D2M2: A Systems Approach to Optimizing Regional Dredging

Application to Long Island Sound, NY/CT

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Background

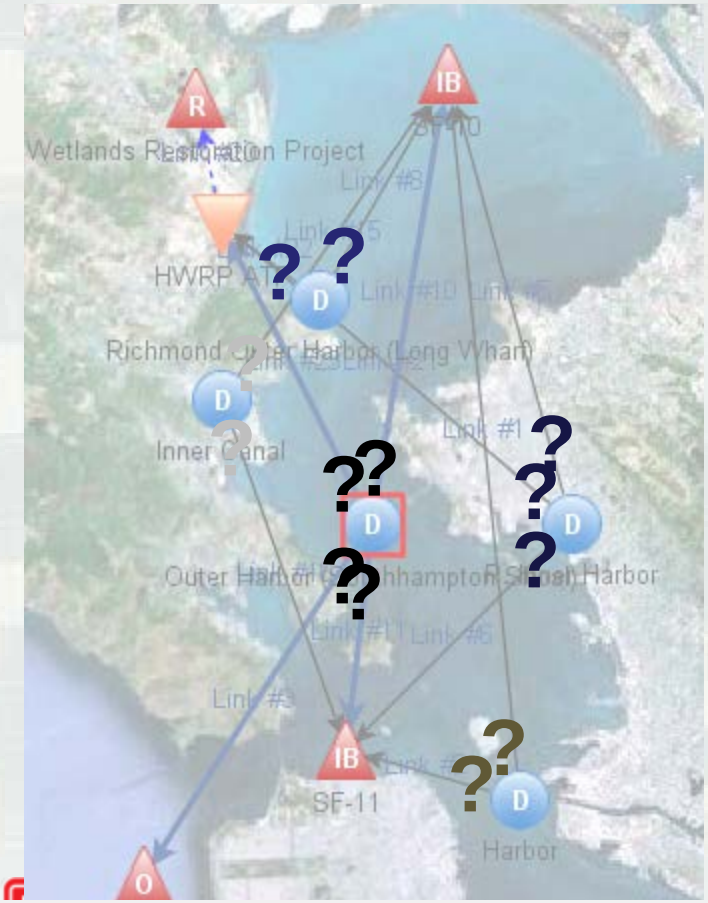
- The US Army Corps of Engineers spends nearly $1 billion annually dredging public waterways.
- This secures access for over 2.2 billion tones of commercial shipping + national security and recreation.
- Strategic placement of dredged material is complex, involving many objectives, interactions, & constraints.

Background

- Optimization helps w/ multifaceted systems problems:
  - Multiple stakeholders with opposing interests.
  - Public concern over environmental effects.
  - High complexity in number of site variables.
  - Desire to use material beneficially for limited cost.

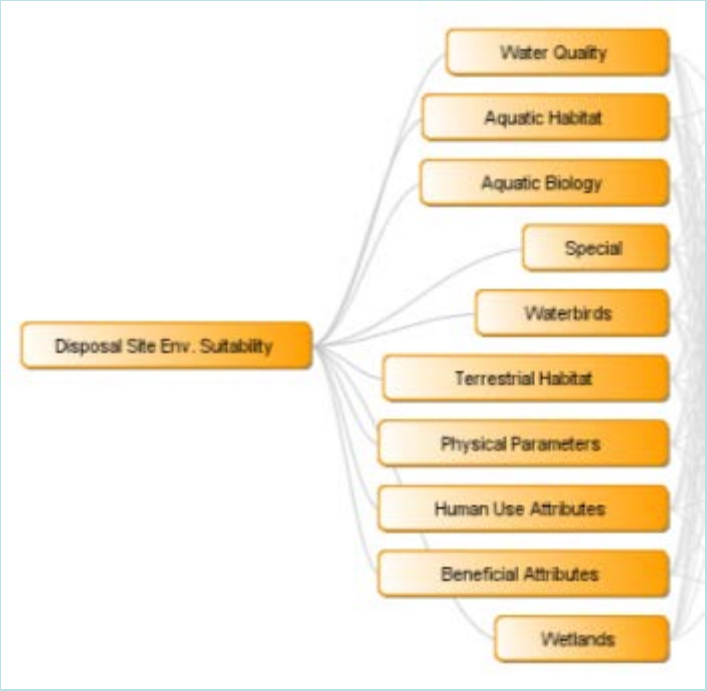
D2M2: Dredged Material Management Decisions

What is the most efficient way to connect potential dredging and placement sites?



…How does this change when we consider temporal, regulatory, capacity, material-type, equipment, and other constraints?

How do we maximize efficiency when tradeoffs need to be evaluated across multiple criteria or types of impact?



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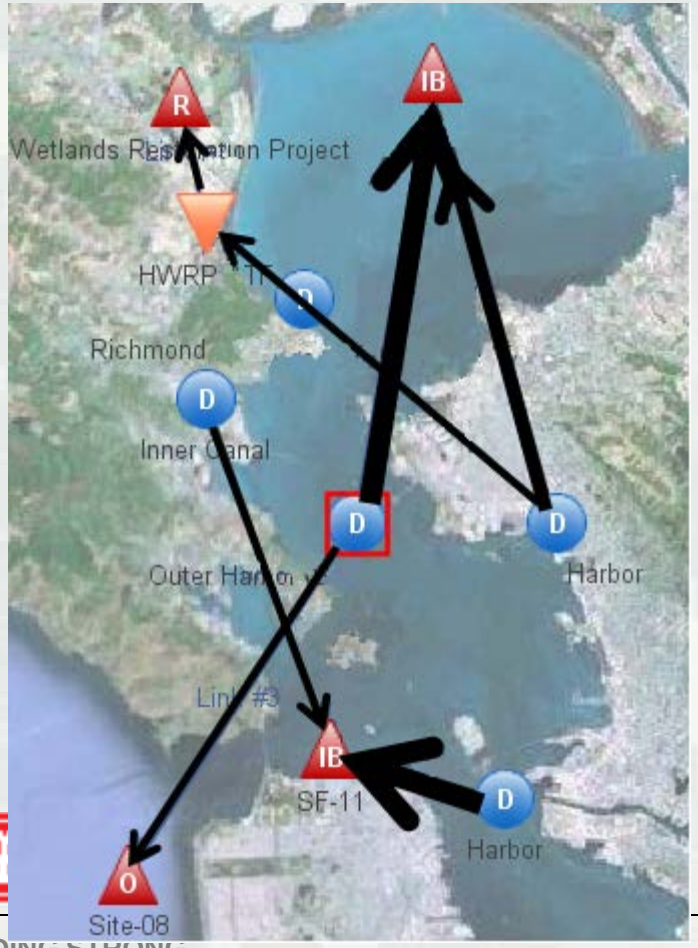
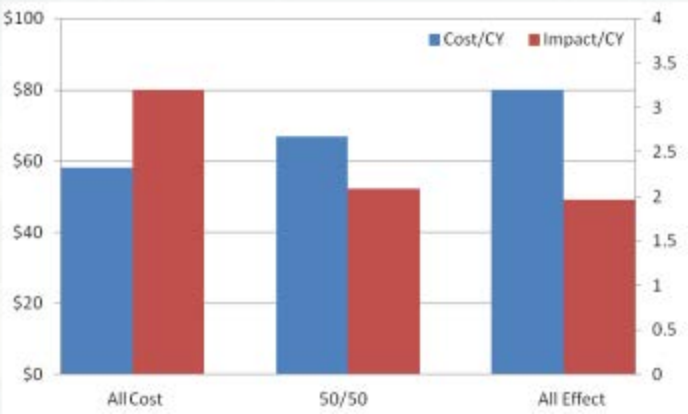
D2M2: Dredged Material Management Decisions

D2M2 uses computer optimization to balance all dredging needs and system constraints with respect to multiple criteria and objectives. The results outline the most efficient DM strategies over time.



This can be helpful in identifying tradeoffs surrounding identifying the 'federal standard' – least cost, environmentally acceptable solution.



…or with different scenarios (e.g., "what if different sites were available?", "what if the costs or impacts were different?") .

D2M2: Dredged Material Management Decisions

- *Optimize system* of dredging, transfer and sediment-placement sites.
- Address multiple *competing objectives* (e.g., environmental, cost).
- Integrate decision maker & *stakeholder value* with *technical data*.

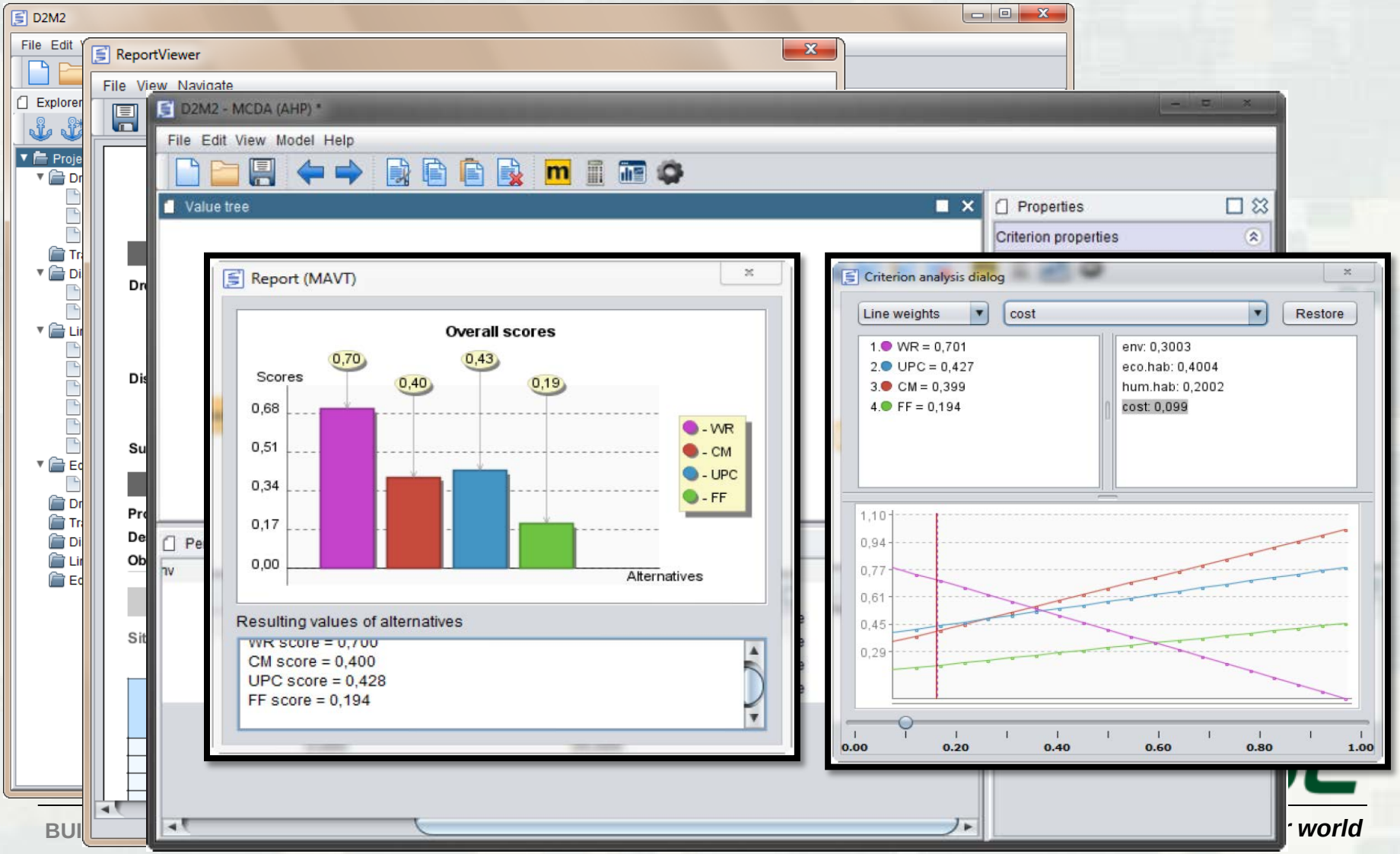
D2M2 Modules:

▪**Optimization:** Add dredging & placement site, route, and link data, optimization criteria, and tradeoff weights to calculate optimal and alternative solutions.

▪**Decision Support:** Conduct multi-criteria decision analysis to screen or rank potential sites or material management plans based on other factors.

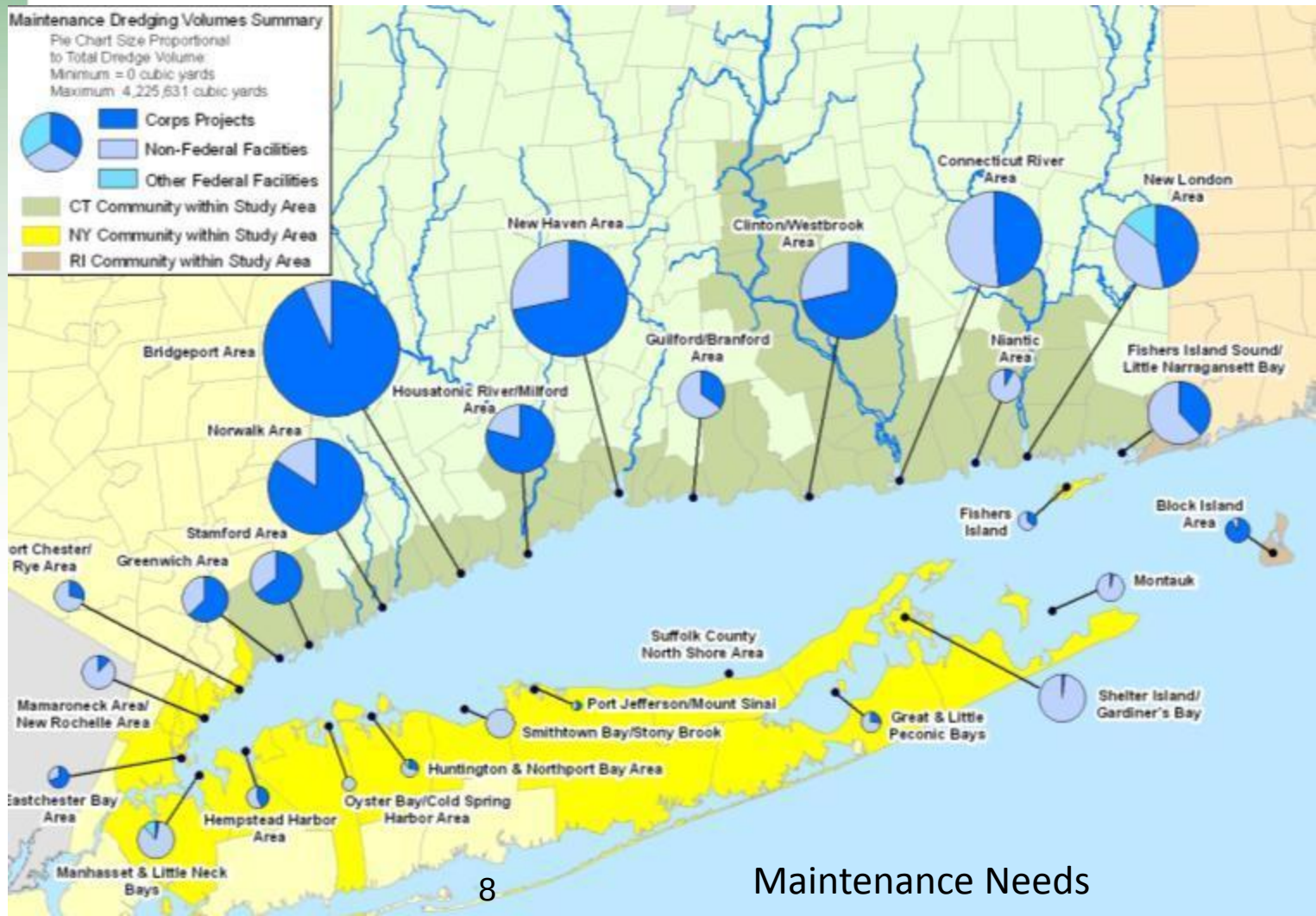
▪**GIS:** Input regional dredging sites, generate routes between them. (Or upload from Excel template.)

D2M2 Screenshots



Long Island Sound: D2M2 Case Study

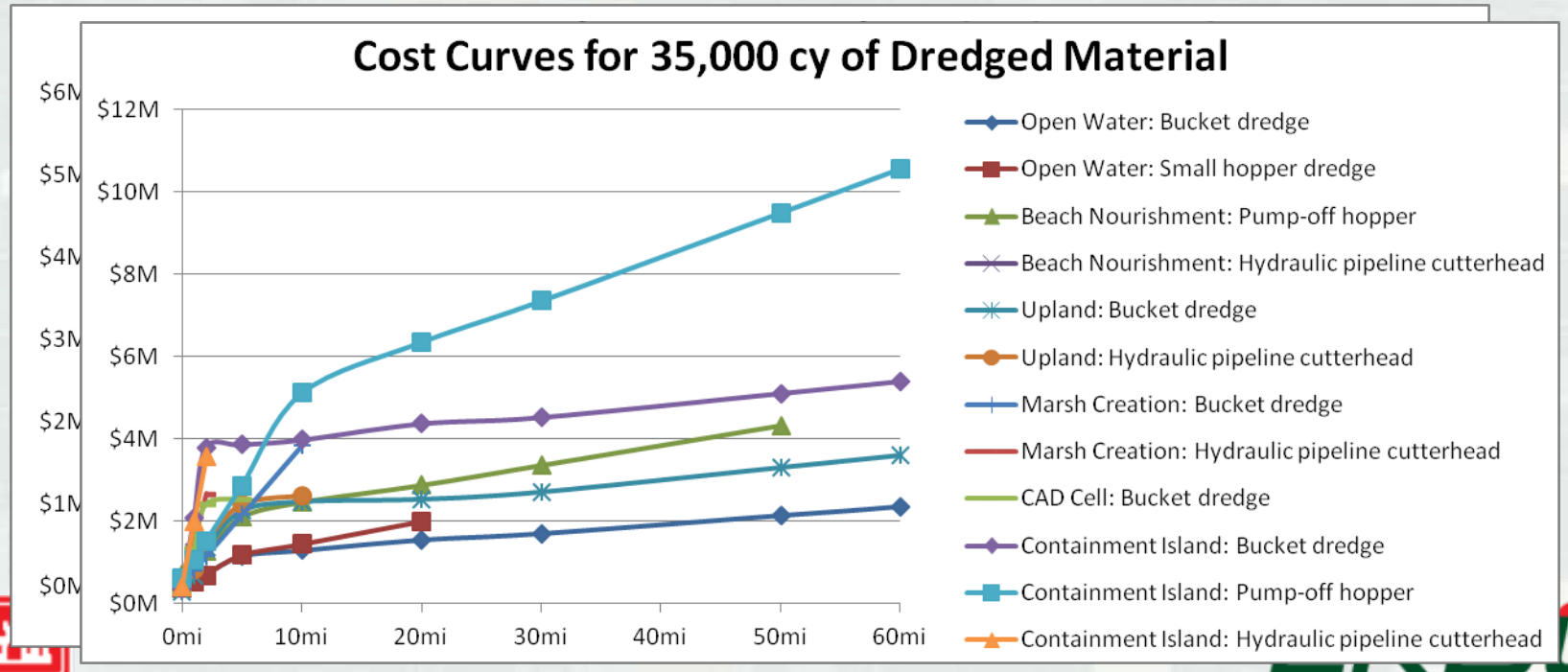
- 38.5 million cubic yards of dredged material produced in 30 years
- Majority of combined needs from CT:
- New Haven
- ~8.7 million cy
- Bridgeport
- ~4.6 million cy
- New London
- ~2.5 million cy
- Connecticut River
- ~2.4 million cy
- Clinton/Westbrook
- ~2.4 million cy
- Norwalk
- ~2.2 million cy



Maintenance Needs

LIS Case Study Data

- Cost estimates from USACE New England engineering data:
  - Relative comparison for LIS region based on placement type.
  - Costs defined in terms of an initial cost and per unit (cy*mi) costs.
  - 50 cost curves generated for each type of equipment, volume, & distance.



LIS Case Study Data

- Effect (impact/benefit) data from LIS reports & SME judgment:

Criteria	Sub-Criteria
Cultural Effects	Shipwrecks, Historic Districts, Archaeological Sites
Environmental Effects	Wetlands, Federal and State Listed Species, Shellfish, Federally Managed Species, Submerged Aquatic Vegetation (SAV), Marine Protected Areas, Birds, Marine Mammals, Terrestrial Wildlife
Infrastructure Effects	Mooring Areas, Navigation Channels and Shipping, Ports, Coastal Structure, Cable/Power/Utility Crossings, Recreational Areas, Commercial and Industrial Facilities, Aquaculture, Dredged Materials Disposal Sites
Physical Effects	Sediments, Littoral Drift, Currents, Waves

LIS Case Study Data

- Effect (impact/benefit) data from LIS reports & SME judgment:

			Cultural Effects				Environmental Effects										Infrastructure Effects										Physical Effects					
Case Study Placement Site	**Site Type**	**Description**	Shipwrecks	Historic Districts	Archaeological Sites	**Total**	Wetlands	Federal and State Listed Species	Shellfish	Federally Managed Species	SAV	Marine Protected Areas	Birds	Marine Mammals	Terrestrial Wildlife	**Total**	Mooring Areas	Navigation Channels and Shipping	Ports	Coastal Structure	Cable/Power/Utility Crossings	Recreational Areas	Commercial and Industrial Facilities	Aquaculture	Dredged Material Disposal Sites	**Total**	Sediments	Littoral Drift	Currents	Waves	**Total**	***Total Effects Score***
Blydenburgh Road Landfill Complex	Landfill - Upland	create new landfill site				**0**		1		1			1		1	**4**										**0**					**0**	***4***
Town of Brookhaven Landfill	Landfill - Upland	create new landfill site				**0**		1		1			1		1	**4**										**0**					**0**	***4***
Southold Municipal Beaches	Beach Nourishment	create new beach nourishment site				**0**	-1	1	1	1			-1	1		**2**				-1		-1				**-2**		1		1	**2**	***2***
Manchester Landfill	Landfill - Upland	create new landfill site				**0**		1		1			1		1	**4**										**0**					**0**	***4***
Jacobs Beach	Beach Nourishment	create new beach nourishment site				**0**		1	1	1		1	-1	1		**4**				-1		-1				**-2**				1	**1**	***3***
Madison Municipal Beaches	Beach Nourishment	create new beach nourishment site				**0**		1	1	1		1	-1	1		**4**				-1		-1				**-2**				1	**1**	***3***
Westerly Municipal Beaches	Beach Nourishment	create new beach nourishment site	1			**1**		1	1	1			-1	1		**3**				-1	1	-1				**-1**		1		1	**2**	***5***
Norton Basin/Little Bay borrow pits	Marsh Creation	create new habitat restoration site				**0**	-1	1	-1	1		1	-1	-1		**-1**				1						**1**	1				**1**	***1***
Plum Island	Redevelopment - Upland	create new redevelopment site	1			**1**		1	-1	1	1	1	-1	-1		**1**				1				-1		**0**	1	1			**2**	***4***
Western Long Island Sound	Open Water	create new open water site				**0**		1	1	1				1		**4**		1								**1**	1				**1**	***6***
Central Long Island Sound	CAD Cell	create new CAD Cell site				**0**		1	1	1				1		**4**		1								**1**					**0**	***5***
Cornfield Shoals	Open Water	create new open water site				**0**		1	1	1				1		**4**		1								**1**	1				**1**	***6***
New London	Open Water	create new open water site				**0**		1	1	1				1		**4**		1								**1**	1				**1**	***6***
Bush Terminal Piers	Brownfield - Upland	create new open water site				**0**		1		1			-1		-1	**0**						-1				**-1**					**0**	***-1***
Flushing Airport	Redevelopment - Upland	create new redevelopment site	1			**1**	-1	1		1			-1			**0**						-1	-1			**-2**	1				**1**	***0***

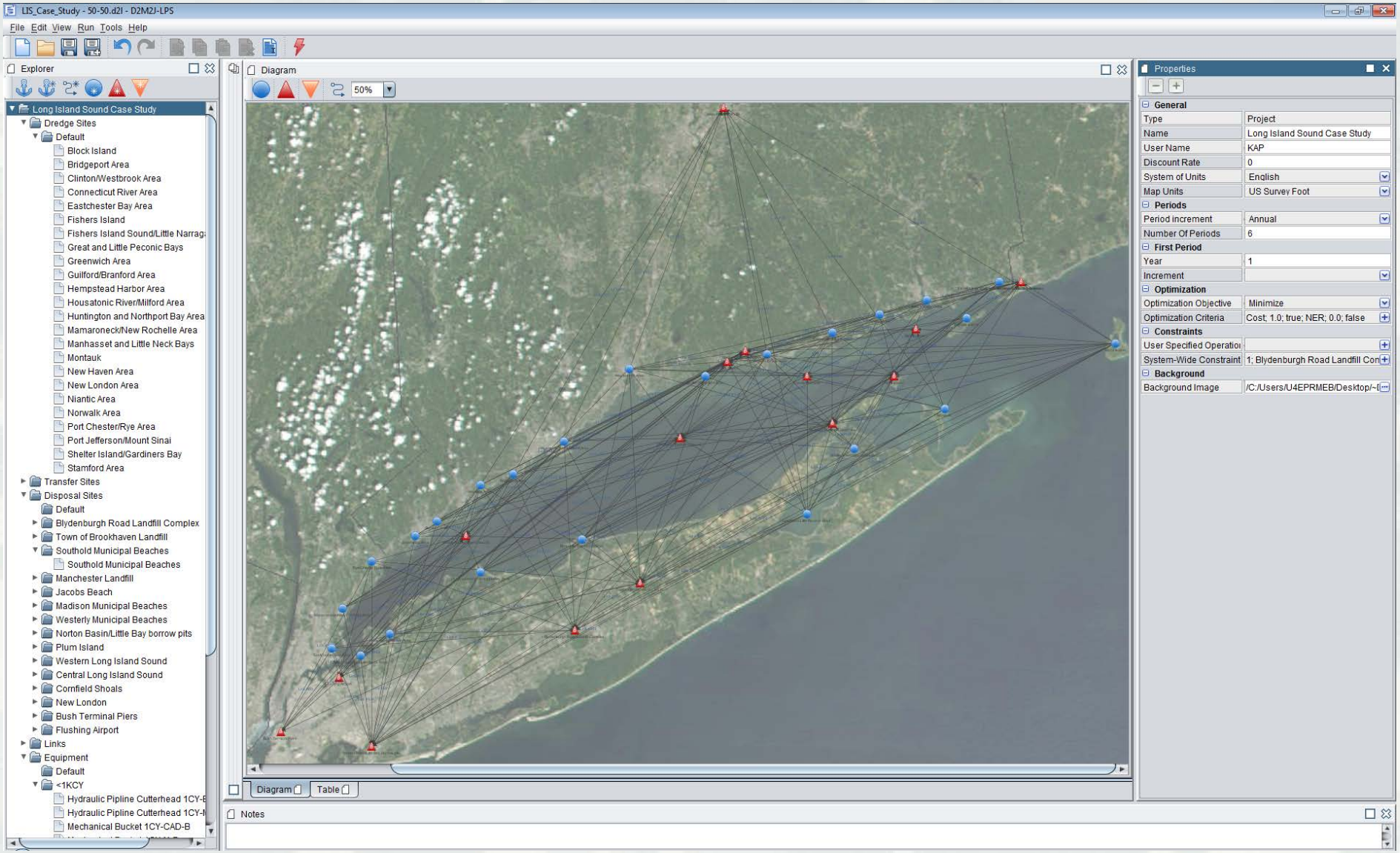
**Note: Positive values represent impacts, negative values represent benefits. This case study demonstrates these values derived from expert judgment informed by LIS report details. For operational use, these values could come more detailed studies.*

LIS Case Study Data

The D2M2 model represents relevant intricacies of the LIS system:

- Strategically connect each dredging site with a subset of relevant placement sites to represent system topology.
- Add constraints about which placement sites will and will not be available at what volumes in each of six five-year time periods.
- Add constraints for links or types of sites by year and volume.
- Include details about placement site acquisition time and cost, lease end dates and potential renegotiation costs, O&M management costs, potential for beneficial reuse, etc.
- Include details about material bulking factors, transfer sites, site-specific costs and effects, equipment use, etc.

LIS Case Study System Network

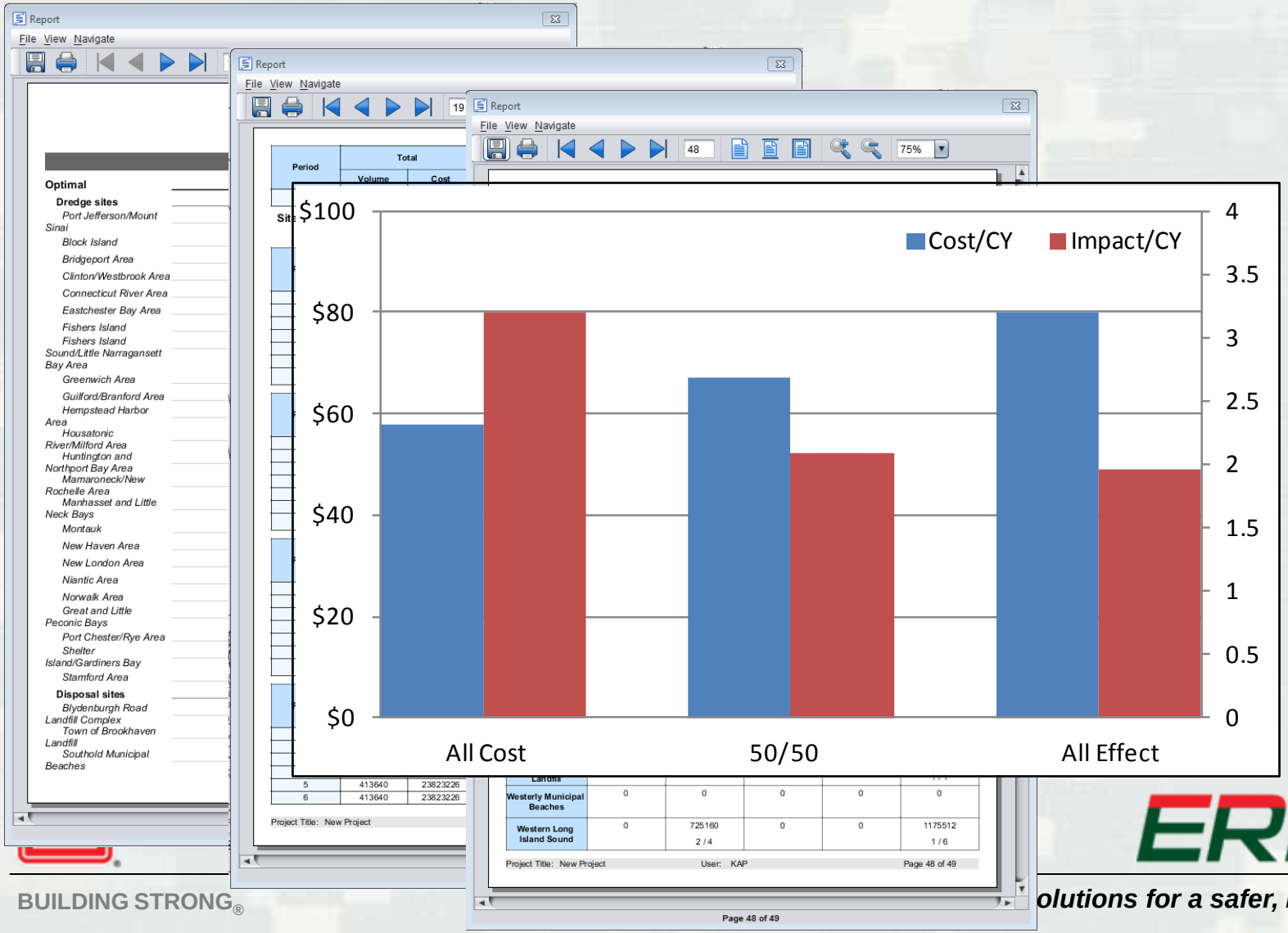


*Note: Straight line indicate logical connection between site pairs, nonlinear transit distance can be used in the calculations.

Case Study Results

- Compare optimal recommended dredging plan under three scenarios: 100% cost, 100% effects (split evenly), & 50/50.
- Results show:
  - Cost-centric scenario favors open water disposal, with minimal other (e.g., beneficial) uses.
  - Effects-centric scenario favors beneficial uses, with minimal open water or landfill placement.
  - 50/50 scenario uses a mix of open water, landfill, and beneficial uses for placement, depending on how the location, costs, and effect implications play out for each potential pair of sites.

Case Study Results



Case Study Results

100% weight on operational cost

Placement Site / Dredge Site	Blydenburgh Road Landfill Complex	Town of Brookhaven Landfill	Southold Municipal Beaches	Manchester Landfill	Jacobs Beach	Madison Municipal Beaches	Westerly Municipal Beaches	Norton Basin/Little Bay borrow pits	Plum Island	Western Long Island Sound	Central Long Island Sound	Cornfield Shoals	New London	Bush Terminal Piers	Flushing Airport	Total CY
Manhasset and Little Neck Bays										10,000 (2028-2037)						10,000
Hempstead Harbor Area										50,000 (2008-2012, 2018-						50,000
Huntington and Northport Bay Area											30,000 (2028-2037)					30,000
Port Jefferson/Mount Sinai											10,000 (2028-2037)					10,000
Great and Little Peconic Bays											24,000 (2013-2017, 2028-					24,000
Shelter Island/Gardiners Bay											10,000 (2028-2037)					10,000
Montauk											5,000 (2013-2017)					5,000
Block Island											60,000 (2018-2027)		60,000 (2008-2017)			120,000
Fishers Island											25,000 (2028-2037)					25,000
Fishers Island Sound/Little							41,700 (2018-2022)				649,900 (2018-2037)					691,600
New London Area											770,046 (2028-2037)					770,046
Niantic Area											20,000 (2028-2037)					20,000
Connecticut River Area									342,772 (2018-2037)			281,740 (2008-2012)	382,440 (2008-2012)			1,006,952
Clinton/ Westbrook Area			1,385,826 (2018-2037)										140,000 (2008-2012)			1,525,826
Guilford/ Branford Area											176,554 (2018-2037)					176,554
New Haven Area			5,568,885 (2013-2027)							725,160 (2013-2027)	250,000 (2028-2037)	169,044 (2013-2017)				6,713,089
Housatonic River/Milford Area		50,000 (2008-2012)	737946 (2028-2037)							50,000 (2013-2022)						837,946
Bridgeport Area			3,937,882 (2008-2012, 2028-													3,937,882
Norwalk Area		258,280 (2008-2012)						343,488 (2028-2037)		1,175,512 (2008-2012, 2018-						1,777,280
Stamford Area											406,140 (2028-2037)					406,140
Greenwich Area										299,648 (2028-2037)						299,648
Port Chester/Rye Area										60,000 (2008-2017)						60,000
Mamaroneck/ New Rochelle Area											30,000 (2028-2037)					30,000
Eastchester Bay Area										70,000 (2008-2012, 2018-						700,000
TOTAL Dredged Material Transferred		308,280	11,630,539				41,700	343,488	342,772	2,440,320	2,456,640	450,784	582,440			18,596,963

Case Study Results

50/50% between operational costs & effects

Placement Site / Dredge Site	Blydenburgh Road Landfill Complex	Town of Brookhaven Landfill	Southold Municipal Beaches	Manchester Landfill	Jacobs Beach	Madison Municipal Beaches	Westerly Municipal Beaches	Norton Basin/Little Bay borrow pits	Plum Island	Western Long Island Sound	Central Long Island Sound	Cornfield Shoals	New London	Bush Terminal Piers	Flushing Airport	Total
Manhasset and Little Neck Bays										10,000 (2028-2037)						10,000
Hempstead Harbor Area	30,000 (2013-2017)									20,000 (2028-2037)						50,000
Huntington and Northport Bay Area											20,000 (2028-2037)					20,000
Port Jefferson/Mount Sinai											10,000 (2028-2037)					10,000
Great and Little Peconic Bays											24,000 (2013-2017, 2028-					24,000
Shelter Island/Gardiners Bay											10,000 (2028-2037)					10,000
Montauk											5,000 (2013-2017)					5,000
Block Island									60,000 (2018-2027)				60,000 (2008-2017)			120,000
Fishers Island											25,000 (2028-2037)					25,000
Fishers Island Sound/Little			691,600 (2018-2037)													691,600
New London Area			770,046 (2028-2037)													770,046
Niantic Area											20,000 (2028-2037)					20,000
Connecticut River Area			1,006,952 (2008-2012,													1,006,952
Clinton/ Westbrook Area			1,525,826 (2008-2012,													1,525,826
Guilford/ Branford Area			176,554 (2018-2037)													176,554
New Haven Area			6,713,089 (2013-2037)													6,713,089
Housatonic River/Milford Area			837,946 (2008-2012, 2018-													837,946
Bridgeport Area			3,937,882 (2008-2012,													3,937,882
Norwalk Area		457,280 (2008-2012, 2018-						1,000,000 (2008-2012, 2028-							320,000 (2008-2012)	1,777,280
Stamford Area			406,140 (2028-2037)													406,140
Greenwich Area										299,648 (2028-2037)						299,648
Port Chester/Rye Area										30,000 (2013-2017)					30,000 (2008-2012)	60,000
Mamaroneck/ New Rochelle Area											30,000 (2028-2037)					30,000
Eastchester Bay Area										60,000 (2008-2012, 2018-				10,000 (2008-2012)		70,000
TOTAL Dredged Material Transferred	30,000	457,280	16,066,035					1,000,000	60,000	419,648	144,000		60,000	10,000	350,000	18,596,963

Case Study Results

100% weight on effects (split evenly)

Placement Site / Dredge Site	Blydenburgh Road Landfill Complex	Town of Brookhaven Landfill	Southold Municipal Beaches	Manchester Landfill	Jacobs Beach	Madison Municipal Beaches	Westerly Municipal Beaches	Norton Basin/Little Bay borrow pits	Plum Island	Western Long Island Sound	Central Long Island Sound	Cornfield Shoals	New London	Bush Terminal Piers	Flushing Airport	Total CY
Manhasset and Little Neck Bays			10,000 (2028-2037)													10,000
Hempstead Harbor Area			50,000 (2013-2017, 2028-													50,000
Huntington and Northport Bay Area			20,000 (2028-2037)													20,000
Port Jefferson/Mount Sinai			10,000 (2028-2037)													10,000
Great and Little Peconic Bays			24,000 (2013-2017, 2028-													24,000
Shelter Island/Gardiners Bay			10,000 (2028-2037)													10,000
Montauk			5,000 (2013-2017)													5,000
Block Island			120,000 (2008-2027)													120,000
Fishers Island			25,000 (2028-2037)													25,000
Fishers Island Sound/Little			691,600 (2018-2037)													691,600
New London Area			770,046 (2028-2037)													770,046
Niantic Area			20,000 (2028-2037)													20,000
Connecticut River Area			1006952 (2008-2012,													1,006,952
Clinton/ Westbrook Area			1,525,826 (2008-2012,													1,525,826
Guilford/ Branford Area			176,554 (2018-2037)													176,554
New Haven Area			6,713,089 (2013-2037)													6,713,089
Housatonic River/Milford Area			837,946 (2008-2012, 2018-													837,946
Bridgeport Area			3,937,882 (2008-2012,													3,937,882
Norwalk Area	48,640 (2008-2012)	422,520 (2008-2012, 2018-			4,840 (2023-2027, 2033-	6,280 (2018-2022, 2028-		945,000 (20008-2012, 2028-							350,000 (2008-2012)	1,777,280
Stamford Area			406,140 (2028-2037)													406,140
Greenwich Area			299,648 (2028-2037)													299,648
Port Chester/Rye Area	30,000 (2013-2017)							30,000 (2008-2012)								60,000
Mamaroneck/ New Rochelle Area			30,000 (2028-2037)													30,000
Eastchester Bay Area		35,000 (2018-2027)						25,000 (2008-2012)						10,000 (2008-2012)		70,000
TOTAL Dredged Material Transferred	78,640	457,520	16,689,683		4,840	6,280		1,000,000						10,000	350,000	18,596,963

Conclusions

D2M2 is a multi-objective optimization tool that helps solve complex & multifaceted dredging planning/ops problems:

- Automatically explores thousands of potential solutions.
- Enables explicit consideration of multiple objectives (e.g., economic, environmental, social, etc.).
- Shows opportunity cost/benefit of beneficial use, etc.
- Adds transparency, replicability, & flexibility to analyses.
- Enables easy scenario and “what if” analysis.
- Helpful in discussing tradeoffs around “federal standard”.
- Useful for adopting a systems perspective.

Thank You!

Any Questions?

Email: *Matthew.E.Bates@usace.army.mil*

Download: *http://el.erdc.usace.army.mil/dots/models.html*

Backup Slides

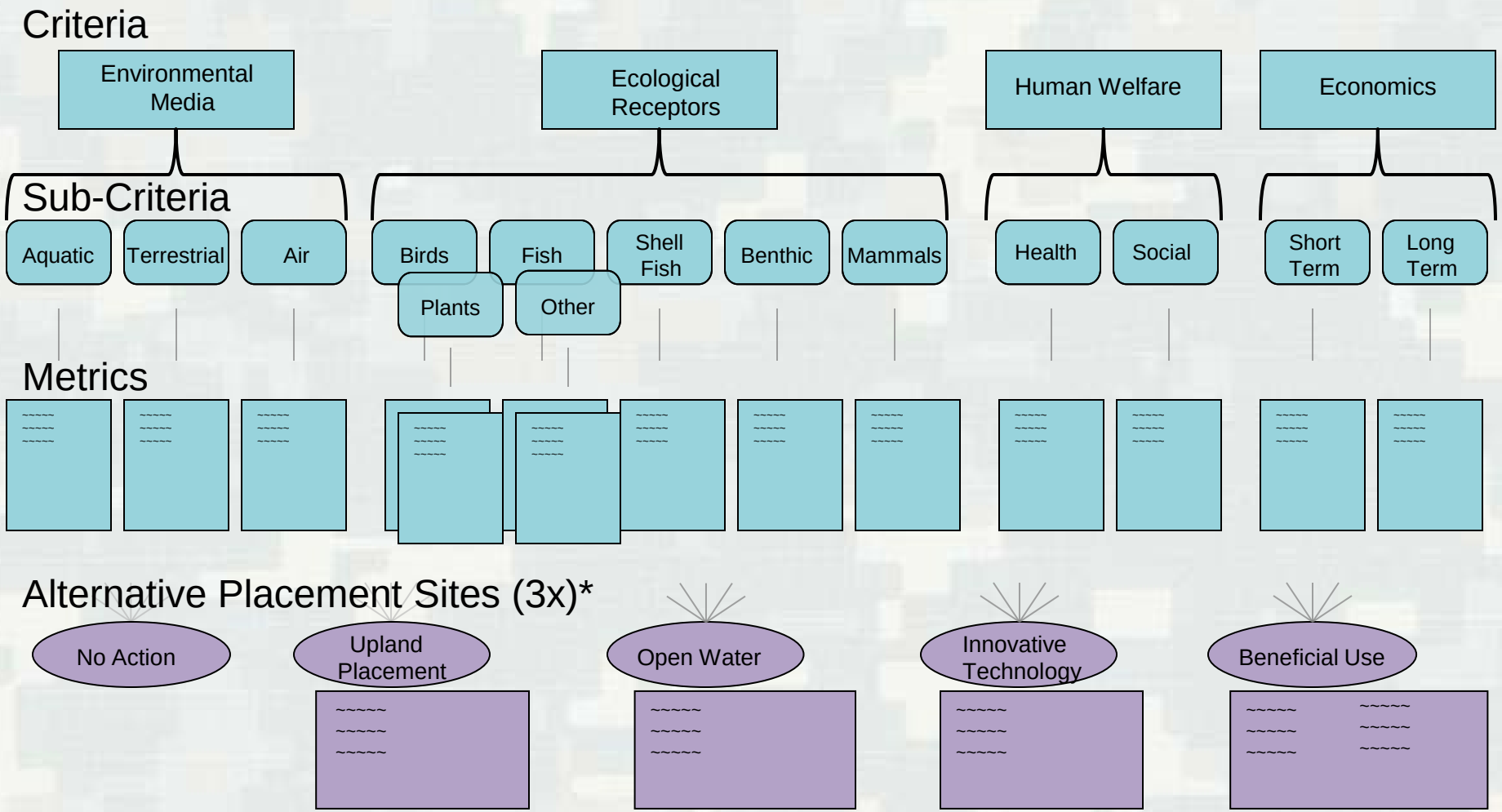
LIS DMMP Decision Model Process

- Individual stakeholder organizations identify & weight criteria & sub-criteria relevant to the sediment placement.
- Results will form one component of the LIS DMMP.
- In the future, district scientists & engineers can perform technical analysis to score individual placement options in the LIS region against these metrics.
- Technical scores & stakeholder weights can be combined through an MCDA model to rank regional placement sites.
- D2M2 is one tool that can incorporate these data.

LIS DMMP Working Group Progress

- ✓ Explored background materials on various dredged-material placement alternatives so that all WG members have a common basis of understanding [*completed in meetings 1-3*].
- ✓ Developed a broad hierarchy of criteria, sub criteria, and metrics for evaluating the impacts and benefits of dredged materials placement [*completed in meetings 2-4*].
- ✓ In individual interviews, WG members shared the perspectives of their respective organizations by quantifying preferences for and trade-offs between these impacts and benefits of dredged-material placement [*completed in 2012*].
- ✓ The interview responses were coalesced and summarized to show the distribution of priorities encountered in the WG *[in meeting 5].*

Structure of the LIS Decision Model



*Note: The potential alternative placement sites will be different for Unsuitable, Suitable Fine and Suitable Sandy materials. Different weights will be elicited from the stakeholder organizations for each of these three cases.

LIS DMMP Criteria, Sub-criteria, & Metrics

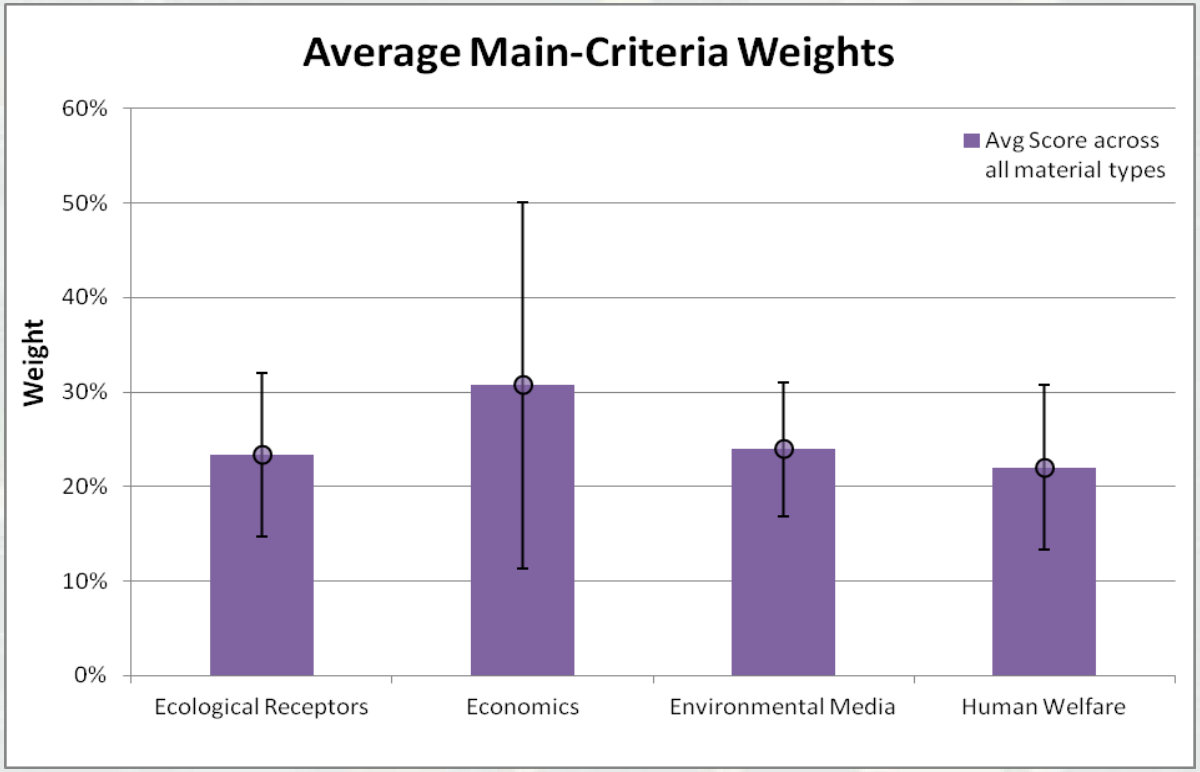
Environmental Media
Aquatic
-Source/destination water & sediment compatibility
-Water quality
-Sediment stability
Terrestrial
-Suitability for intended end use
-Material stability and potential for erosion
-Exposure and potential for transport
Air
-Short-term air quality (equipment & transportation)
-Exposure and potential for transport

Human Welfare
Health
-Operational safety
-Navigation safety
-Exposure to contaminants
Social
-Implementability
-Beneficial use
-Recreation, education, & research
-Cultural and historical
-Aesthetics
-Other conflicting uses
-Affected populations

Ecological Receptors
Birds
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Fish
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Shellfish
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Benthic
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Mammals
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Plants
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations
Other
-Short-term impacts or benefits to individual animals & habitats
-Long-term impacts or benefits to populations & habitats
-Other considerations

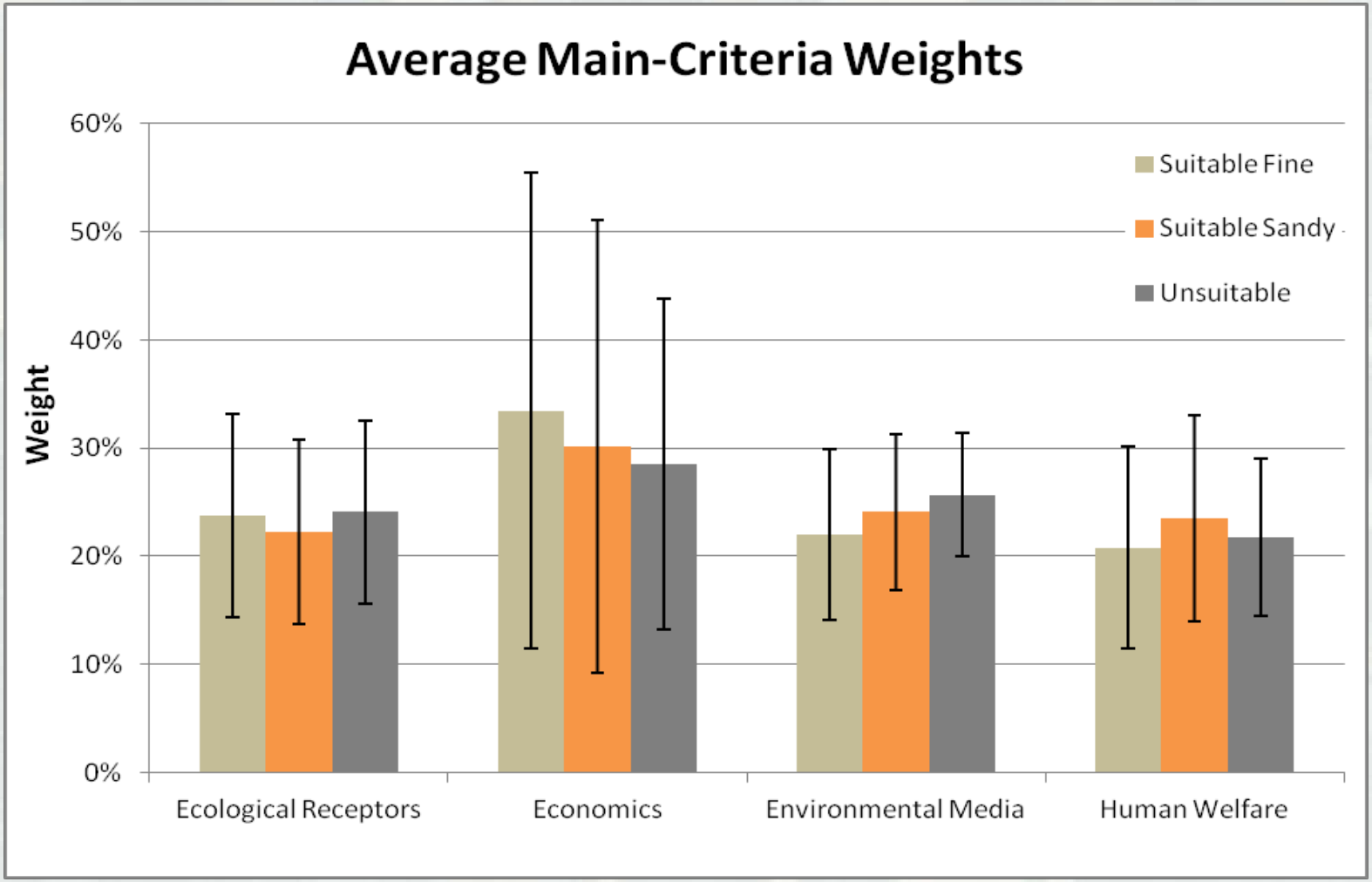
Economics
Short Term
-Direct construction
-Cost sharing requirement
-Monitoring costs
-Market and infrastructure limitations
-Indirect & opportunity costs
Long Term
-Maintenance & management costs
-Monitoring costs
-Change to commercial & recreational fisheries
-Ecosystem services
-Hurricane-barrier & flood-protection benefits
-Development & improvement
-Capacity issues
-Indirect, cumulative, & opportunity costs

Interviews Show ~Relative Balance Among the Various Criteria



**Note: Error bars show one standard deviation about the mean.*

LIS DMMP Interview Results



**Note: Error bars show one standard deviation about the mean.*

LIS DMMP Classification of Placement Alternatives

Alternatives	*Type of Material*		
Type of Alternative	**Unsuitable**	**Suitable Fine**	**Suitable Coarse (e.g., Sandy)**
No Action:	No Action	No Action	No Action
Upland Placement:	Shoreline CDF*, Upland CDF*, Mines & Quarries*, Landfills*	Shoreline CDF*, Upland CDF*, Mines & Quarries*, Landfills*	Shoreline CDF*, Upland CDF*, Mines & Quarries*, Landfills*
Aquatic Placement:	In-Harbor CAD Cell, Confined Open Water Placement, Island CDF	Unconfined Open Water Placement, Island CDF	Unconfined Open Water Placement, Island CDF, Near Shore Placement
Innovative Treatment Technologies:	Varies by Product* (results in material unrestricted for final placement or use)	N/A	N/A
Beneficial Uses:	Brownfields & Other Redevelopment*, Island Creation or Restoration	Brownfields & Other Redevelopment*, Island Creation or Restoration, Agriculture*/ Aquaculture†, Shoreline Restoration†, Habitat Restoration / Enhancement or Creation, Road Bed & Berm Material*, Landfill* & CDF* / CAD Cap Material	Brownfields & Other Redevelopment*, Island Creation or Restoration, Agriculture*/ Aquaculture†, Shoreline Restoration†, Habitat Restoration / Enhancement or Creation, Road Bed & Berm Material*, Landfill* or CDF* / CAD Cap Material, Beach and Dune Nourishment†, Nearshore Bar Placement, Asphalt / Cement & Other Aggregates*

*Requires use of a dredged material transfer facility
†May need the use of a dredged material transfer facility
CDF = Confined Disposal Facility; CAD = Confined Aquatic Disposal