Risk-Informed Decision Making for Port and Coastal Development

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Engineers Australia

“Sustainable Dredging and Sediment Management: Assessing and Managing Environmental Effects and Benefits”

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US Army Corps of Engineers

ERDC
Engineer Research and Development Center

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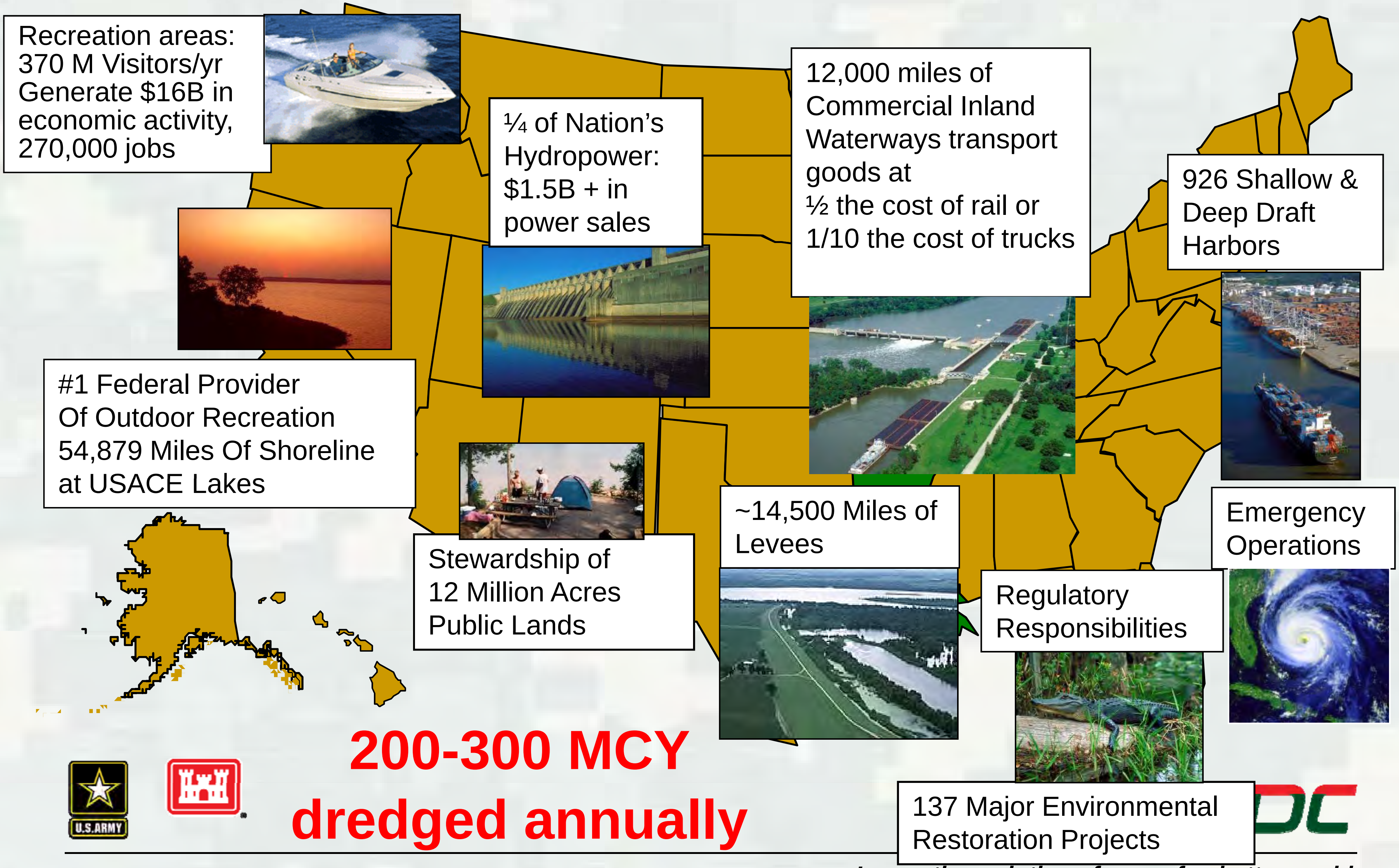
- U.S. Army's Senior Research Scientist (ST) for Environmental Science
- Director, Center for Contaminated Sediments
- Program Manager, Dredging Operations Environmental Research
- Program Manager, USACE Engineering With Nature
- >20 years of experience developing and applying science and engineering for USACE, U.S. Army, DoD, USEPA, others
- Awards
  - 2009 recipient of the Government Service Award from the Society of Environmental Toxicology and Chemistry
  - 2012 recipient of Outstanding Practitioner Award from the Society for Risk Analysis
- Published >60 scientific papers and book chapters and numerous technical reports
- PhD, Biological Oceanography, North Carolina State University, 1992

USACE Civil Works Value to the Nation



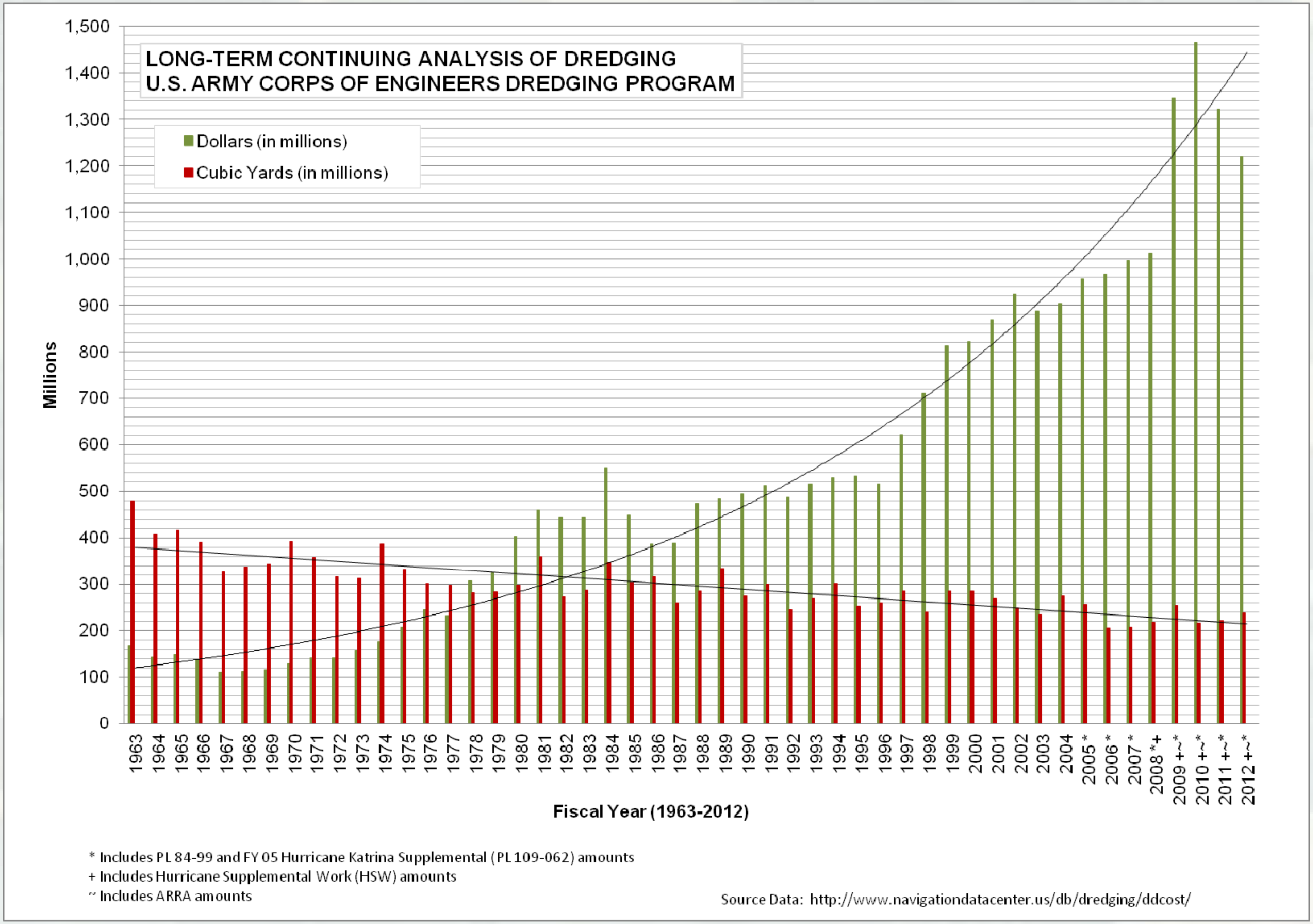
200-300 MCY dredged annually

A Systems View

- We build and manage systems to achieve specific objectives
  - ► Navigation system:
    - locks, dams, channels
  - ► Flood risk reduction system:
    - Structural, nonstructural, ecosystem features
  - ► Ecosystems supporting values and services
- Balancing objectives and optimizing
  - ► Law, regulation, dialogue and deliberation

U.S. Environmental Laws and Regulations

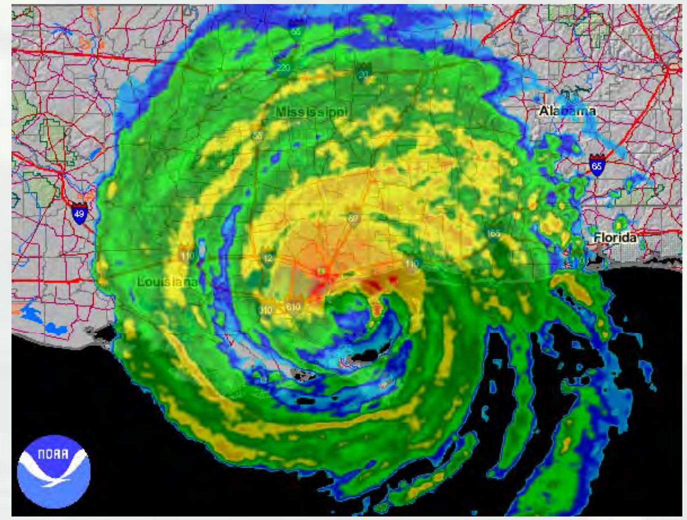
- National Environmental Policy Act of **1969**
- Federal Water Pollution Control Act of **1972** (amended and renamed the Clean Water Act in **1977**)
- Marine Protection, Research, and Sanctuaries Act of **1972** (commonly called the Ocean Dumping Act)
- Coastal Zone Management Act of **1972**
- Marine Mammal Protection Act of **1972**, amended **1994**
- Endangered Species Act of **1973**
- Resource Conservation and Recovery Act of **1976**
- Magnuson-Stevens Act as reauthorized by the Sustainable Fisheries Act of **1996**
- Etc.



LONG-TERM CONTINUING ANALYSIS OF DREDGING
U.S. ARMY CORPS OF ENGINEERS DREDGING PROGRAM
Dollars (in millions)
Cubic Yards (in millions)
Millions
Fiscal Year (1963-2012)
* Includes PL 84-99 and FY 05 Hurricane Katrina Supplemental (PL 109-062) amounts
+ Includes Hurricane Supplemental Work (HSW) amounts
~ Includes ARRA amounts
Source Data: http://www.navigationdatacenter.us/db/dredging/ddcost/

What is risk-informed decision making?

- A process for making risk management decisions that can be supported in terms of quantitative evidence about risk reduction, where
  - ► *risk* considers the likelihood for all relevant adverse impacts
  - ► uncertainties are explicitly considered and processes are implemented to manage them
  - ► the investment is commensurate with the magnitude of the risks

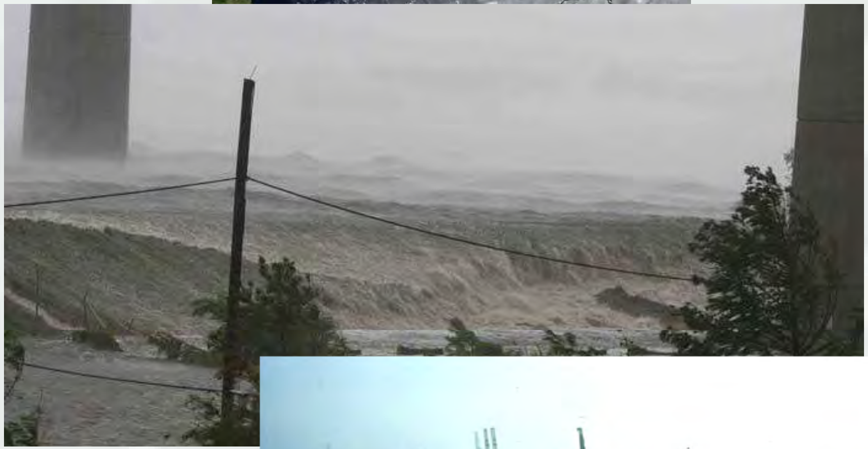


“Transforming Practice to Apply Risk-Informed Decision Making.” T.S. Bridges 2007
“Transforming the Corps into a Risk Managing Organization.” D. Moser, T. Bridges, S. Cone, Y. Haimes, B. Harper, L. Shabman, C. Yoe. 2007

Risk Defined

Risk: The likelihood or probability for an adverse outcome

- Examples
  - Likelihood that a family picnic will be spoiled by inclement weather
  - Probability of injury resulting from a car accident
  - Likelihood that you will spend more than necessary on your next car purchase (or dredging project)



The USACE Navigation Mission:

To provide safe, reliable, efficient, effective and environmentally sustainable waterborne transportation systems for movement of commerce, national security needs, and recreation

- Observations
  - ► The Corps' navigation mission involves multiple objectives
  - ► Managing the risks relevant to these objectives requires making tradeoffs

What risks are we concerned about?

- Economic losses associated with reduced performance of a channel
- Environmental impacts associated with dredging
- Environmental impacts associated with DM placement, disposal, or beneficial use
- Navigation accidents
- Unnecessary costs for the dredging program
- Environmental impacts associated with contaminated sediments when dredging must be deferred

Risk Analysis

Risk-Informed Decision Making

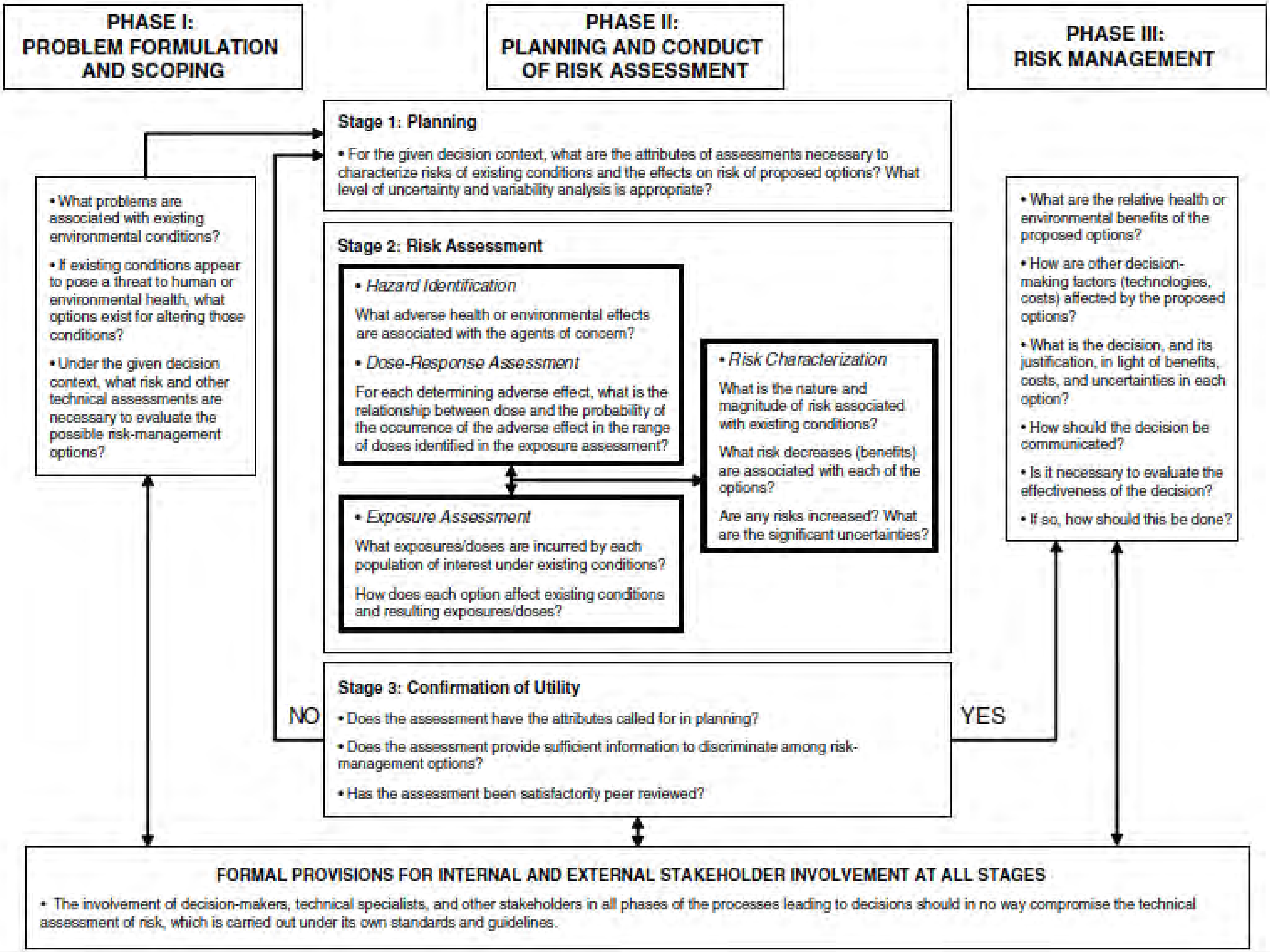
- *Risk Assessment*: an approach to developing an understanding of the processes shaping the scope and nature of risks and uncertainties that is sufficient to support decision making
  - ▸ What is the risk?
  - ▸ Why and how are the risks occurring?
  - ▸ What is the uncertainty associated with the risk estimate?

Risk-Informed Decision Making

- *Risk Management*: a process to evaluate, select, implement, monitor and modify actions to alter levels of risk
  - ► What are my decision alternatives?
  - ► How will I evaluate the performance of those decision alternatives?
  - ► How do the decision alternatives differ in terms of risks?
  - ► What are the tradeoffs in terms of costs, benefits, and risks among the alternatives?

Risk-Informed Decision Making

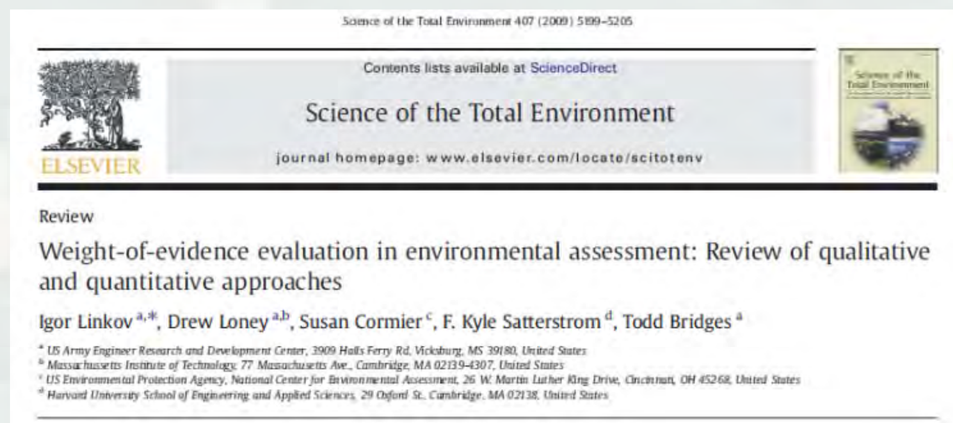
- *Risk Communication*: exchange of information about risks that supports deliberation and decision-making
  - ▶ Why are we communicating?
  - ▶ With whom are we communicating?
  - ▶ How will we communicate?
  - ▶ What are we communicating?



National Research Council. 2009. Science and Decisions: Advancing Risk Assessment. Washington DC, National Academies Press.

Weight-of-Evidence

- (WOE): an approach for synthesizing individual lines-of-evidence using qualitative or quantitative methods in order to develop conclusions about risks.
  - ► Structures and formalizes consideration of multiple lines-of-evidence
  - ► Supports transparency in decision making
  - ► Consistency, repeatability



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ELSEVIER

Review

Weight-of-evidence evaluation in environmental assessment: Review of qualitative and quantitative approaches

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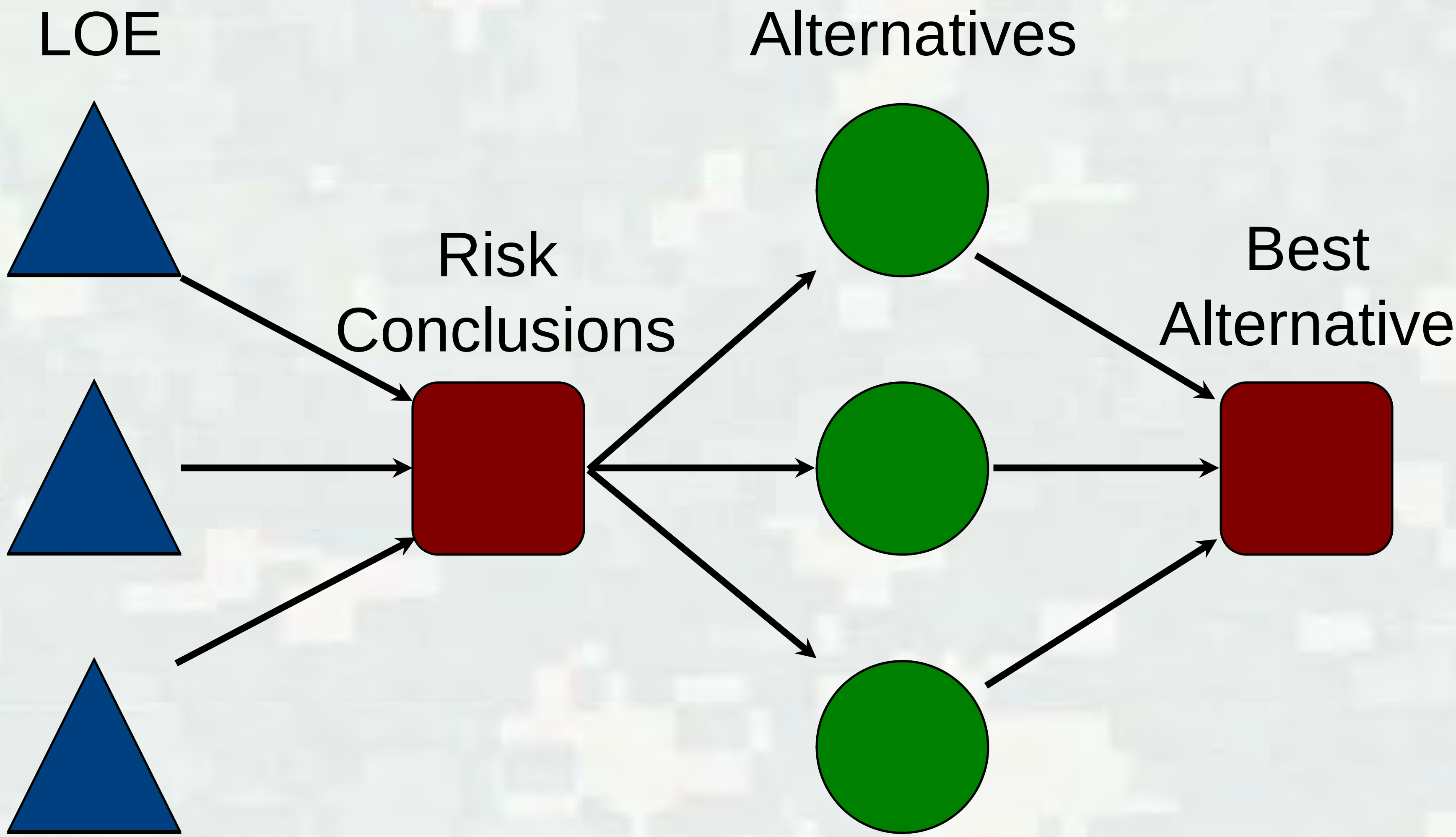
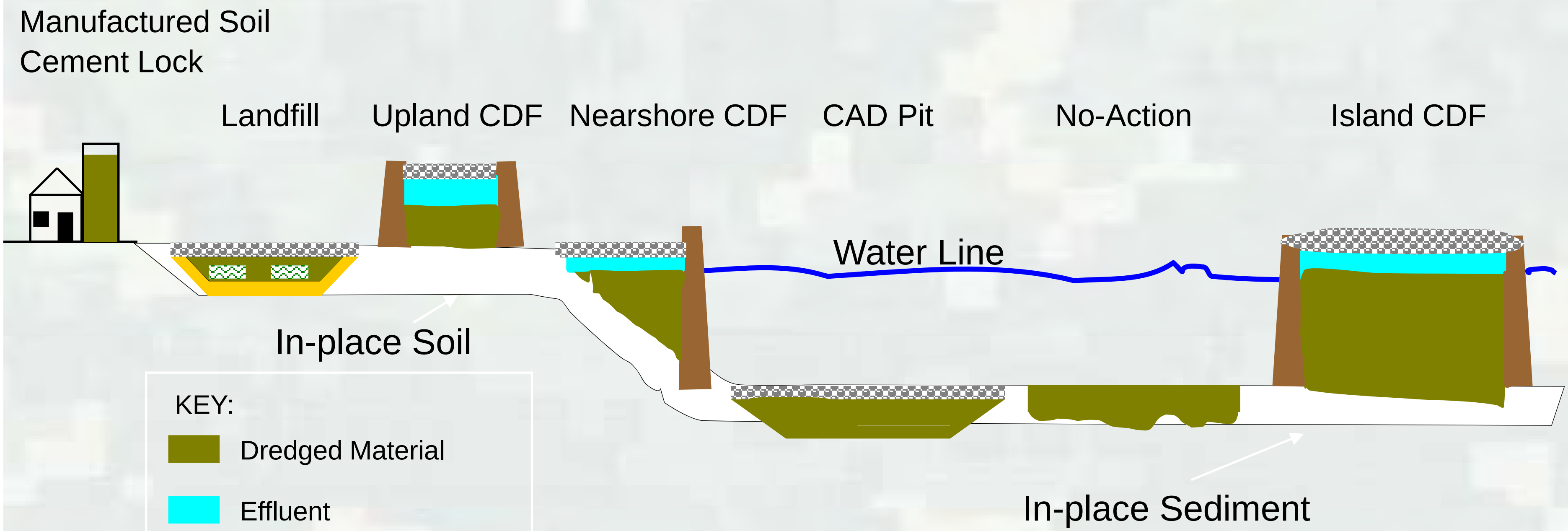
U.S. ARMY

Using Lines-of-Evidence



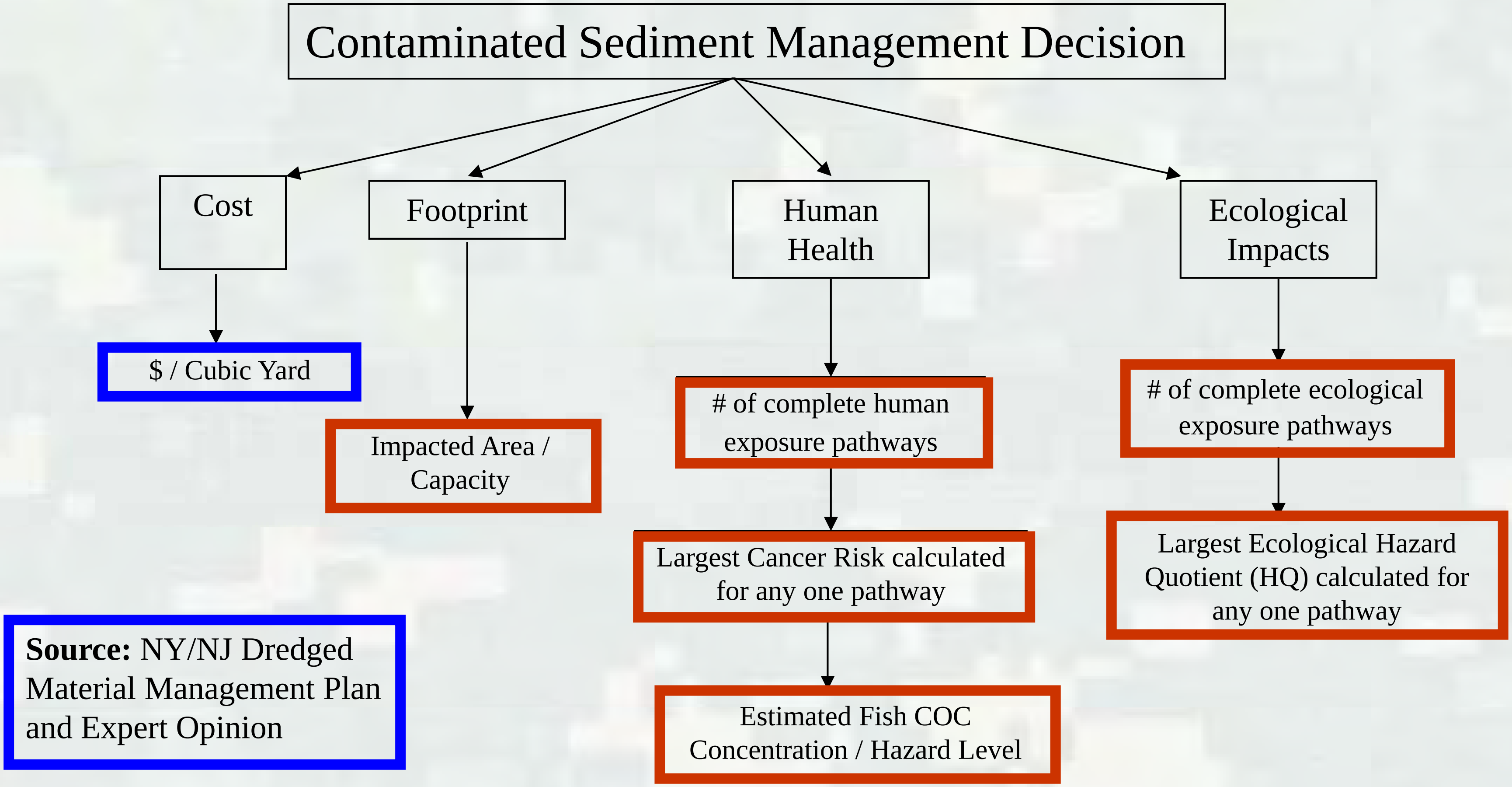
A Sediment Example



Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.

G. A. Kiker, T. S. Bridges, J. B. Kim. 2008. Integrating Comparative Risk Assessment with Multi-Criteria Decision Analysis to Manage Contaminated Sediments: An Example From New York/New Jersey Harbor. *Human and Ecological Risk Assessment* 14:495-511.

Decision Criteria: NY/NJ Harbor



Source: Kane Driscoll et al. (2002).

Criteria Levels for Each DM Alternative

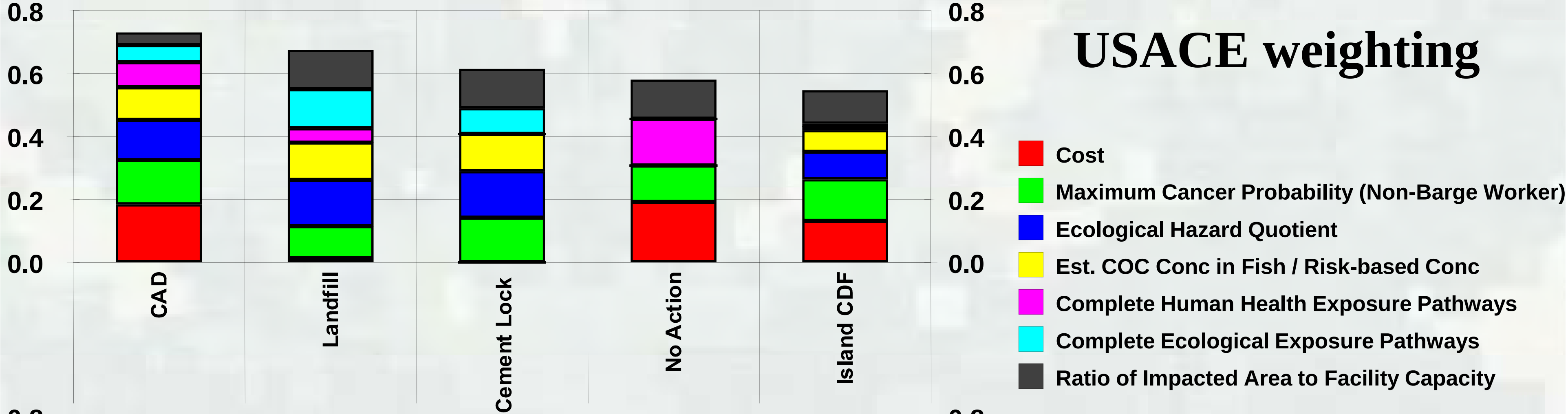
DM Alternatives	*Cost*	*Footprint*	*Ecological Risk*		*Human Health Risk*		
	($/CY)	Impacted Area/Capacity (acres / MCY)	Ecological Exposure Pathways	Magnitude of Ecological HQ	Human Exposure Pathways	Magnitude of Maximum Cancer Risk	Estimated Fish COC / Risk Level
CAD	5-29	4400	23	680	18	2.8 E -5	28
Island CDF	25-35	980	38	2100	24	9.2 E -5	92
Near-shore CDF	15-25	**6500**	38	900	24	3.8 E -5	38
Upland CDF	20-25	**6500**	38	900	24	3.8 E -5	38
Landfill	29-70	0	0	0	21	3.2 E –4	0
No Action	**0-5**	0	**41**	**5200**	12	2.2 E –4	**220**
Cement-Lock	**54-75**	0	14	0.00002	**25**	2.0 E -5	0
Manufactured Soil	54-60	750	18	8.7	22	**1.0 E –3**	0

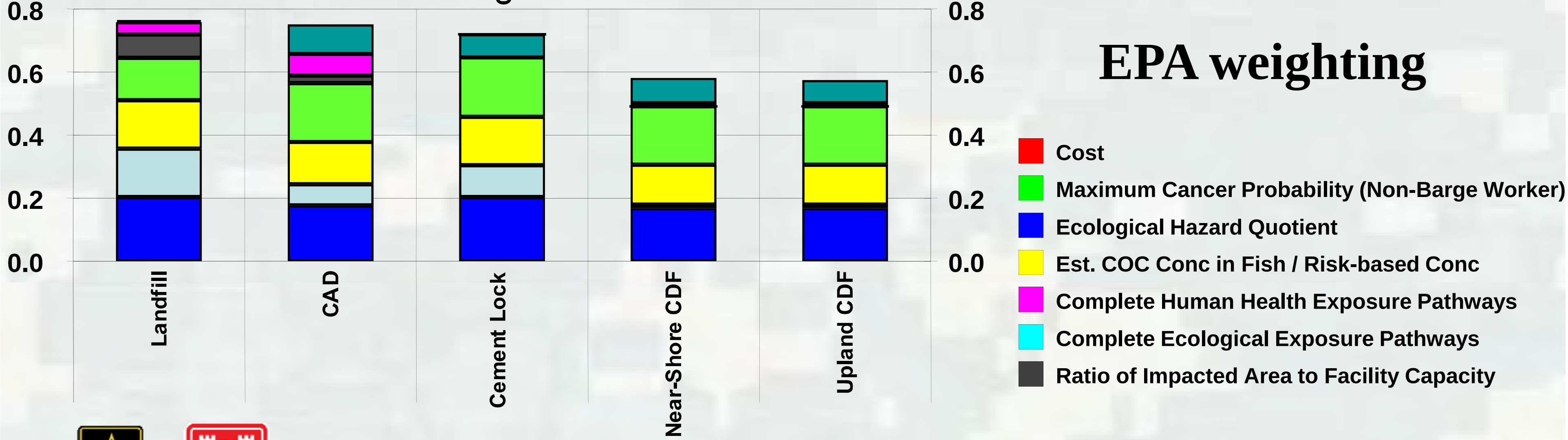
Blue Text: Most Acceptable Value
Red Text: Least Acceptable Value

USACE/EPA Survey Results: Criteria Weights (%)

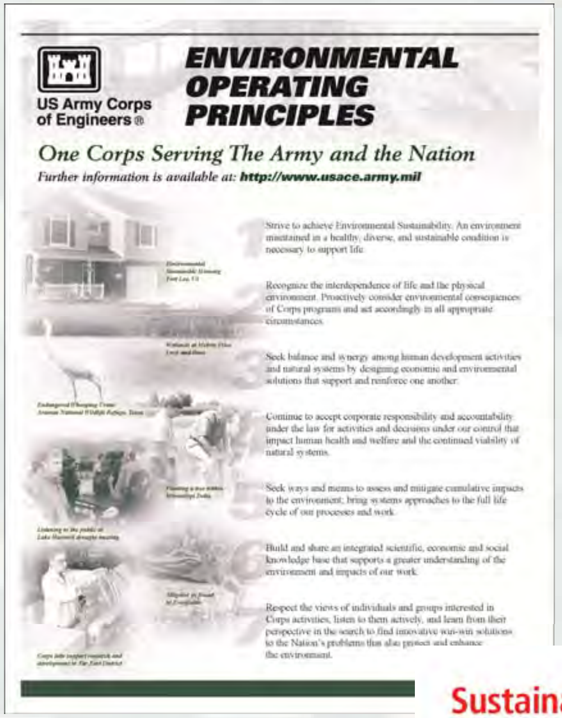
	EPA	USACE
Footprint	7.4	12.5
Ecological Health	35.6	27.1
Human Health	47.0	40.7
Cost	10.0	19.7

MCDA Rankings





Sustainability



Goals:

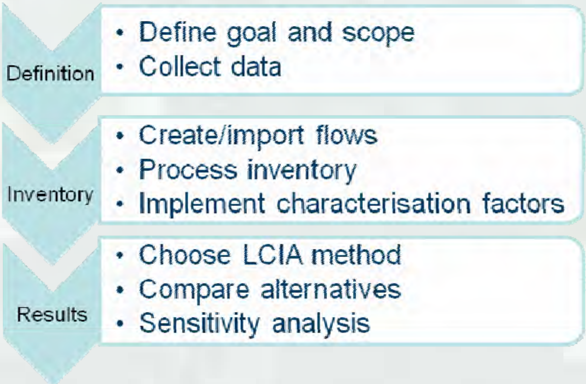
- More efficient, cost effective engineering and operational practices.
- More collaboration and cooperation, less unproductive conflict.
- Sustainable projects: Triple-win outcomes integrating social, environmental and economic objectives.

Vision: “Contribute to the strength of the Nation through innovative and environmentally sustainable solutions to the Nation’s water resources challenges.”

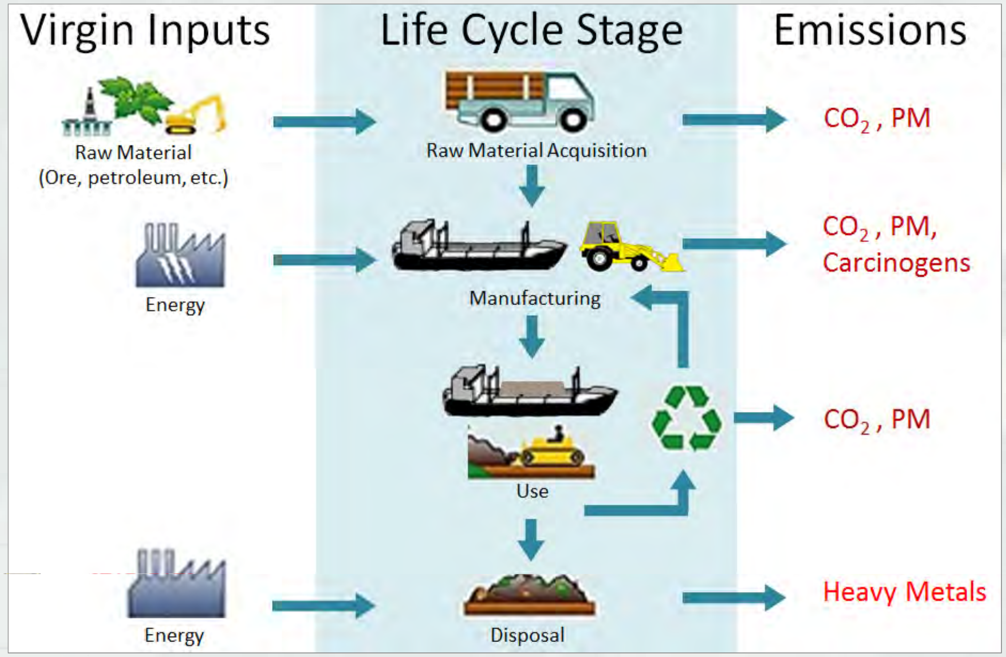
ERDC

Life Cycle Assessment Process Overview

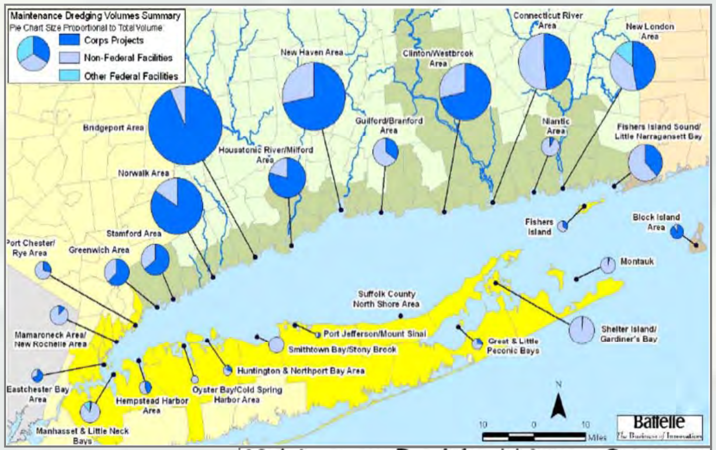
1. Goal and Scope Definition
2. Inventory Analysis
3. Impact Assessment
4. Results and Interpretation

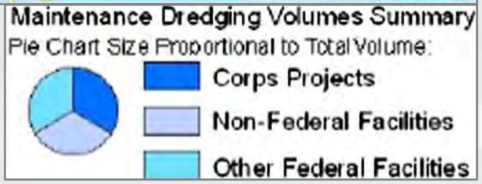


Source: ISO 14040 (2006)



Long Island Sound LCA Project





Site Issues

- Fishing and environmental communities prefer upland placement for all sediment.
- 4 open water sites located in LIS are closer/cheaper for uncontaminated sed.

Study Objectives

- Use LCA to inventory broad environmental impacts for three disposal methods at varying distances.

Alternatives

Upland/Landfill

Island Creation

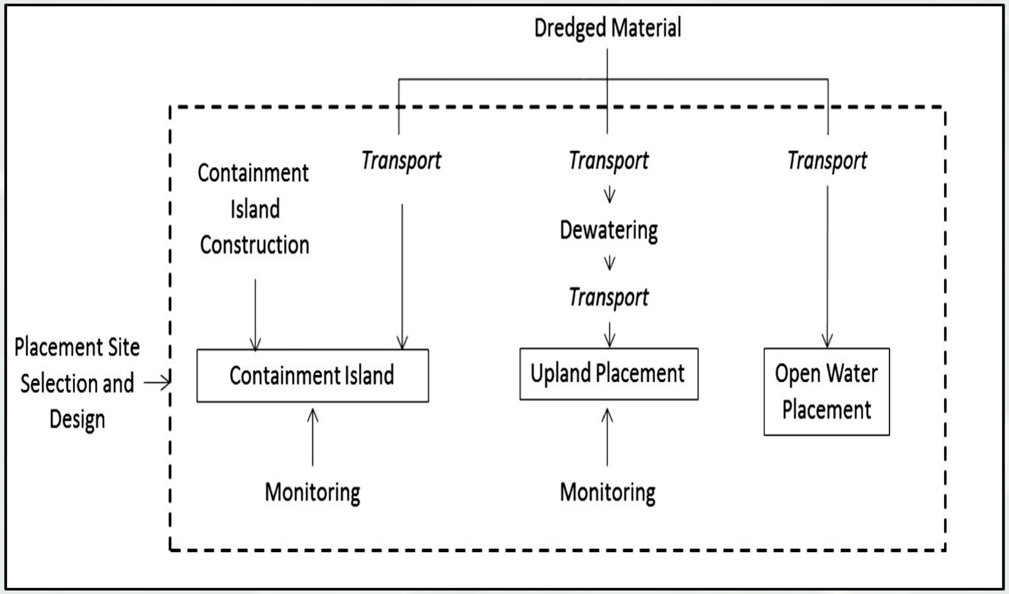
Open Water

Each at 10 mi, 20 mi, 60 mi distances

Reference: Bates et al. (2015) Life cycle assessment for dredged sediment placement strategies. *Sci Tot Env.* 511, 309-318.

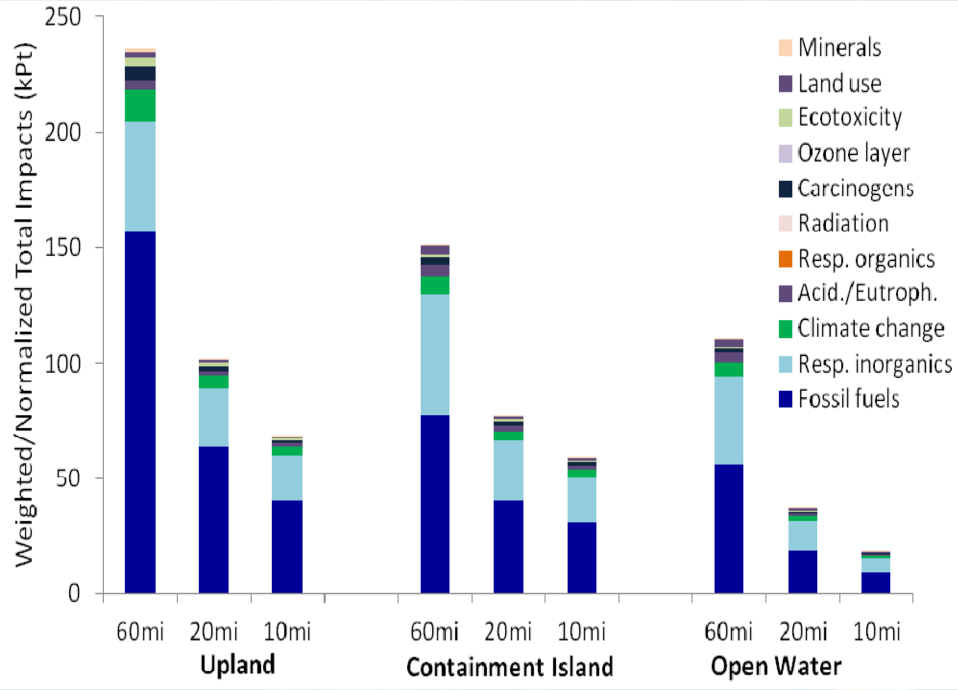
Long Island Sound LCA Project
Life Cycle Inventory

- Identify system boundaries and processes.
- Model sediment placement and track resource inputs and environmental outputs for all equipment and fuel usage.



Long Island Sound LCA Project
Impact Assessment

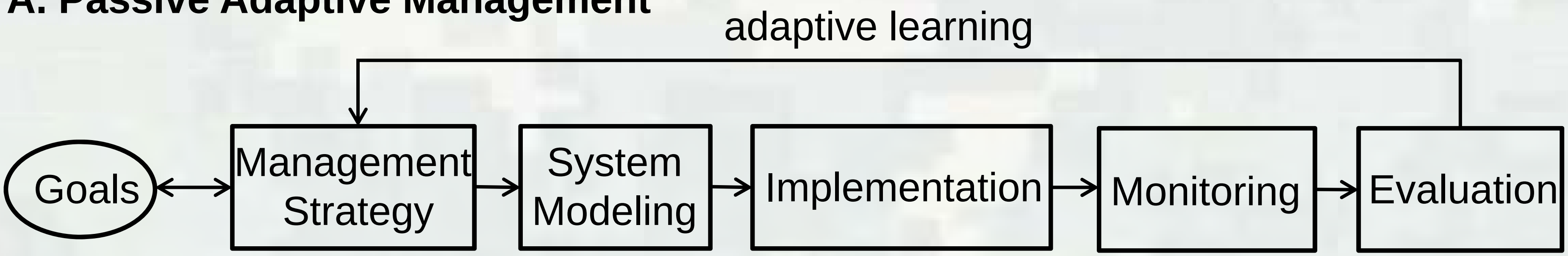
- Compare alternatives on individual health, atmosphere, aquatic and terrestrial impacts or on overall life-cycle impact score.



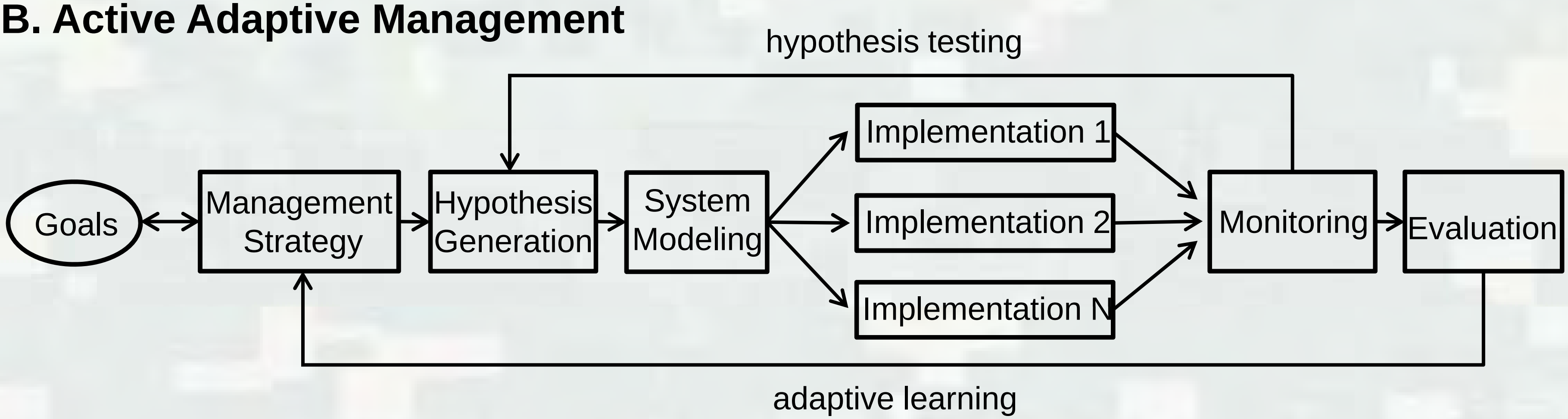
Adaptive Management

- Uncertainty is inherent to planning, design, construction, and O&M
- Adaptive management requires a framework for collecting and using information that results from:
  - ▸ Implementing a plan
  - ▸ Monitoring the performance of the plan
  - ▸ Learning
  - ▸ Adjusting

A. Passive Adaptive Management



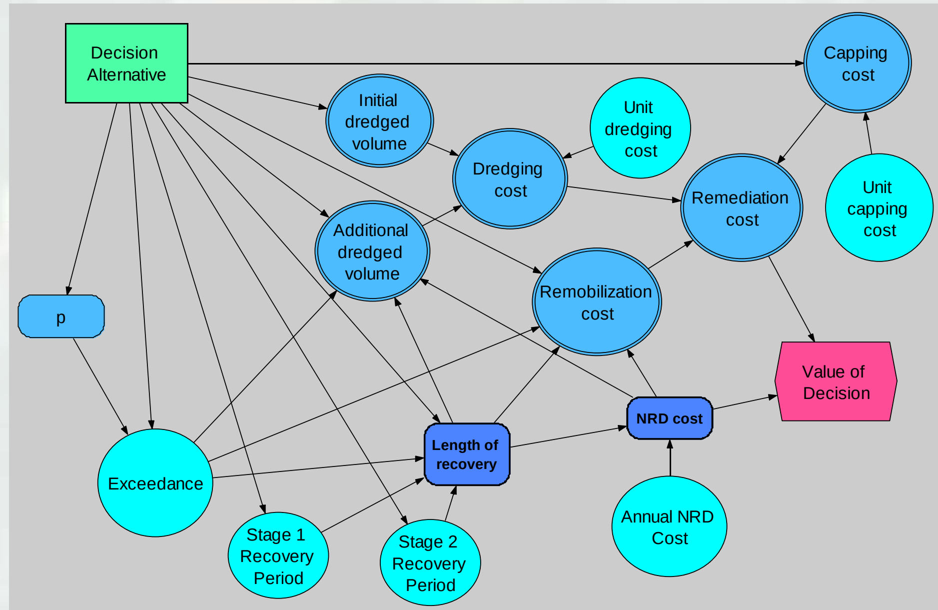
B. Active Adaptive Management



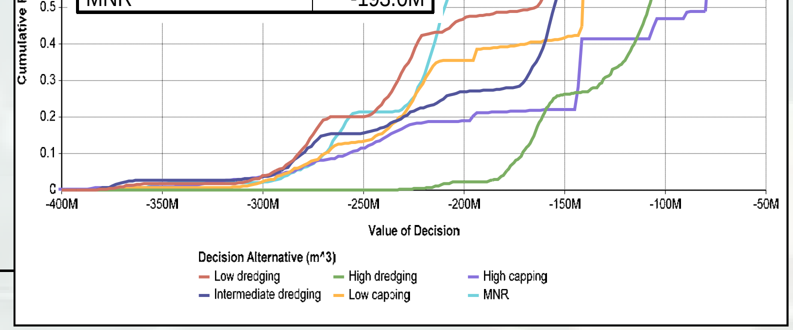
"Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality." Nikola Tesla, *Modern Mechanics and Inventions, July, 1934*

Quantitative Adaptive Management

- Decision modeling and Value of Information analysis provides opportunity to:
  - Determine the consequences of differences in values and risk attitudes among decision-makers and stakeholders
    - i.e., how these differences could affect decison-making and outcomes
  - Explore the consequences of decision-relevant uncertainties
  - Quantify the value of information (VoI)
    - Defining the expected return for investing in more information about X, Y, Z…



Alternatives		Expected Value
Dredging	Low	-193.5M
	Intermediate	-162.1M
	High	**-121.2M**
Capping	Low	-161.2M
	High	-130.5M
MNR		-193.0M



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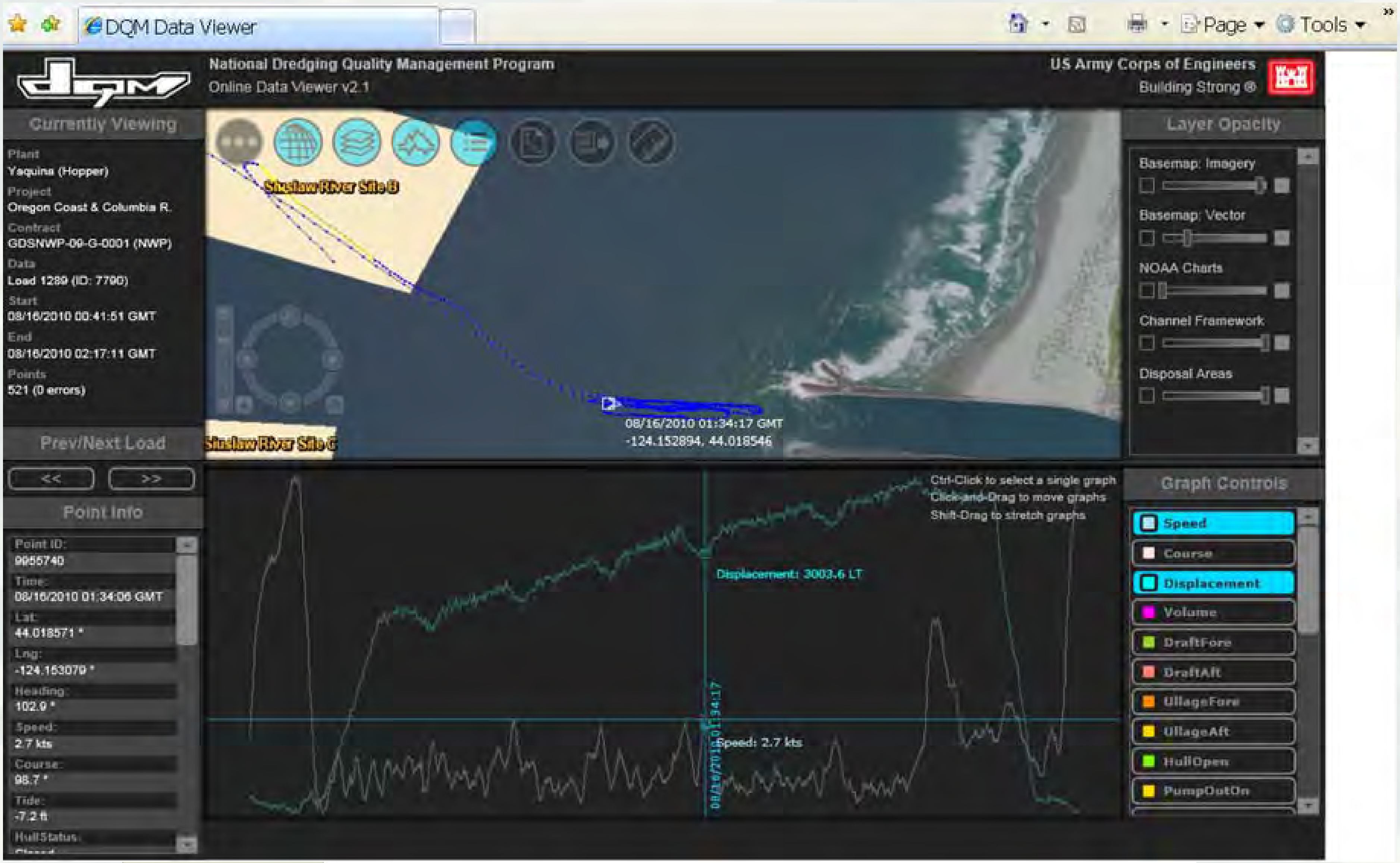

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10 Guidelines for Robust Risk Management

1. Risk management is undertaken through credible, scientific processes
2. Risk management assumes a forward-looking posture
3. Specific and measurable objectives are developed in a transparent and rigorous manner
4. Risk management is accomplished through open, transparent and deliberative processes
5. Uncertainties are acknowledged and addressed through quantitative analysis
6. Risk management investments are commensurate with the magnitude of risks and uncertainties
7. Risk management is a system-scale activity
8. Risk reduction is most reliably achieved through the use of an integrated network of multiple remedial technologies and actions
9. Risk communication is integral to effective risk management
10. Risk management is achieved through formal application of adaptive management

T. Bridges, K. Gustavson. 2013. Risk Management for Contaminated Sediments. In Reible D, ed, *Processes, Assessment, and Remediation of Contaminated Sediment*. Springer Science+Business Media, LLC, New York, NY, USA. pp 197-226.