Integrating Delta Building Physics and Economics: Optimizing Engineered Avulsions in the Mississippi Delta

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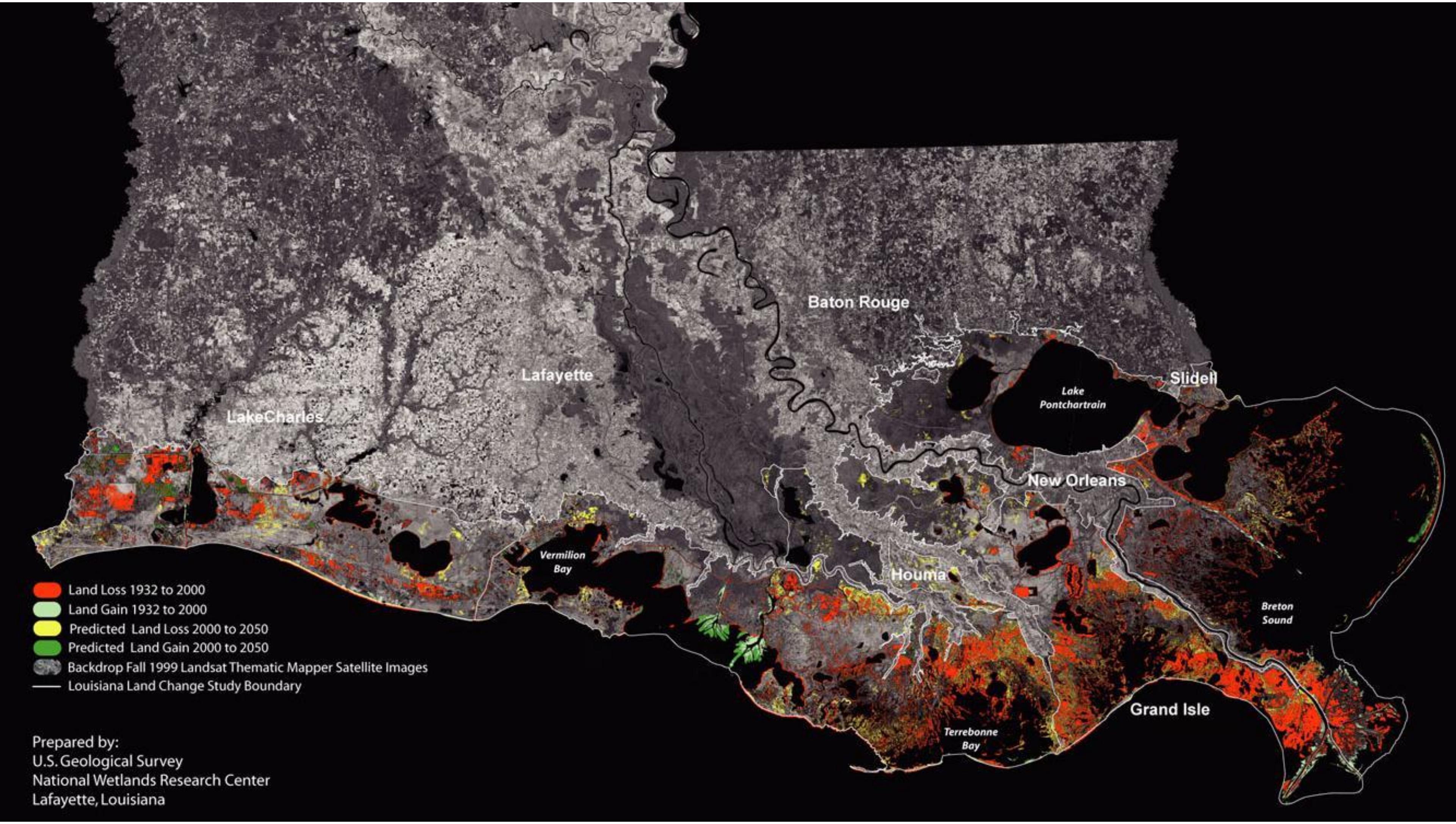
A NSF Science & Technology Center

Motivation: Land Loss in lower delta since 1932



"Most of the Mississippi Delta, some 10,000 square miles, lies less than 3 feet above sea level. Beset by land subsidence and rising sea levels, much of this vast area **will inexorably sink beneath the waters by the end of this century**."

- Bruce Babbitt, Washington Post, 5/18/2007

Sediment Lost to the Deep Gulf

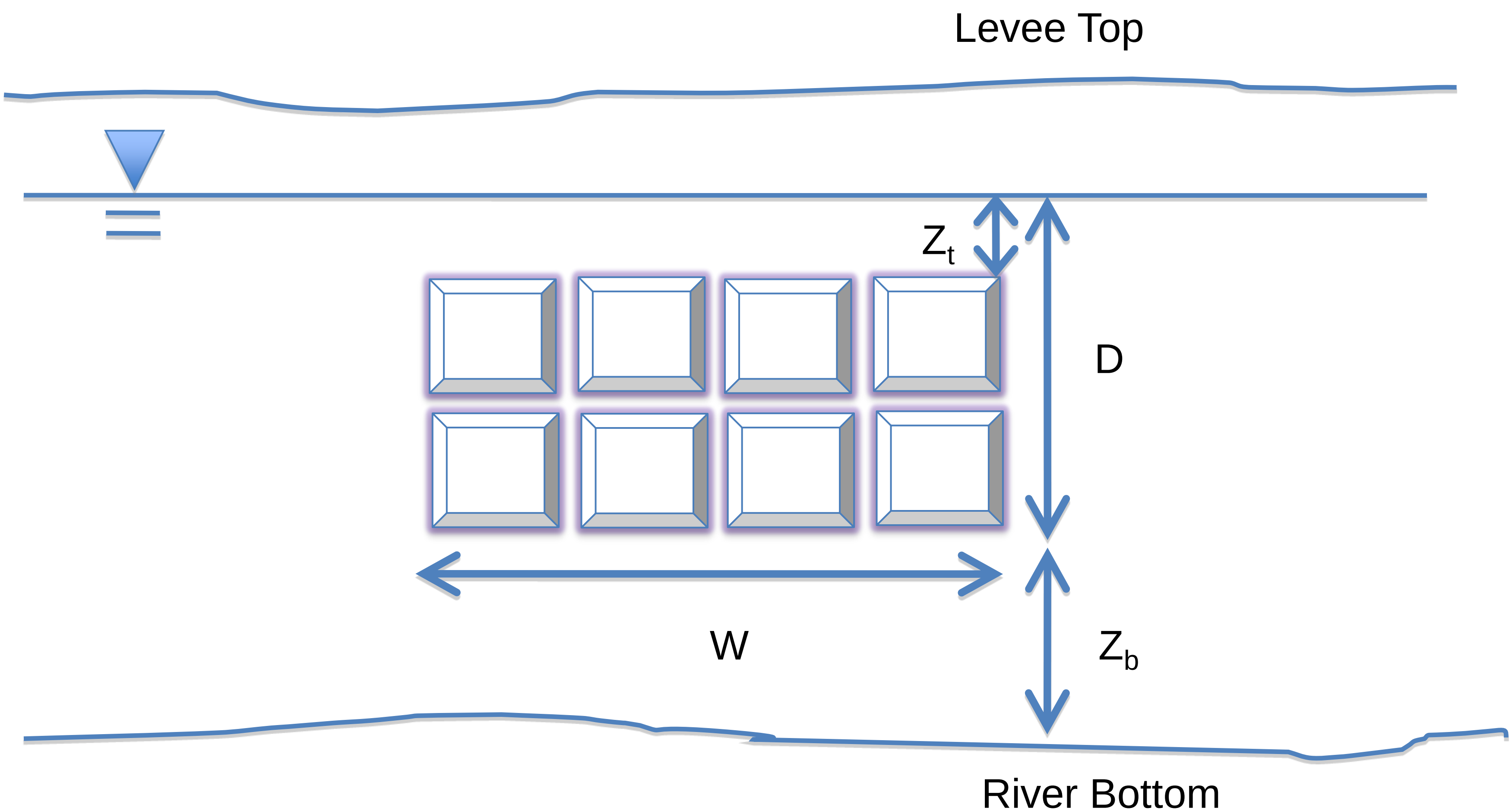
There are a lot of proposed solutions, but… What Engineered Single or Portfolio of Avulsions Gives you the Biggest Bang for your Buck? Deep & Costly *vs.* Shallow & Cheap?

e.g.,Old River Control Structure

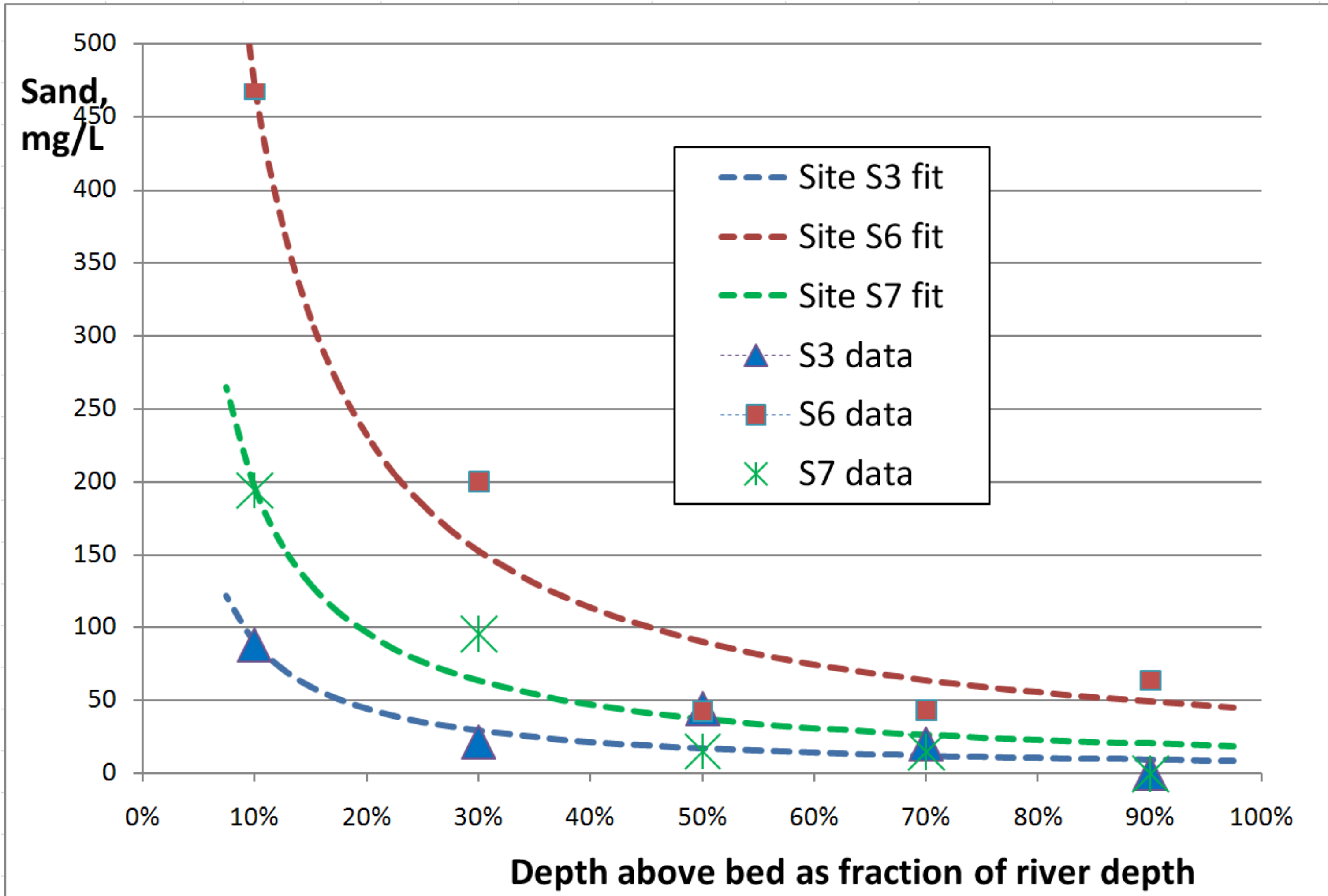
West Bay

Source: http://en.wikipedia.org/wiki/File:Old_River_Control_Structure_Complex.jpg
http://www.mvn.usace.army.mil/prj/westbay/photos/West-Bay-Sediment.gif

Multi-Box Culvert Engineered Avulsion



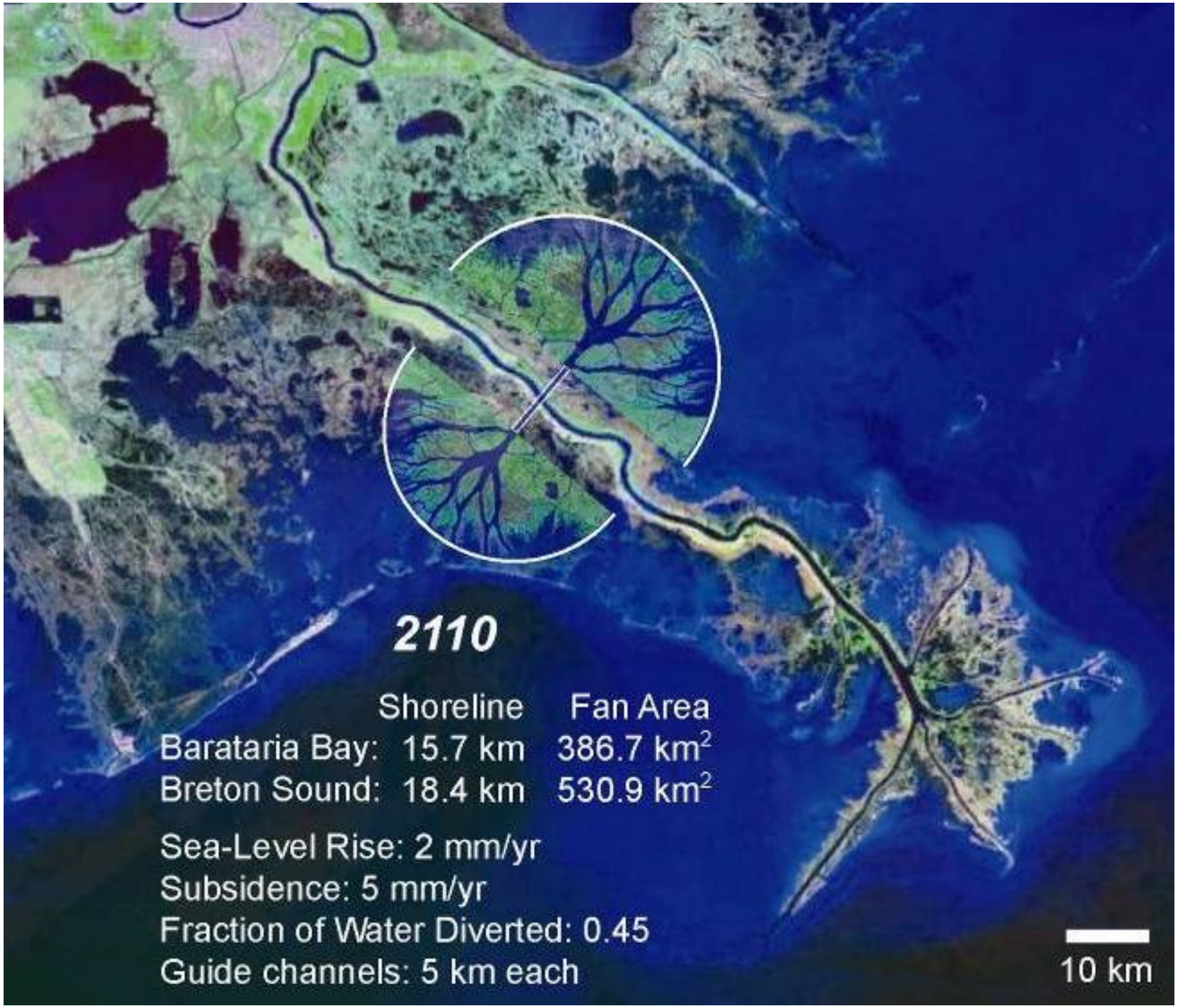
More Sand at Depth



Data: Nittrouer et al. WRR, in press

Dynamic Delta Top: Area is set by a balance between: Sea-level rise + Subsidence and deposition of sediment & organic matter

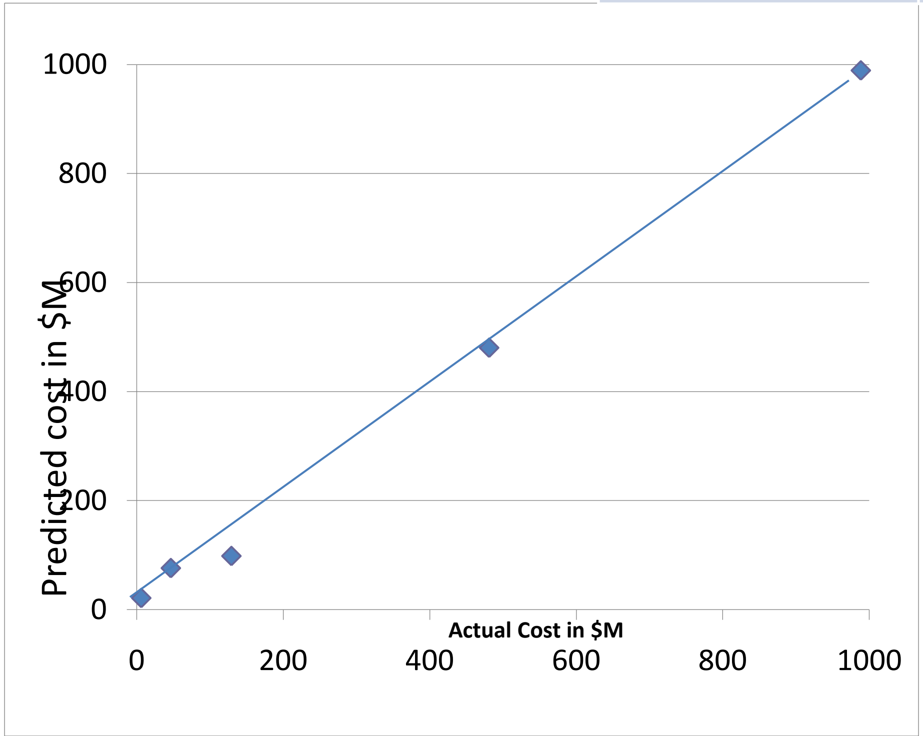
$$\left(\dot{H}+\sigma\right)A_{top} = f_r Q_s + r_{org} A_{top}$$



Results of Land building Model : BASE CASE
(Parker, Kim, Mohrig, Paola & Twilley, AAAS 2008)

Cost Function

	Depth D (m)	Width W (m)	Cost (2010$)
Bonnet Carre	7.62	2330	481,000,000
Caernarvon Diversion	7.32	57	46,300,000
Davis Pond	7.92	74	129,000,000
Old River	19.51	425	989,000,000
West Bay	2.44	170	5,920,000

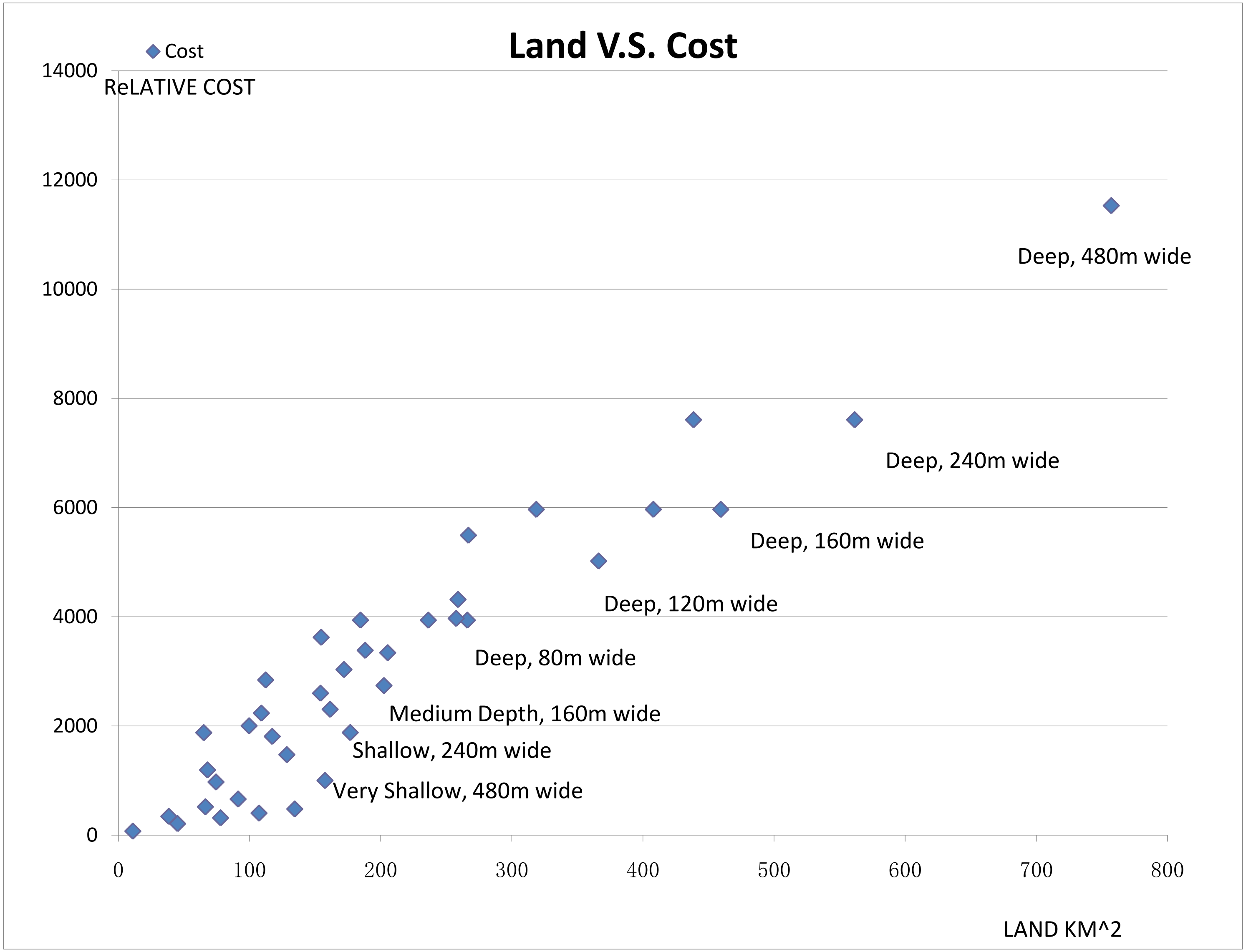


$$\text{Cost (2010\$M)} = 0.427D^{1.634}\,W^{.487}$$

$$R^2 = .997$$

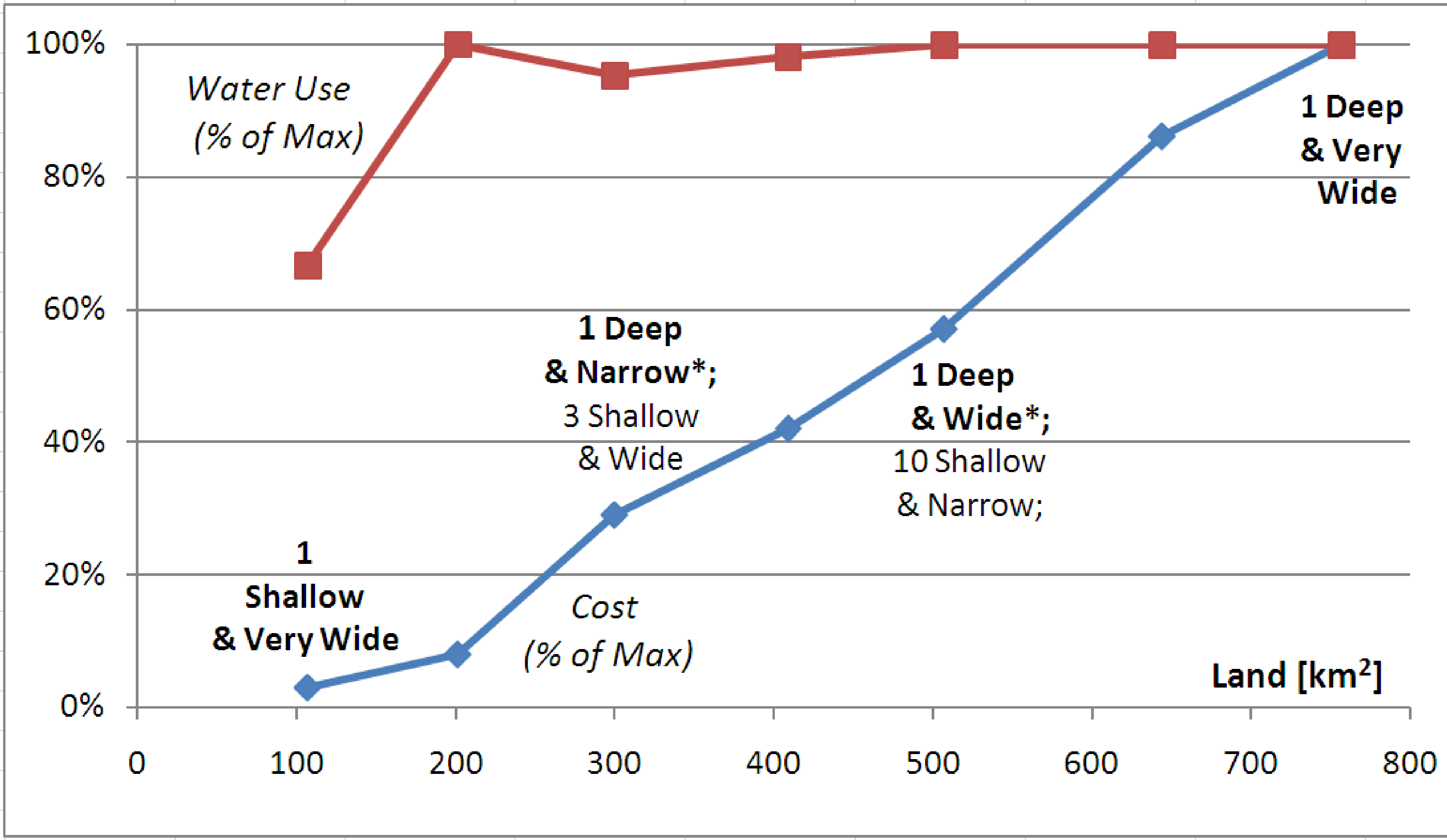
Single Project: Cost of Land Building

(Exponential Function)



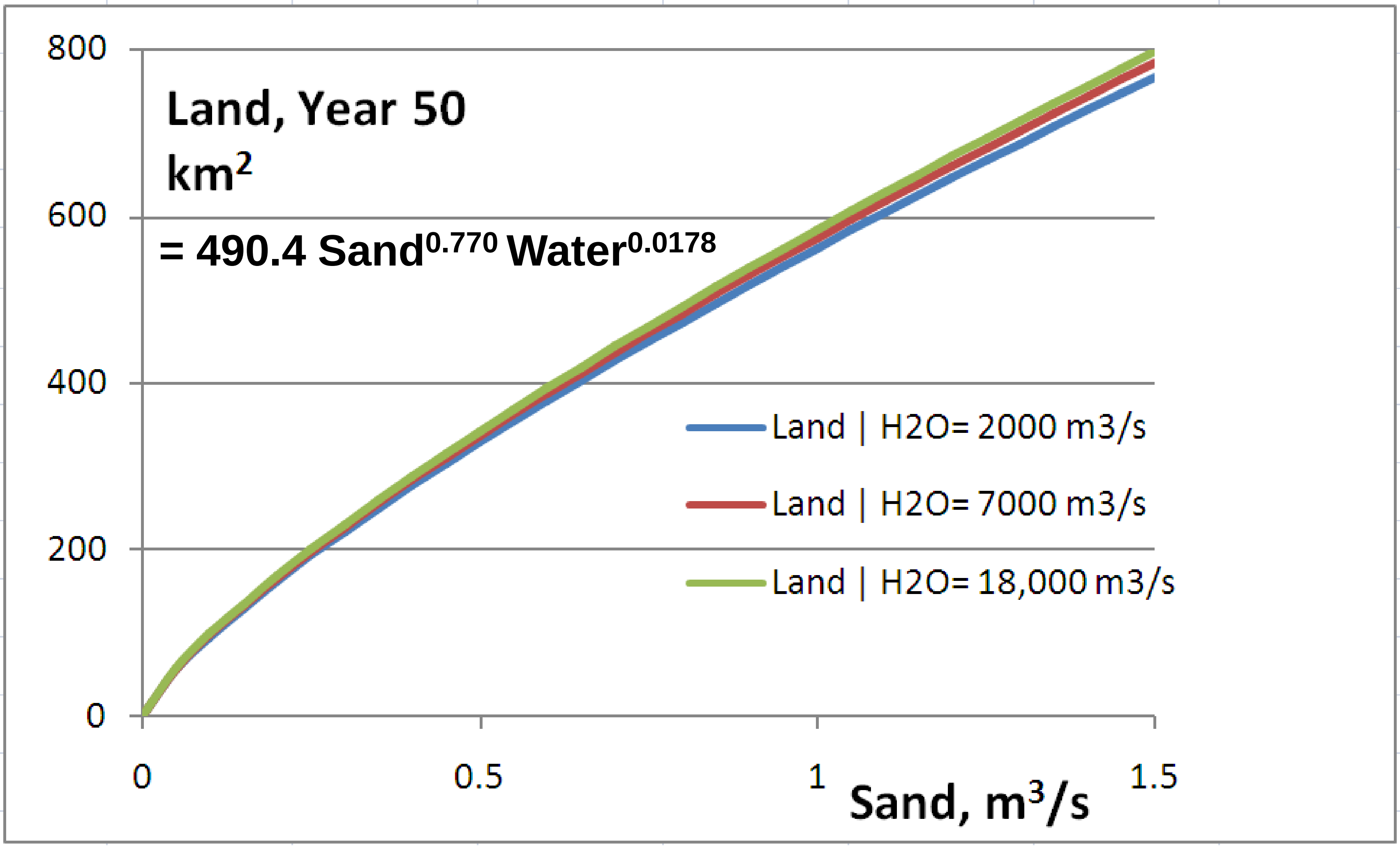
Optimal Project Portfolio

Given: 45% Water Diversion Limit; W Scale Economies, D Scale Diseconomies



*Provides bulk of land

Bathymetry:
Single Project Shows Scale Diseconomies in Land Building as f(Sand Diverted)



Scale Conclusions

- If water diversion limited to 45% of flood flow, can build 700 km^2 after 50 years
- For smaller amounts of land (100-200 km^2):
  - Shallow projects can be most efficient
  - Water diversion limits not binding
- For largest amounts (700 km^2):
  - Deep & costly avulsions preferred
  - Sand concentrations at depth outweigh lower cost of shallow avulsions
    - Especially when diverting maximum allowed total water
  - Usually several narrower projects preferred
    - Large project results in less land per unit sand diverted due to bathemetry
    - 2-5 deep, narrower projects best for land for nearly all cases
    - Exception: if strong W economies and exponential sand, then 1 deep, wide project best

Summary

- Land is a function of water, sediment, and time
- Cost is a function of the diversion depth and width – deeper diversions are more expensive
- Scale tradeoffs:
  - Scale economies:
    - Wider avulsions are cheaper per unit of width
    - Deeper gives more sand per unit water
  - Scale diseconomies:
    - Deeper is more expensive per unit depth
    - More sand results in less land per unit of sand
- On balance, to maximize land building, a portfolio should include <u>multiple projects including at least one deep project</u> because of slope of bed, water constraints
- Caveat: Analysis considers generic cost and sediment functions, not site specific conditions

Thank you!

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