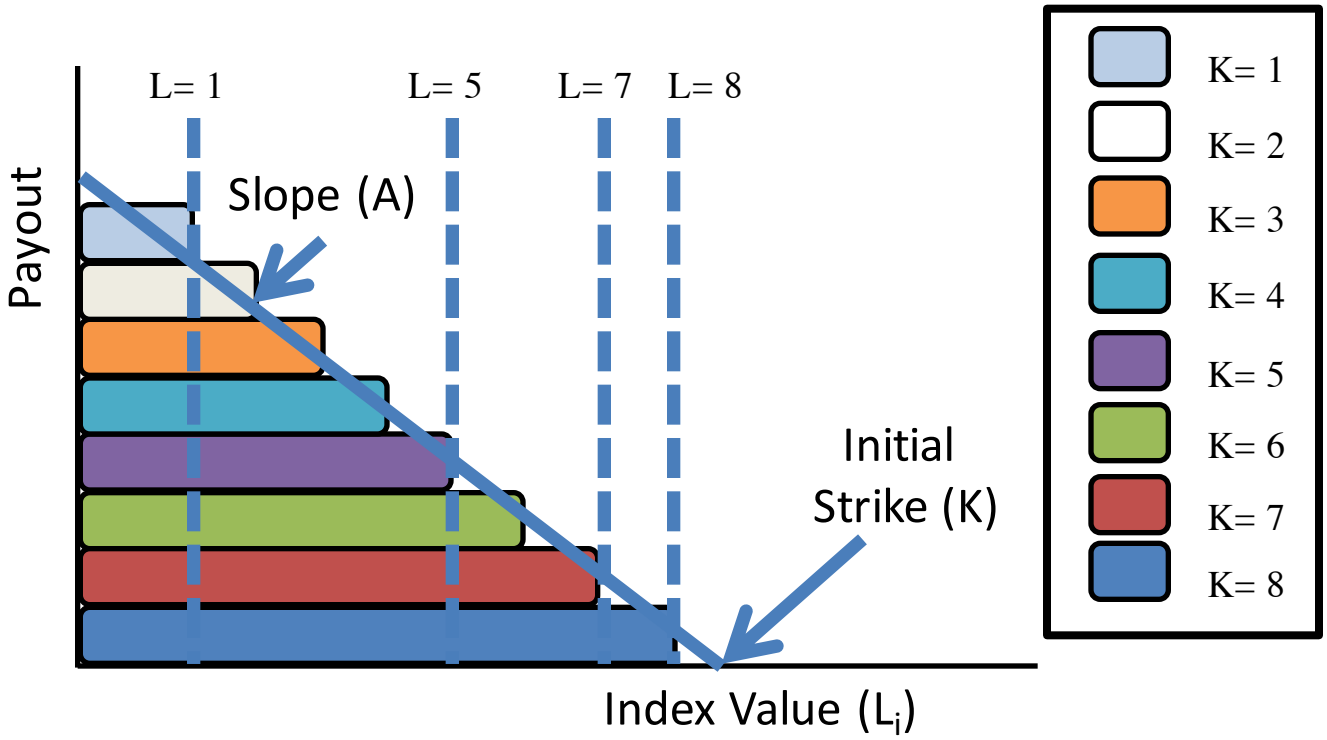


Binary Contracts



$$P(l) = \begin{cases} \Pi & if\ l \leq K \\ 0 & otherwise \end{cases}$$

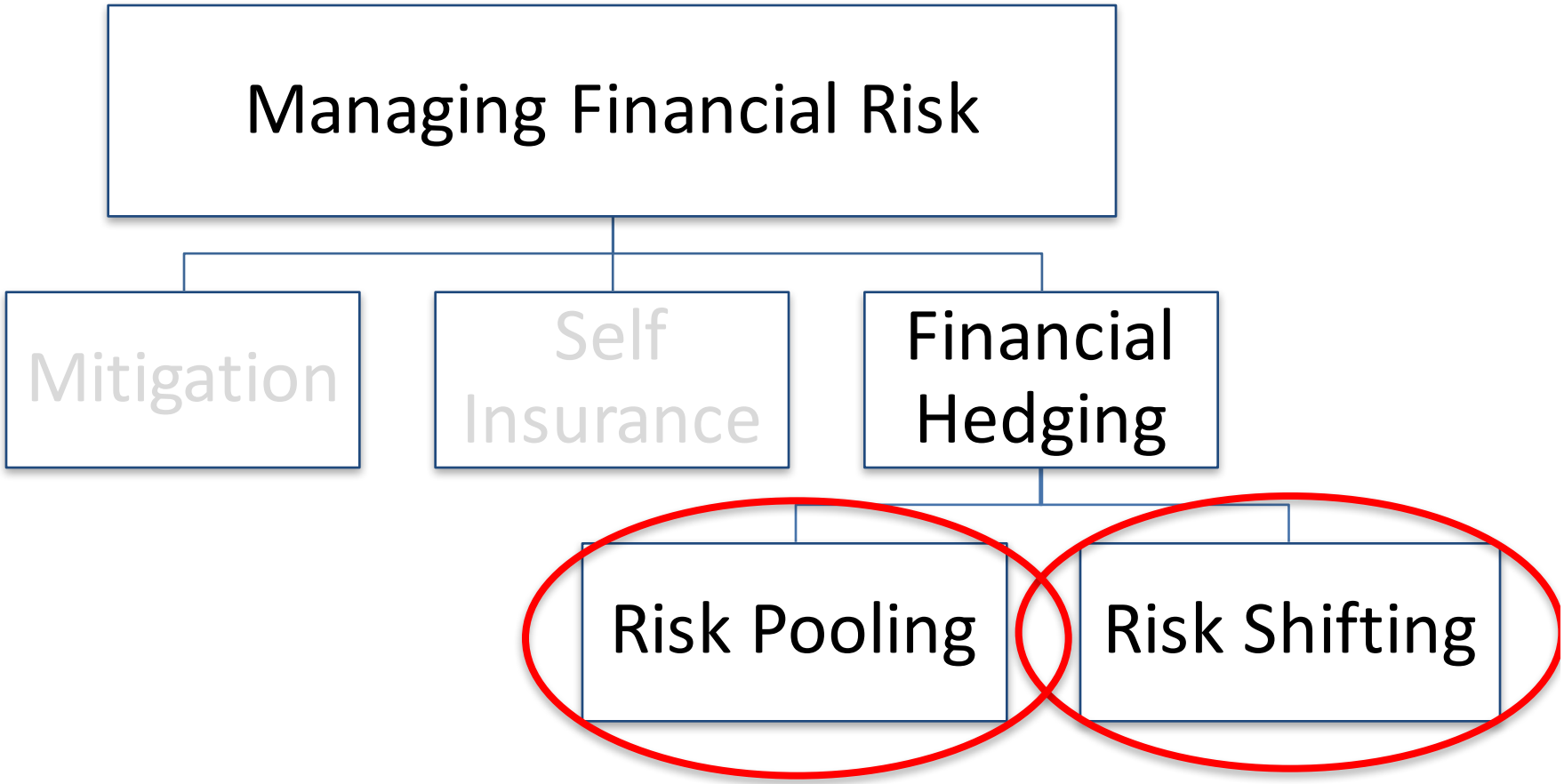
Binary Contracts



$$P(L) = \begin{cases} \Pi & if\ L \leq K \\ 0 & o.w. \end{cases}$$

Meyer, E. S., Characklis, G. W., Brown, C. M. and P. Moody (2015). "Hedging the Financial Risk from Water Scarcity for Great Lakes Shipping," *Water Resources Research*, doi:10.1002/2015WR017855.

Financial Risk Mitigation



Managing Environmental Financial Risk

1. Identify linkages between financial conditions and environmental conditions (in our case, mostly hydrologic)
2. Model the hydrologic and economic systems as a coupled system, assessing their interdependencies
3. Characterize the financial risk
   i.e. how severe are the losses and how often do they occur?
4. Develop new tools and strategies to manage that risk

Thanks to our funding agencies