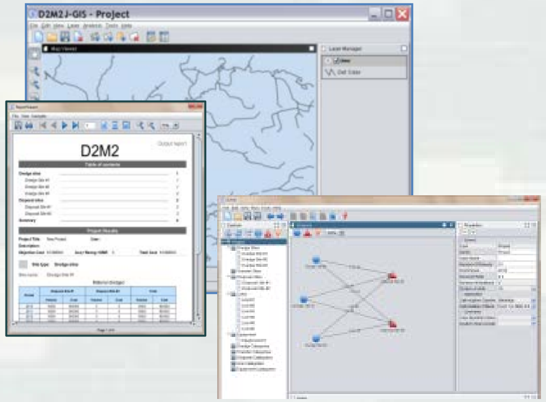
The USACE Dredged Material Management Decisions (D2M2) Tool



DOTS Webinar

Wednesday Jan 28, 2014

Presented by: Matthew Bates

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ERDC EL Risk and Decision Science Team

Background

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

Background

- Typical complexities include:
  - Multiple stakeholders with opposing interests.
  - Public interest in both costs & environmental effects.
  - Many potential site factors/variables to consider.
  - Limited placement site availability & timing.
- Decision analysis & multi-objective optimization can help.

D2M2: The "Dredged Material Management Decisions" Tool

Three D2M2 Modules:

- Optimization: Networked system of dredging & placement sites, routes, and links, optimization criteria, and tradeoff weights to calculate optimal and alternative solutions.

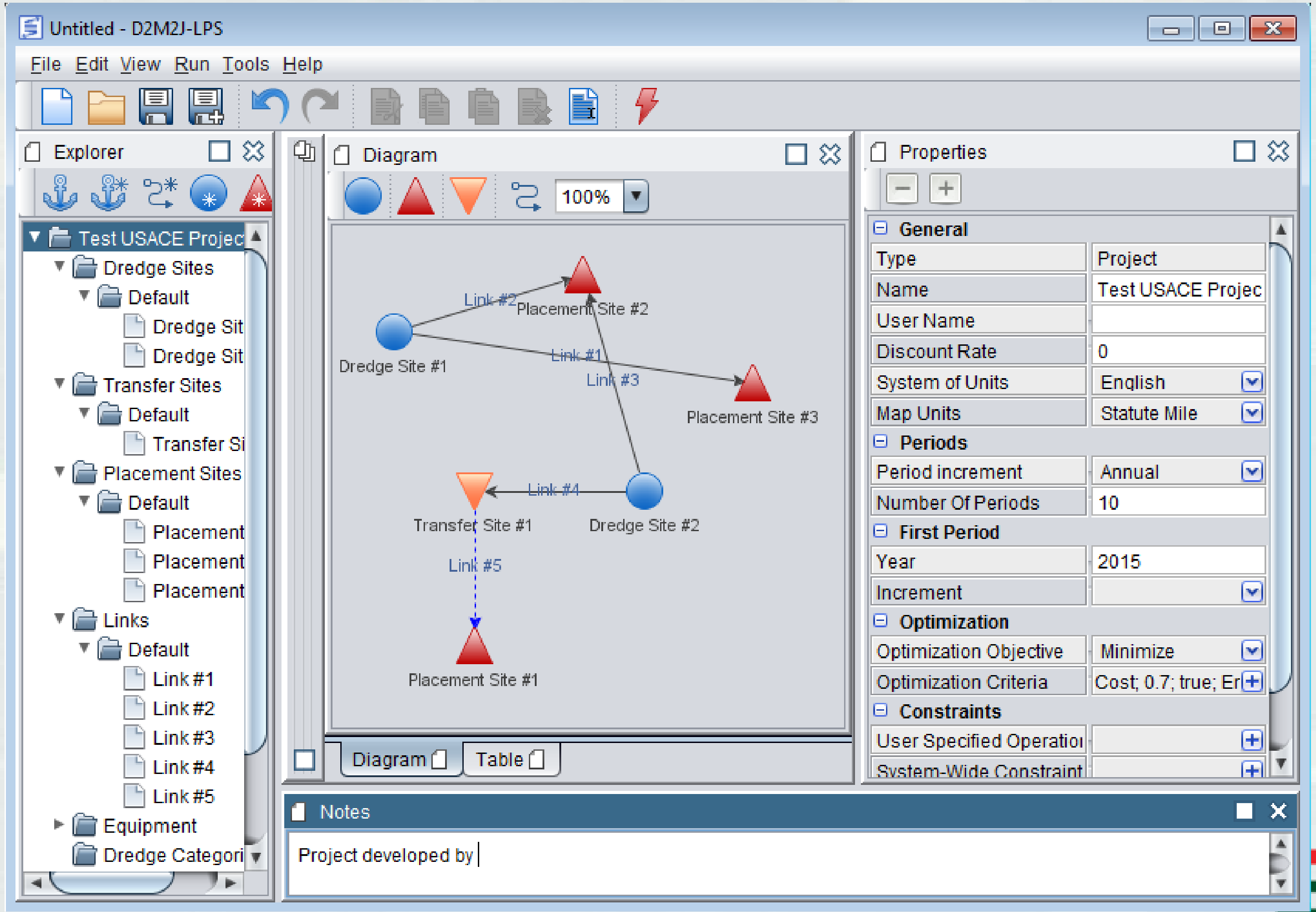
- Decision Analysis: Tools to screen/rank potential sites or management plans.

- GIS: Input regional dredging sites, link to national datasets, generate routes between sites (or, alternatively, upload site data from an Excel template).

D2M2 Optimization Module

- Originally developed several decades ago, recently updated
- Provides a dynamic optimization-model-builder tool
- “Mixed Integer Linear Programming” approach
- Flexible, unique model formulation in each case:
  - Min/Max weighted sum of some multi-objective value function
  - Subject to set of volume & user defined system constraints
  - Given fixed and variable costs/impacts/effects for links and source & sink nodes (piecewise linear by volume & distance)
- Exclude prior solutions to explore near-optimal space
- Implemented with UI in Java & model in LPSOLVE

D2M2 Optimization Module



D2M2 Optimization Module

- Typical data requirements (can be flexible):
  - Identify dredging sites and volumes over time.
  - Identify placement sites and capacities.
  - Identify any transfer sites (e.g., where cost curves transition).
  - Identify site details related to placement & transfer site costs, benefits, timelines for availability, O&M, material reuse, constraints, etc.
  - Develop links between possible source-sink site pairs.
  - Develop cost & benefit curves that relate the outcomes of moving material from site A to site B. *(These can be generalized, with components drawn from the source site, placement site, and transportation link.)*

Two Case Studies to Summarize

1. Long Island Sound
   - Based on data from the LIS dredged materials management plan.
   - Completed in 2013/2014.

2. Galveston Bay and Houston Ship Channel
   - Ongoing phased project for the Galveston district & RSM program.
   - Part of a larger team involving USACE staff & researchers from ERDC and the Galveston and Mobile districts.

Long Island Sound
Dredged Material Management Plan
Working Group

Long Island Sound: D2M2 Case Study Scope

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

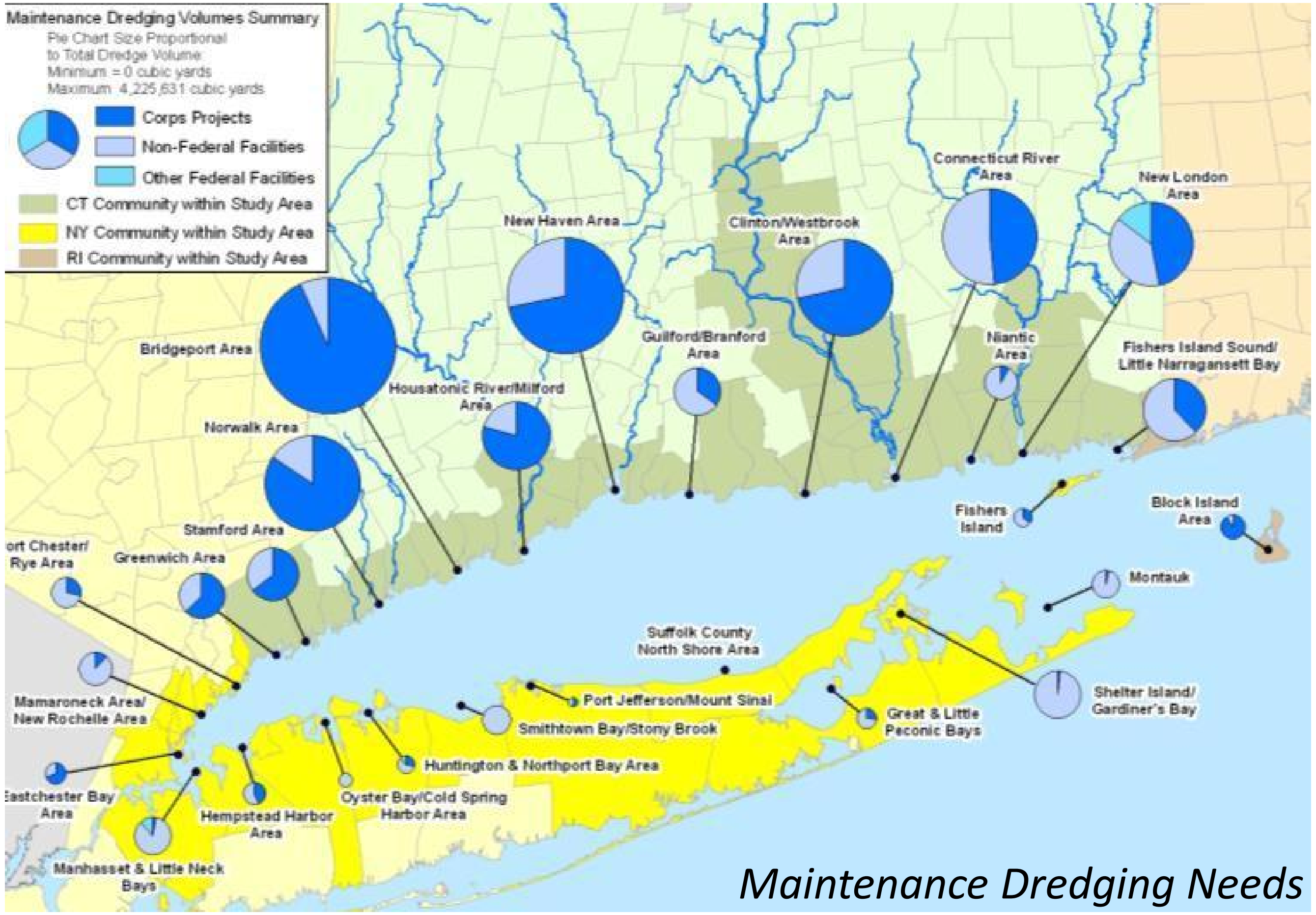
~2.4 million cy

Clinton/Westbrook

~2.4 million cy

Norwalk

~2.2 million cy



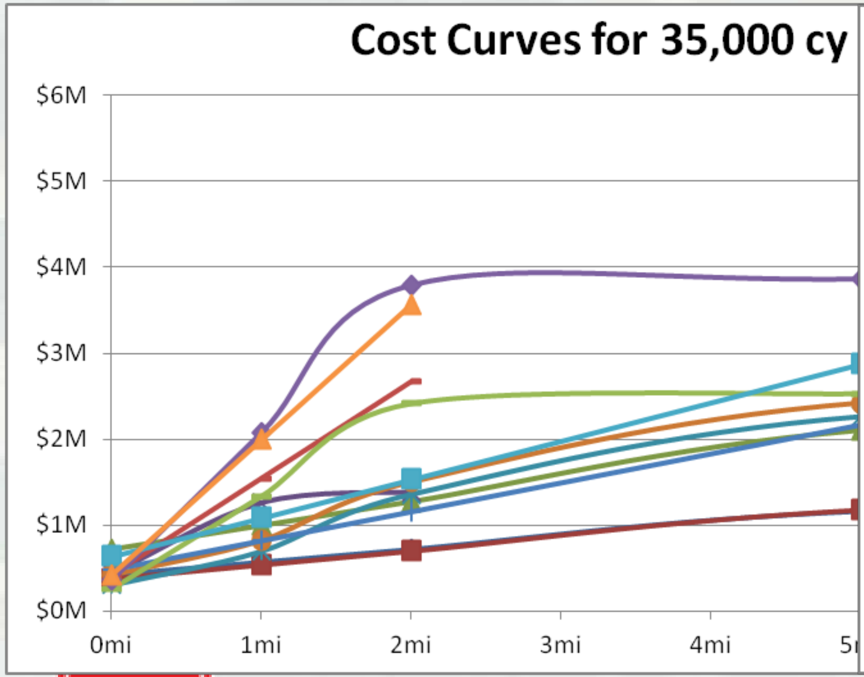
Maintenance Dredging Needs

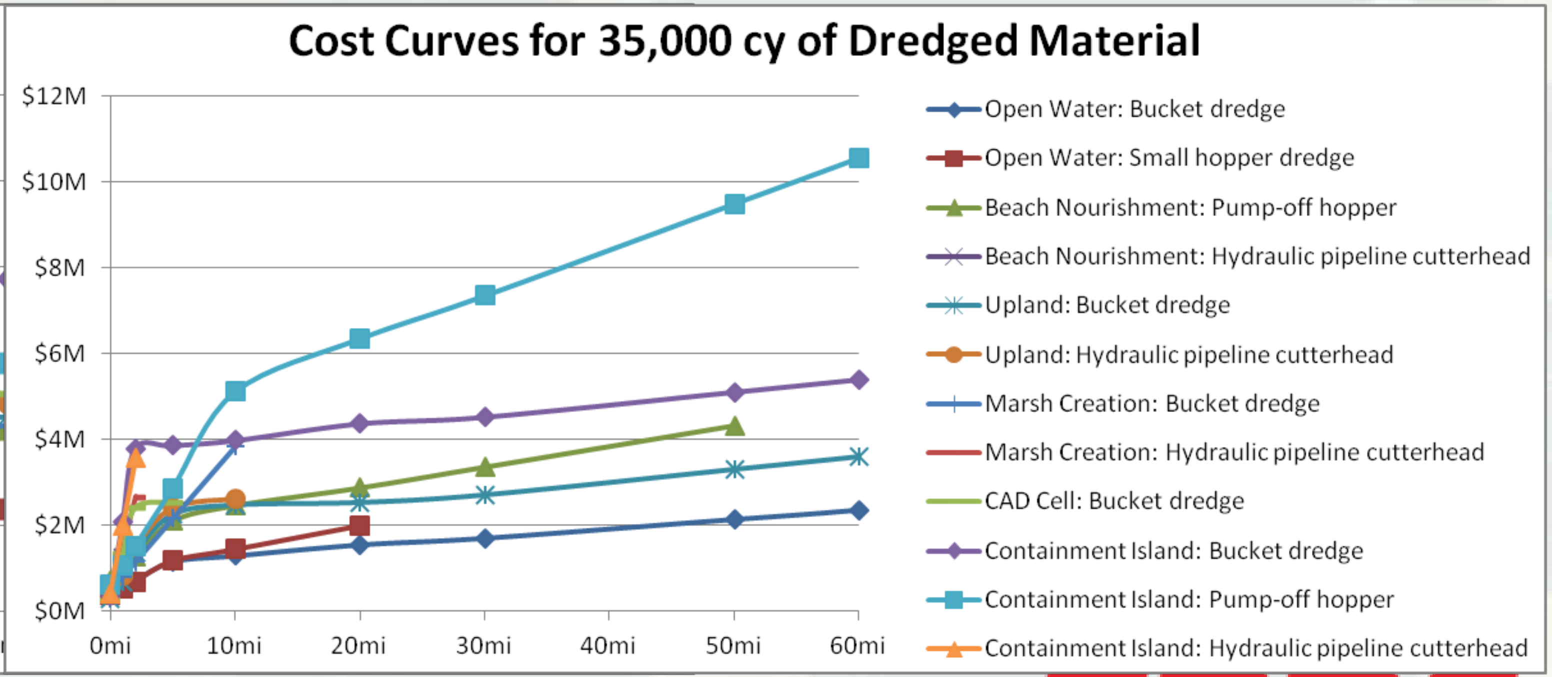
LIS Case Study Approach

- Strategically connect each dredging site with a subset of relevant placement sites to represent the system network.
- Add capacity and volume information for dredging and placement sites in each of six five-year time periods.
- Include basic 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 additional details about material bulking factors, transfer sites, site-specific costs and effects, equipment use, etc.
- Add constraints for links & sites by type, year and volume.

LIS Case Study Data

- Cost estimates from USACE New England engineering team:
  - 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

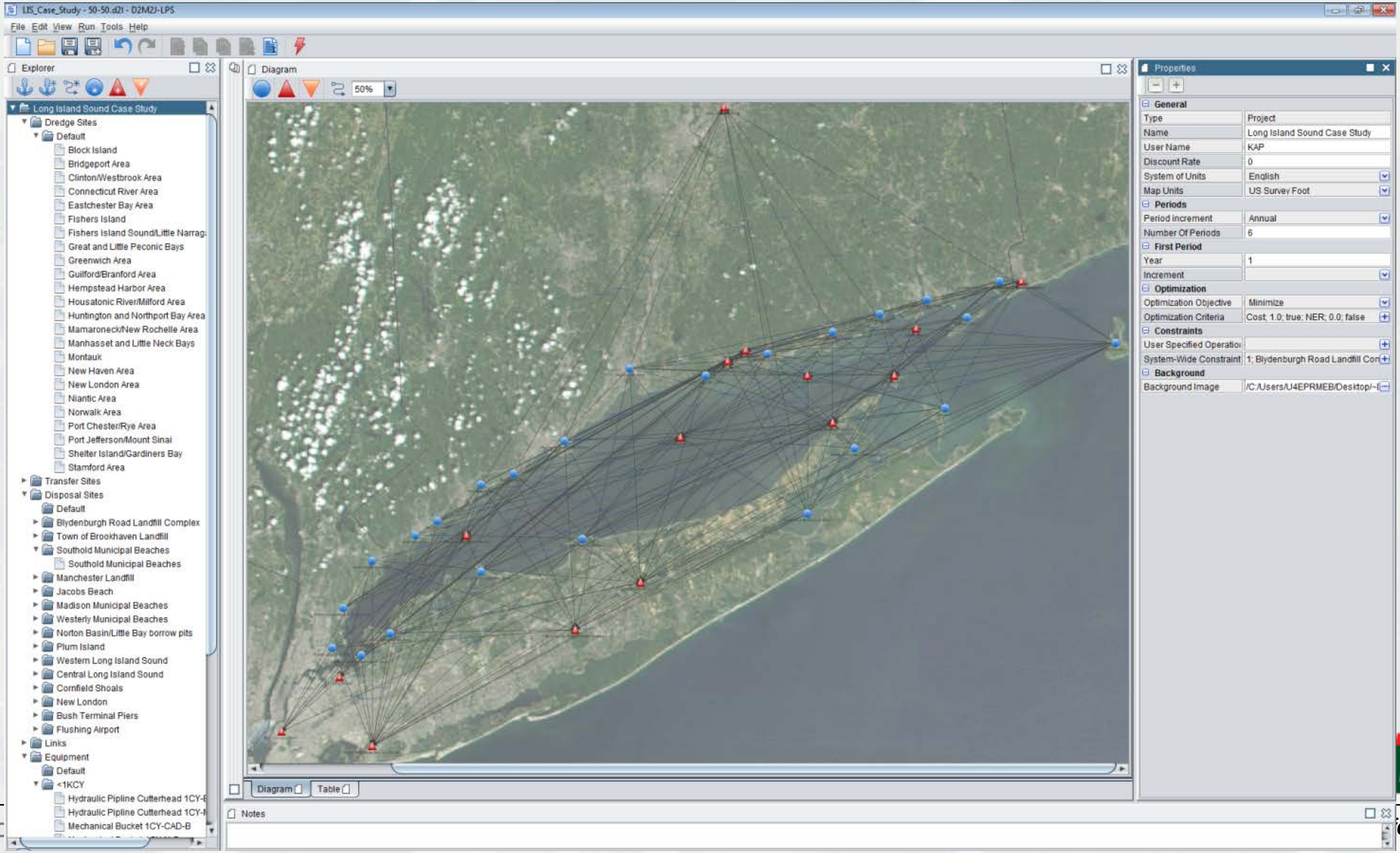
LIS Case Study Data

- Placement site 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. Here, these values derived from expert judgment informed by the LIS report details. In practice, these values should come directly from relevant studies.*

LIS Case Study System Network

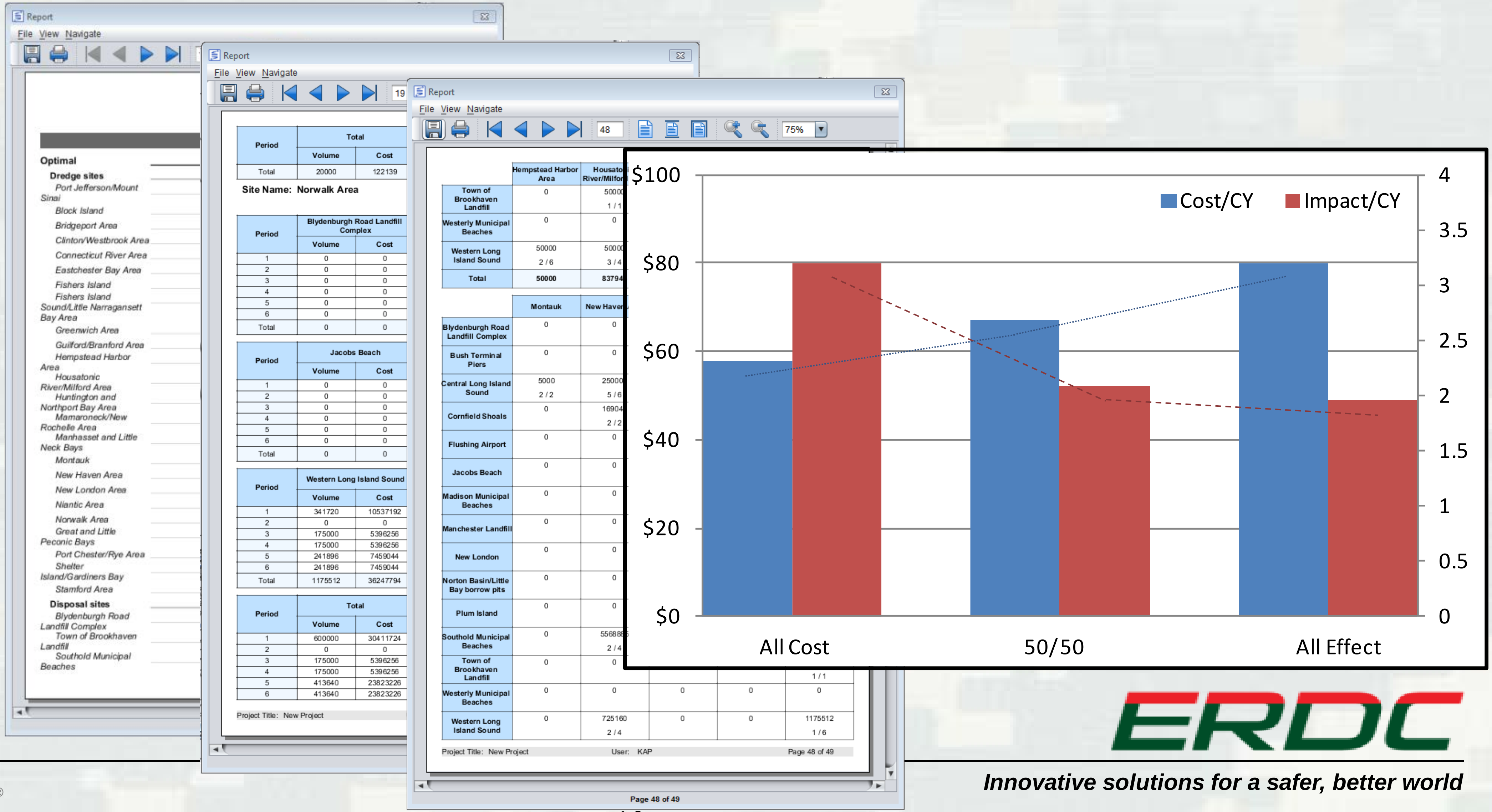


**Note: Straight line indicate logical connection between site pairs, nonlinear transit distance can be used in the calculations.*

LIS Case Study Modeling Scenarios

- 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.

LIS Case Study Results



Galveston Bay & Houston Ship Channel Case Study

(Ongoing project)

Galveston Projects: D2M2 Case Study Scope

Houston Ship Channel

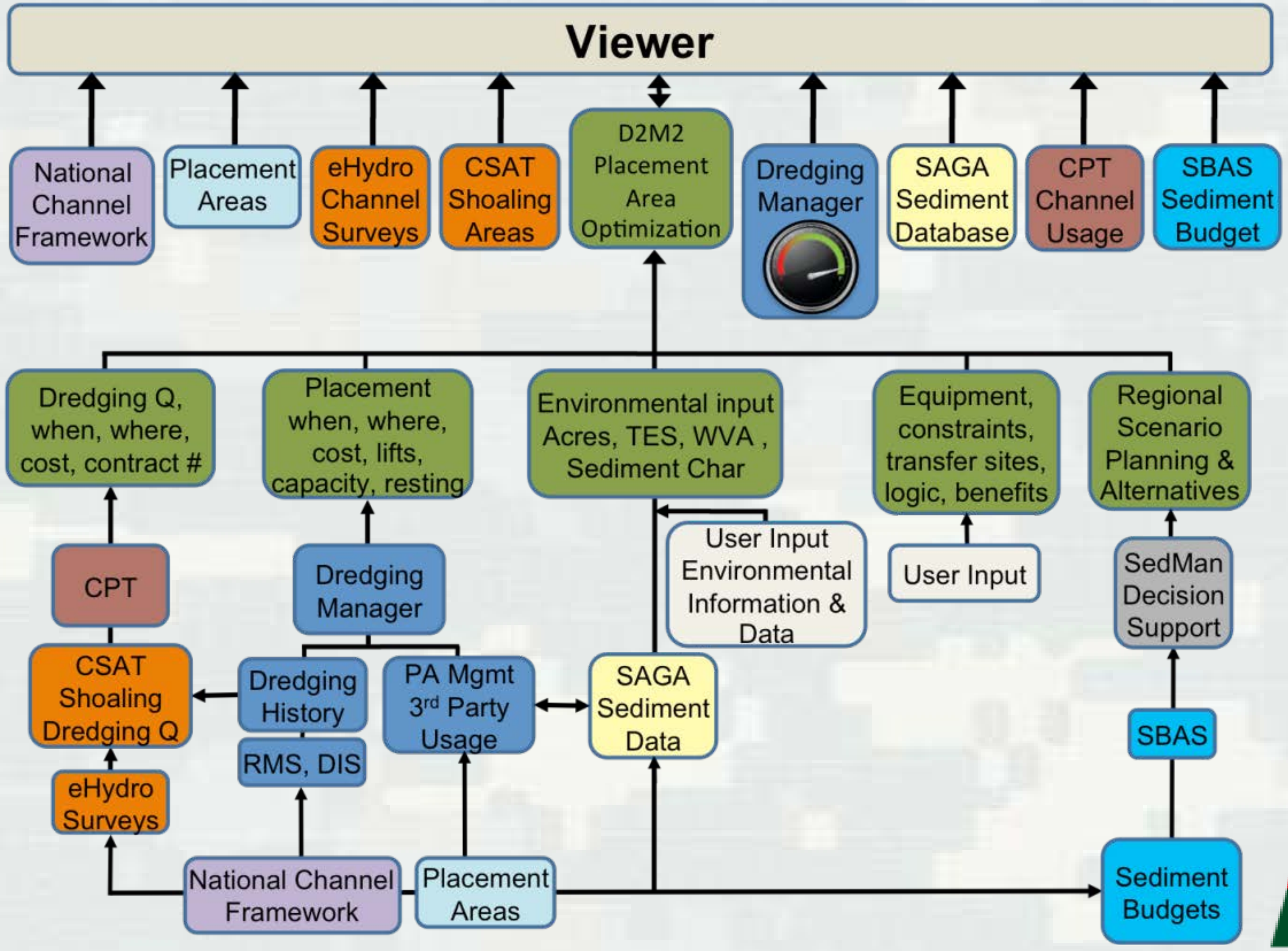
GIWW: High Island to Brazos River

RSM Placement Area Optimization and DMMP Modernization

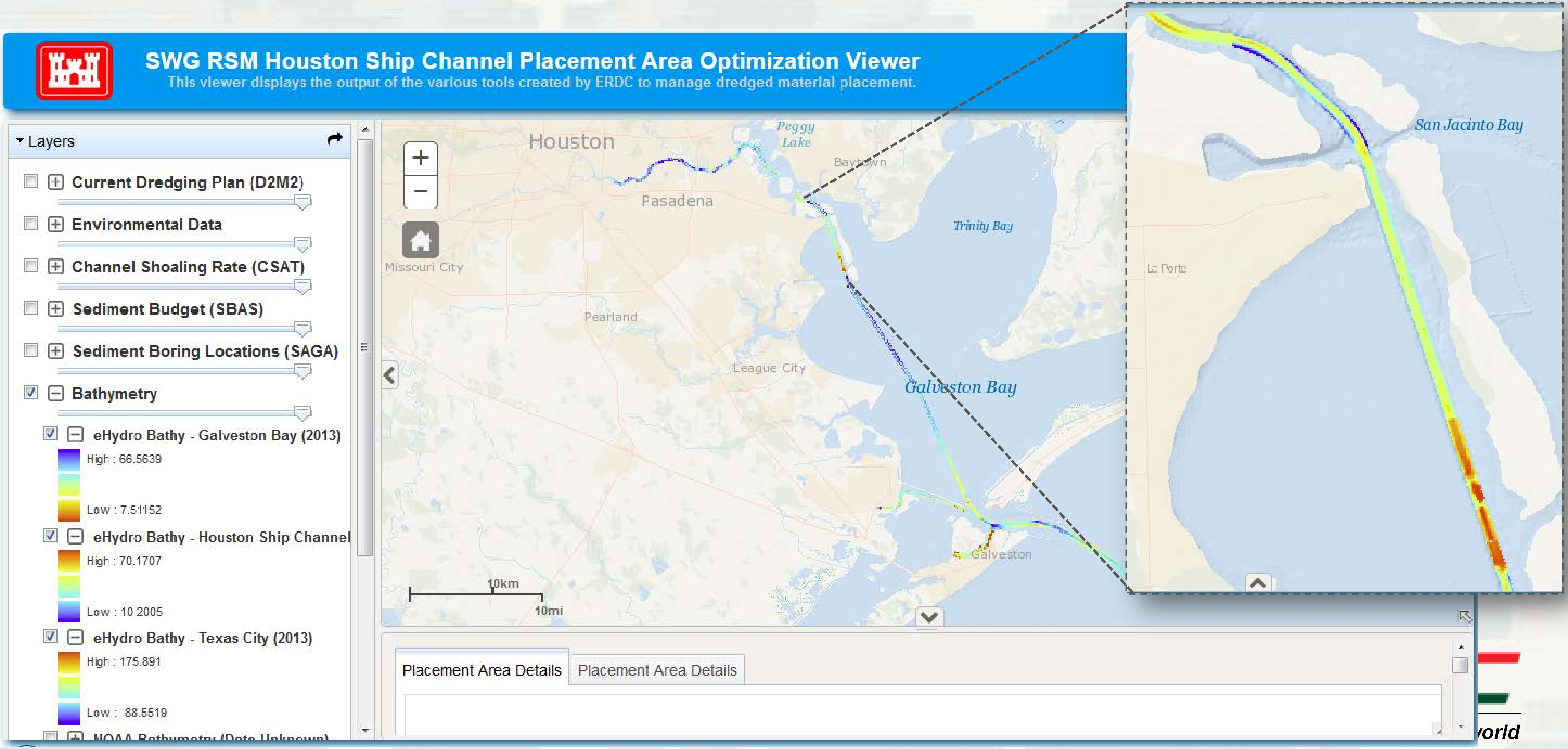
Project 1: RSM Placement Area (PA) Optimization for the Houston Ship Channel (HSC) in Galveston Bay. Evaluate optimization of the navigation channel network, historical sedimentation and dredging, and system of placement areas within the Galveston Bay region focusing on the Houston Ship Channel (FY14/15).

Project 2: DMMP Modernization Gulf Intracoastal WaterWay: High Island to Brazos River Reach. Populate enterprise databases, integrate tools, and transfer technology which will assist SWG in streamlining Preliminary Assessments and DMMP technical analyses (FY15).

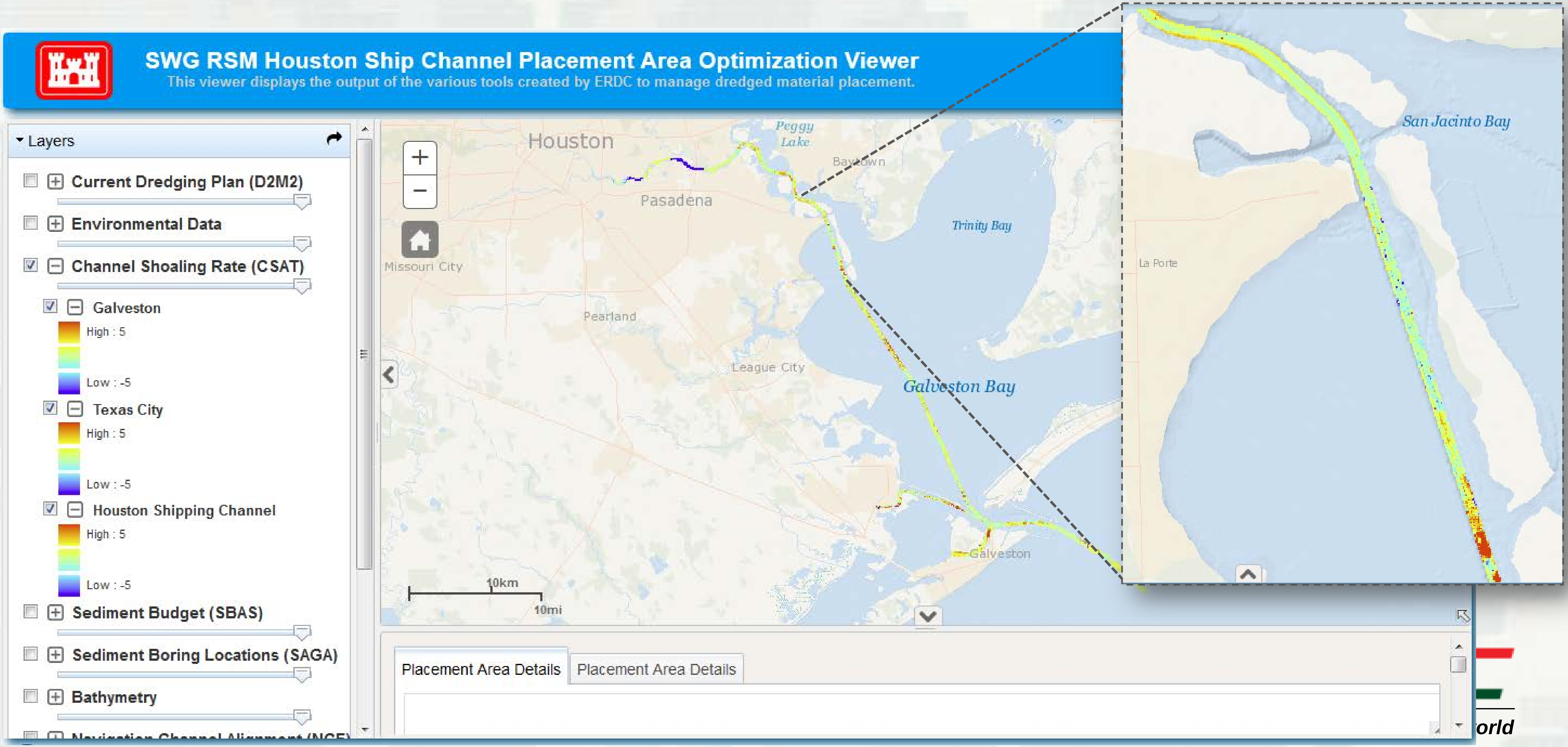
D2M2 in Relation to Other Data & Tools



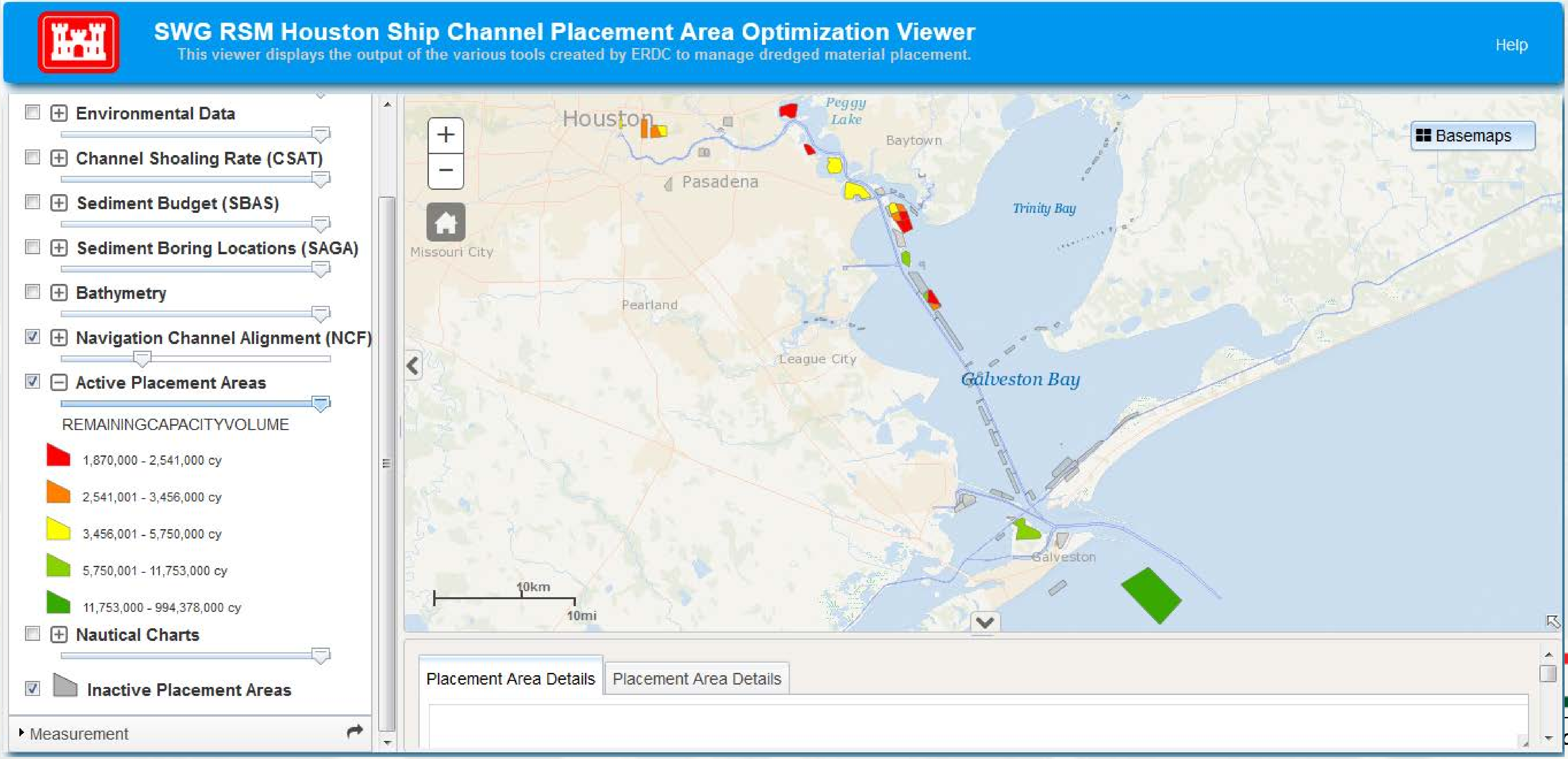
Galveston HSC Dredging Needs: Bathymetry



Galveston HSC Dredging Needs: Shoaling Rates



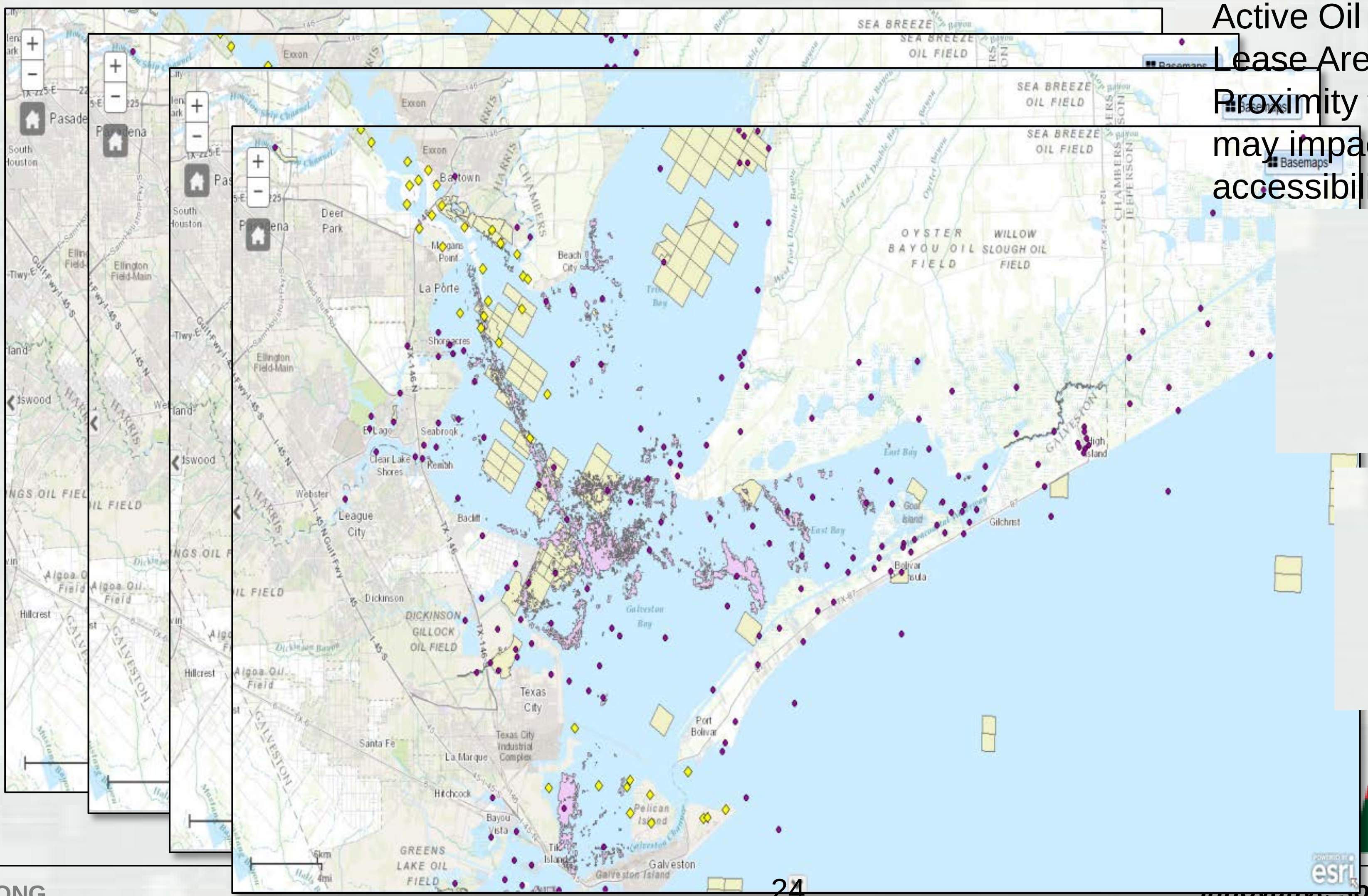
Galveston HSC Placement Areas & Capacities



Galveston HSC Placement Area Details

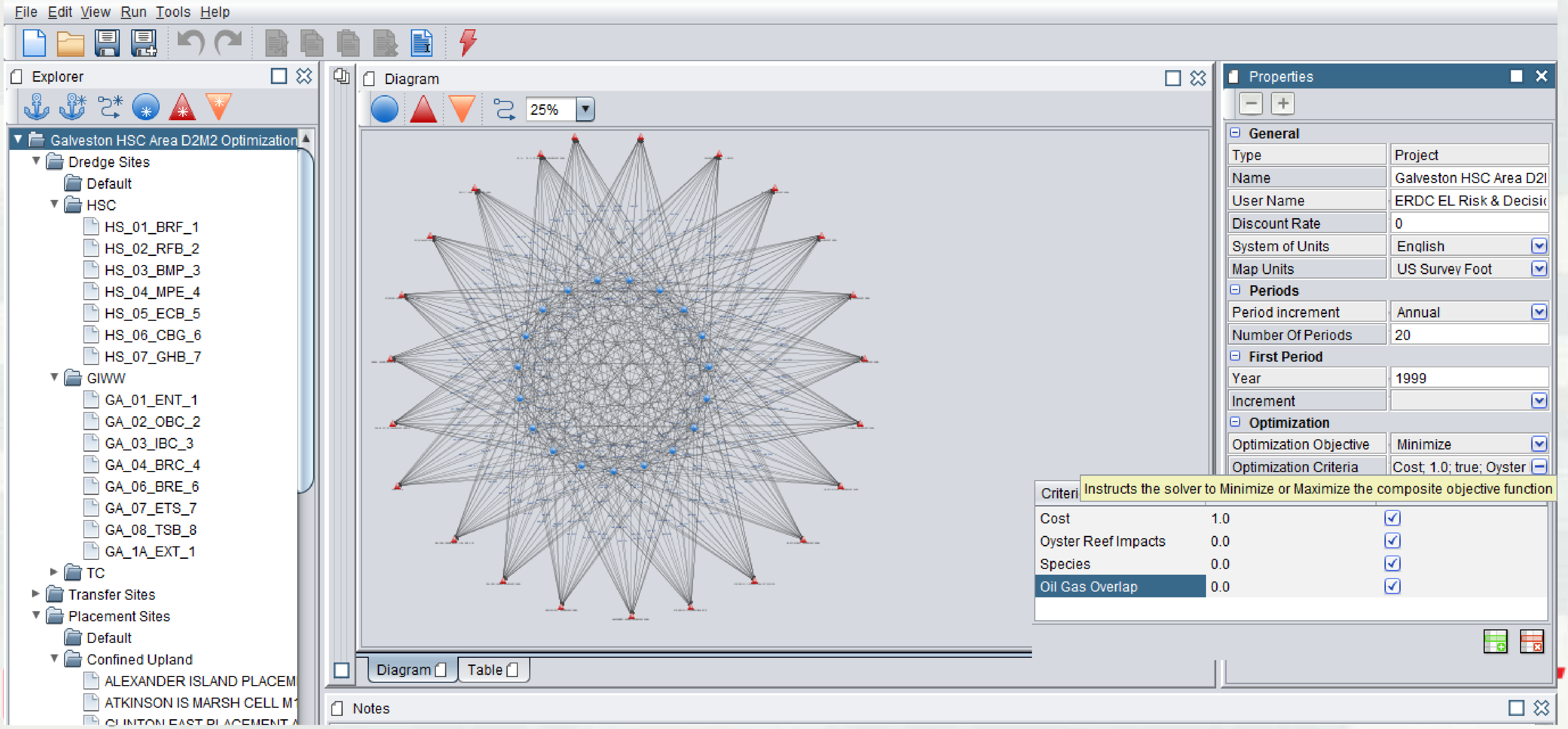
Name	Project	Date Of Capacity	Capacity	Placements	Remaining Capacity	Percent Remaining	Type
PA Spilman Island	HOUSTON SHIP CHANNEL	4-Jul-12	8,000,000	4,086,545	3,913,455	48.92	Open water confined placement area
PA Atkinson Island Marsh Cell 2	HOUSTON SHIP CHANNEL	4-Jul-06	3,000,000	138,985	2,861,015	95.37	Open water semi confined placement area
PA Atkinson Island Marsh Cell 1	HOUSTON SHIP CHANNEL	4-Jul-06	4,000,000	144,171	3,855,829	96.4	Open water confined placement area
PA Atkinson Island Marsh Cell 4	HOUSTON SHIP CHANNEL	4-Jul-06	3,000,000	458,119	2,541,881	84.73	Open water semi confined placement area
PA Mid Bay Cell 3	HOUSTON SHIP CHANNEL	4-Jul-06	4,000,000	2,084,924	1,915,076	47.88	Open water semi confined placement area
PA Lost Lake	HOUSTON SHIP CHANNEL	4-Jul-06	3,000,000	931,572	2,068,428	68.95	Open water confined placement area
PA M5/M6	HOUSTON SHIP CHANNEL	4-Jul-06	4,000,000	1,814,250	2,185,750	54.64	Open water semi confined placement area
PA 14	HOUSTON SHIP CHANNEL	4-Jul-12	10,000,000	2,319,571	7,680,429	76.8	Open water confined placement area
Clinton East Placement Area	HOUSTON SHIP CHANNEL	4-Jul-10	6,000,000	249,425	5,750,575	95.84	Onshore placement area
PA Alexander Island	HOUSTON SHIP CHANNEL	4-Feb-10	6,500,000	2,356,307	4,143,693	63.75	Open water confined placement area
PA Mid Bay Cell 1	HOUSTON SHIP CHANNEL	4-Jul-10	10,000,000	7,022,054	2,977,946	29.78	Open water semi confined placement area
PA Atkinson Island Marsh Cell 3	HOUSTON SHIP CHANNEL	4-Jul-06	4,000,000	1,200,785	2,799,215	69.98	Open water semi confined placement area
PA Mid Bay Cell 2	HOUSTON SHIP CHANNEL	29-Sep-14	12,500,000	746,675	11,753,325	94.03	Open water semi confined placement area
PA Peggy Lake	HOUSTON SHIP CHANNEL	4-Jul-10	4,000,000	2,127,680	1,872,320	46.81	Open water confined placement area
Placement Area w/ Buffer	HOUSTON SHIP CHANNEL	1-Sep-14	1,000,000,000	5,622,917	994,377,083	99.44	Open water confined placement area

Galveston HSC Data for Impact Layers



Active Oil and Gas Lease Areas: Proximity to a PA may impact accessibility

D2M2: System Network



D2M2: Upload Template

2014.09.29 - D2M2 SWG upload_LR.xlsx - Microsoft Excel

Home | Insert | Page Layout | Formulas | Data | Review | View | ApproveIt | Acrobat | Team

A1 — D2M2 spreadshseet template, use to bulk-upload data into D2M2. Enter user-defined inputs in column C.

	A	B	C
1	*D2M2 spreadshseet template, use to bulk-upload data into D2M2. Enter user-defined inputs in column C.*		
2			
3	***Variable Names***	***Comments or possible values***	***User-Defined Project Properties***
4	*Name*	Project	Galveston HSC Area D2M2 Optimization
5	*User Name*		ERDC EL Risk & Decision Science Team
6	*Discount Rate*	0.0	0
7	*System of Units*	SI, English	English
8	*Map Units*	Meter, Centimeter, Degree, Foot, US Survey Foot, Inch, Kilometer, St	US survey foot
9	*Period Increment*	Annual, Semi-annual, Ter-annual , Quarterly , Bi-monthly, Monthly, Se	Annual
10	*Number of Periods*	not greater than 300	20
11	*Year*	0	1999
12	*Increment*	not greater than the length of the selected period increment	1
13	*Optimization Objective*	Minimize	Minimize
14	*Optimization Criteria*	Cost, 1.0, True; NER, 0.0, False	Cost, 1.0, True; Oyster Reef Impacts, 0.0, True; Species, 0.0, True; Oil Gas Overlap, 0.0, True
15	*User Specified Constraints*	semi-colon separated sets: { period index/All, link name, >=/<=/=, value}	
16	*System Wide Constraints*	semi-colon separated sets: { period index/All, category name, >=/<=/=, value}	
17	*Background Image*	path to the file, holding the background image	
18	*Dredge Site Categories*	semi-colon separated list; item2; item3; item4	HSC; GIWW; TC
19	*Transfer Site Categories*	semi-colon separated list; item2; item3; item4	
20	*Placement Site Categories*	semi-colon separated list; item2; item3; item4	Confined Upland; Beneficial Use; Open Water; Confined Bay Marsh
21	*Link Categories*	semi-colon separated list; item2; item3; item4	
22	*Equipment Categories*	semi-colon separated list; item2; item3; item4	Pipeline (Cutterhead);Pipeline (Cutterhead) and Hopper; Hopper; AVG
23			
24			
25			

	A	B	C	D
1	*D2M2 spreadshseet template, use to bulk-upload data into D2M2.*			
2				
3	***Equipment Name***	***Category***	***Average Fixed Cost***	***Distance vs Cost***
4	non-empty name		semi-colon separated costs, one cost per optimization	semi-colon separated set {distance, criterion cost1, ..., criterion cost n}
5	Pipeline (Cutterhead)		0; 0;0;0;0;0	0,0,0,0,0; 1,0.7492,0,0,0
6	Pipeline (Cutterhead) and Hopper		0; 0;0;0;0;0	0,0,0,0,0; 1,0.3328,0,0,0
7	Hopper		0; 0;0;0;0;0	0,0,0,0,0; 1,0.2554,0,0,0
8	AVG		0; 0;0;0;0;0	0,0,0,0,0; 1,0.4285,0,0,0
9				
10				

Placement Site Properties | Transfer Site Properties | **Equipment Properties** | Tra

2014.09.29 - D2M2 SWG upload_LR.xlsx - Microsoft Excel

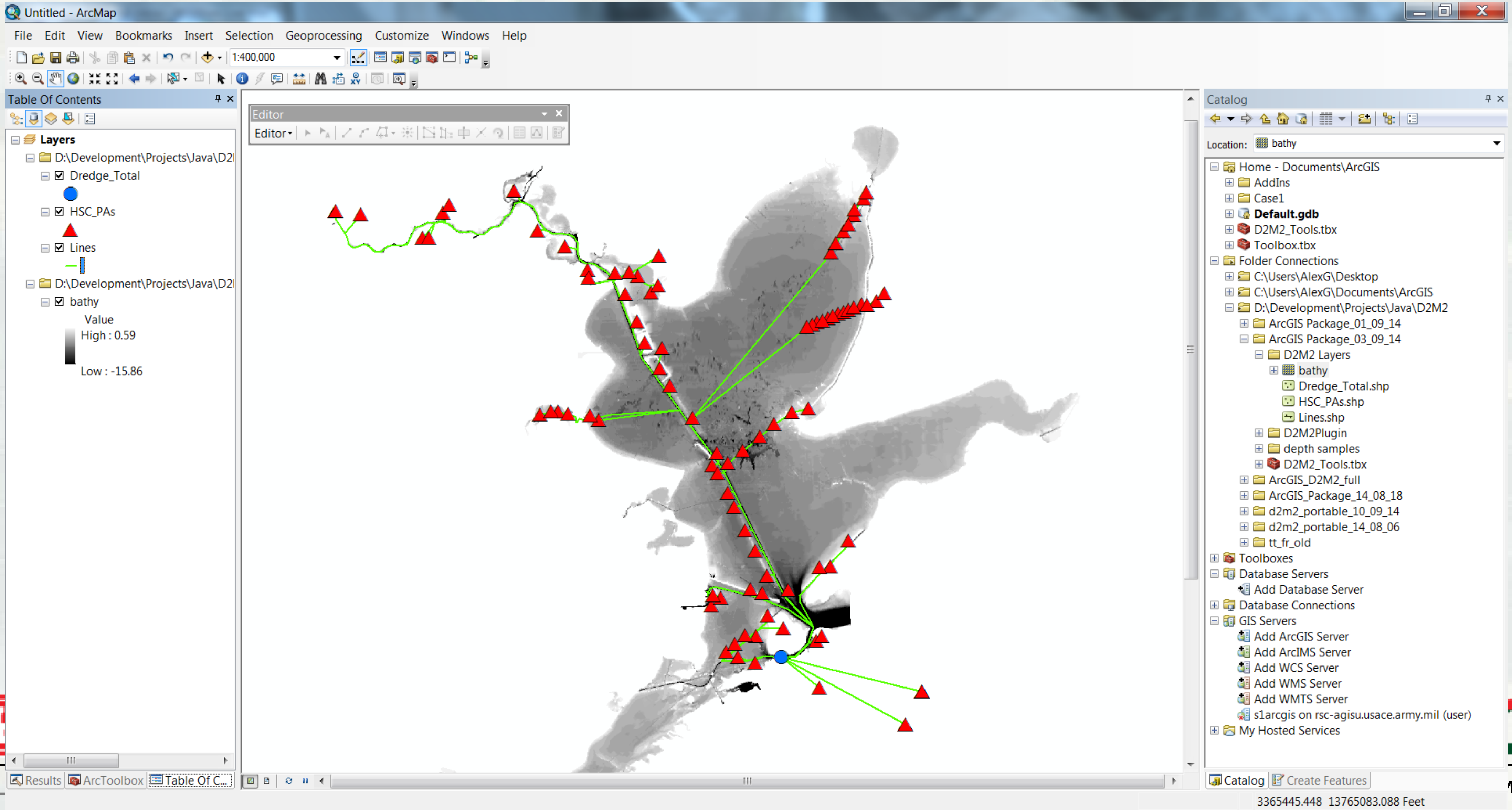
Layout | Formulas | Data | Review | View | ApproveIt | Acrobat | Team

CLINTON EAST PLACEMENT AREA

	A	C	D	E	F	G
		o bulk-upload data into D2M2.				
		Distance	***Maximum Volume***	***Equipment***	***Source site name***	***Destination site name***
		miles	can be blank			
		2.43		Pipeline (Cutterhea	TC_03_INC_3	PELICAN ISLAND PLACEMENT AREA
		6.81		Pipeline (Cutterhea	TC_03_INC_3	PLACEMENT AREA 1 ODMDS
		16.41		Pipeline (Cutterhea	TC_03_INC_3	ROSA ALLEN PLACEMENT AREA
		3.33		Pipeline (Cutterhea	TC_03_INC_3	SAN JACINTO PLACEMENT AREA
		0.68		Pipeline (Cutterhea	TC_03_INC_3	SHOAL POINT PLACEMENT AREA 2
		0.49		Pipeline (Cutterhea	TC_03_INC_3	SNAKE ISLAND PLACEMENT AREA 5/6
		10.47		Pipeline (Cutterhea	TC_03_INC_3	SPILMAN ISLAND PLACEMENT AREA
		1.41		Pipeline (Cutterhea	TC_03_INC_3	SPPA 3/4/5
		11.42		*Pipeline (Cutterhead) and Hopper*	TC_04_ITB_4	ALEXANDER ISLAND PLACEMENT AREA
		8.70		Pipeline (Cutterhea	TC_04_ITB_4	ATKINSON IS MARSH CELL M10
		9.44		Pipeline (Cutterhea	TC_04_ITB_4	ATKINSON IS MARSH CELL M7/M8/M9
		16.68		*Pipeline (Cutterhead) and Hopper*	TC_04_ITB_4	CLINTON EAST PLACEMENT AREA
		16.82		*Pipeline (Cutterhead) and Hopper*	TC_04_ITB_4	CLINTON WEST PLACEMENT AREA
		17.40		AVG	TC_04_ITB_4	FILTERBED PLACEMENT AREA
		17.22		AVG	TC_04_ITB_4	GLENDALE PLACEMENT AREA
		17.21		Pipeline (Cutterhea	TC_04_ITB_4	HOUSE TRACT PLACEMENT AREA
427	*Link #423*	12.96		Pipeline (Cutterhea	TC_04_ITB_4	LOST LAKE PLACEMENT AREA
428	*Link #424*	7.47		Pipeline (Cutterhea	TC_04_ITB_4	MID BAY PLACEMENT AREA
429	*Link #425*	8.56		Pipeline (Cutterhea	TC_04_ITB_4	PA 14
430	*Link #426*	9.23		Pipeline (Cutterhea	TC_04_ITB_4	PA 15
431	*Link #427*	9.11		AVG	TC_04_ITB_4	PA 15 - PA 14 CONNECTION PLACEMENT AREA
432	*Link #428*	11.94		Pipeline (Cutterhea	TC_04_ITB_4	PEGGY LAKE PLACEMENT AREA
433	*Link #429*	2.65		AVG	TC_04_ITB_4	PELICAN ISLAND BENEFICIAL USE SITE
434	*Link #430*	2.62		AVG	TC_04_ITB_4	PELICAN ISLAND PLACEMENT AREA
435	*Link #431*	7.00		AVG	TC_04_ITB_4	PLACEMENT AREA 1 ODMDS
436	*Link #432*	16.60		Pipeline (Cutterhea	TC_04_ITB_4	ROSA ALLEN PLACEMENT AREA
437	*Link #433*	3.52		AVG	TC_04_ITB_4	SAN JACINTO PLACEMENT AREA
438	*Link #434*	0.87		AVG	TC_04_ITB_4	SHOAL POINT PLACEMENT AREA 2
439	*Link #435*	0.68		AVG	TC_04_ITB_4	SNAKE ISLAND PLACEMENT AREA 5/6
440	*Link #436*	10.66		*Pipeline (Cutterhead) and Hopper*	TC_04_ITB_4	SPILMAN ISLAND PLACEMENT AREA
441	*Link #437*	1.60		AVG	TC_04_ITB_4	SPPA 3/4/5

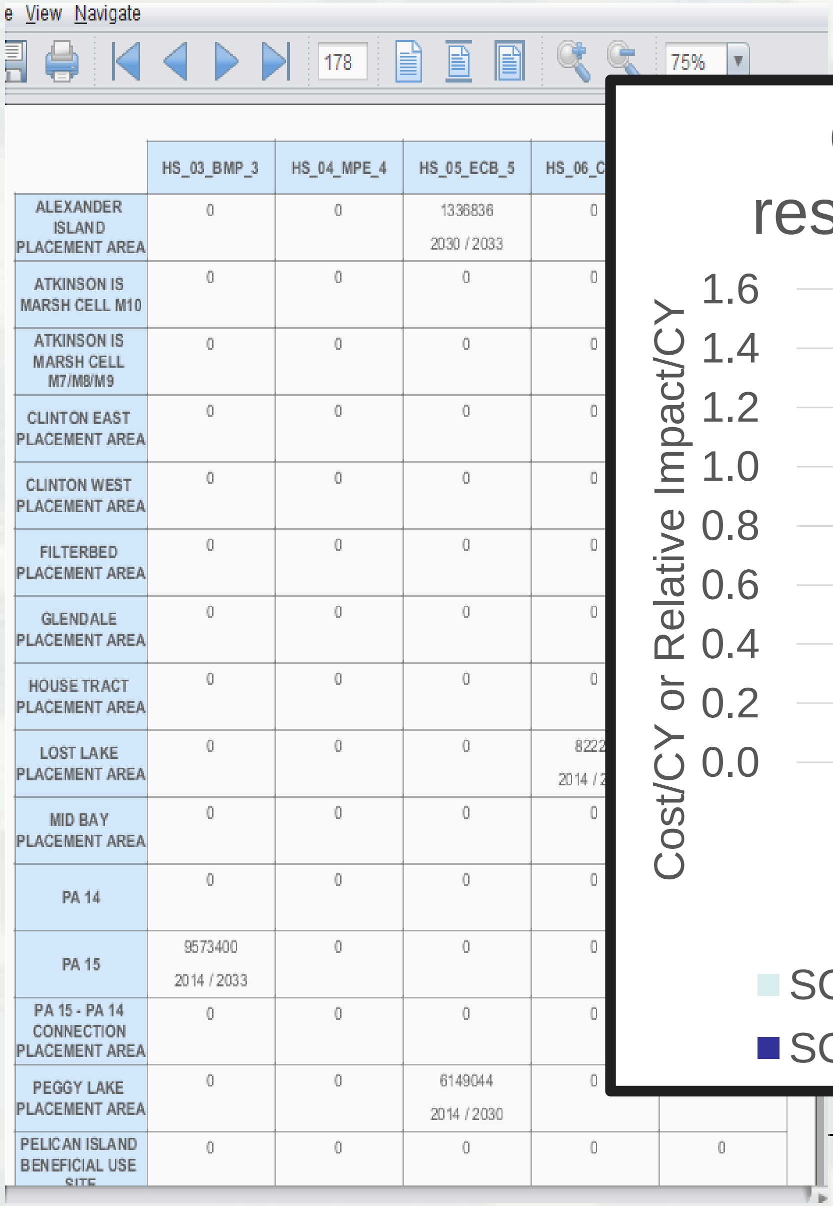
Dredge Site Properties | Placement Site Properties | Transfer Site Properties | Equipment Properties | **Transportation Link Pro**

D2M2: ArcMap Plugin with Connection to National Data

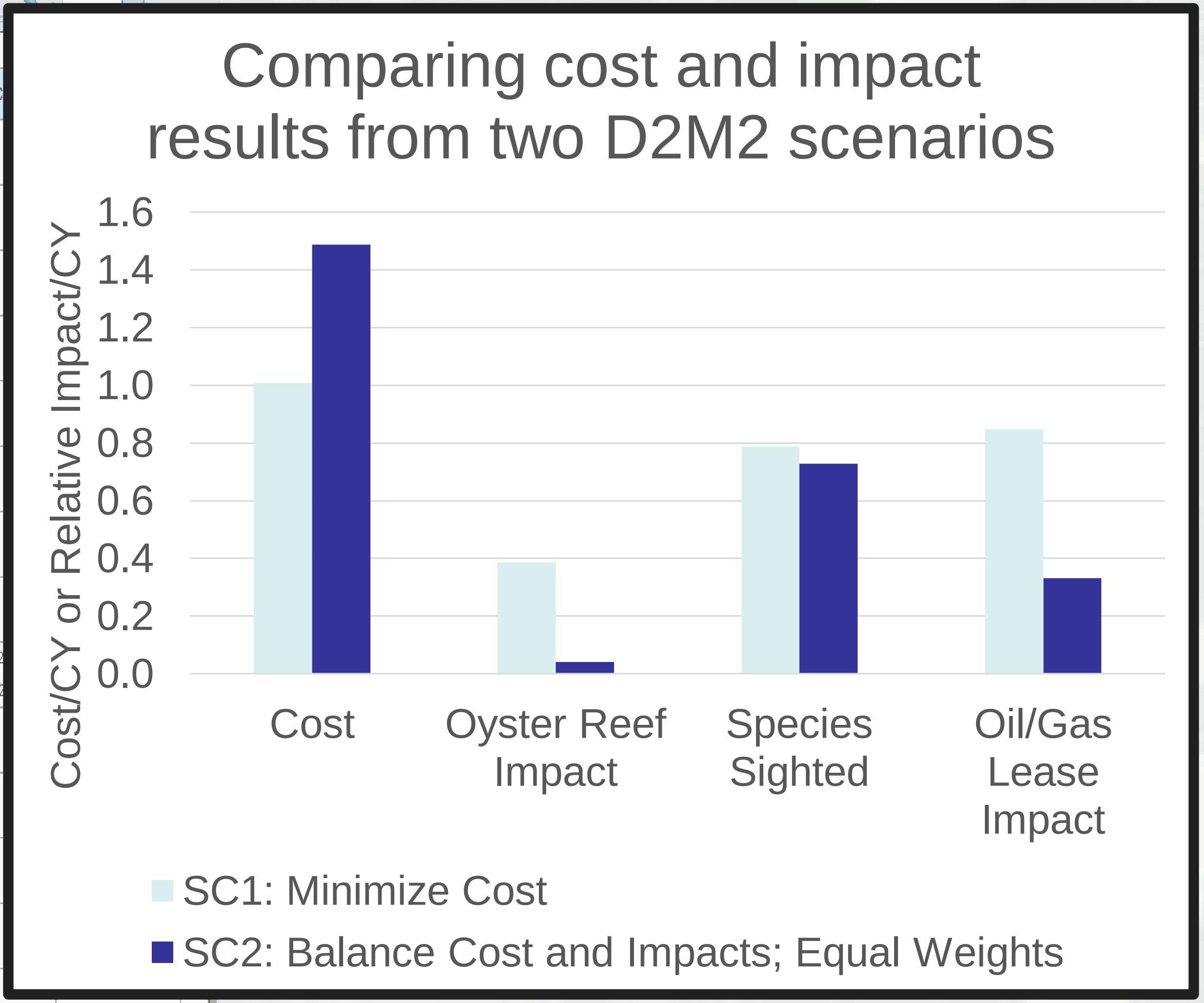


BUIL … world

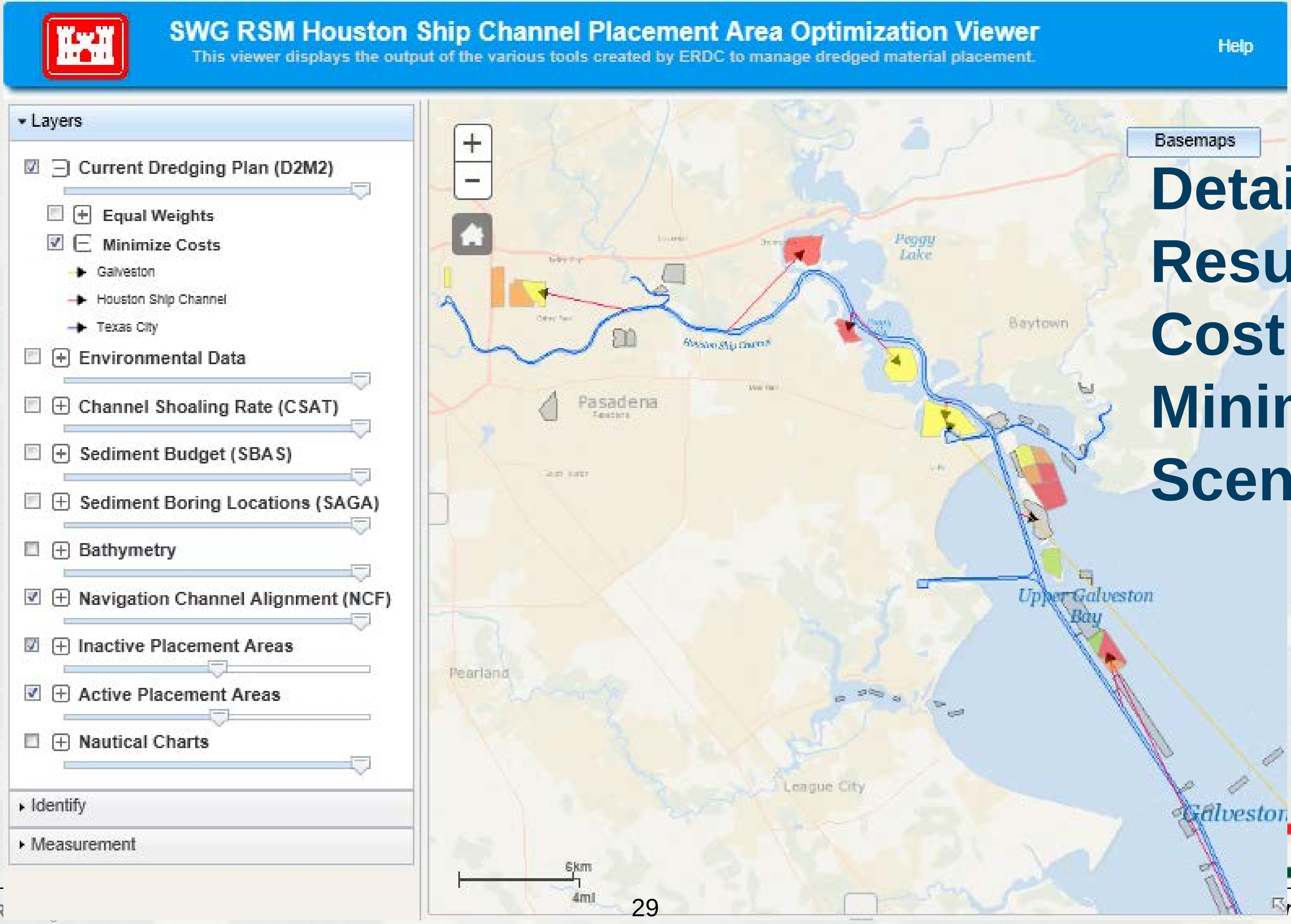
Summary Results: D2M2Galveston HSC Case Study



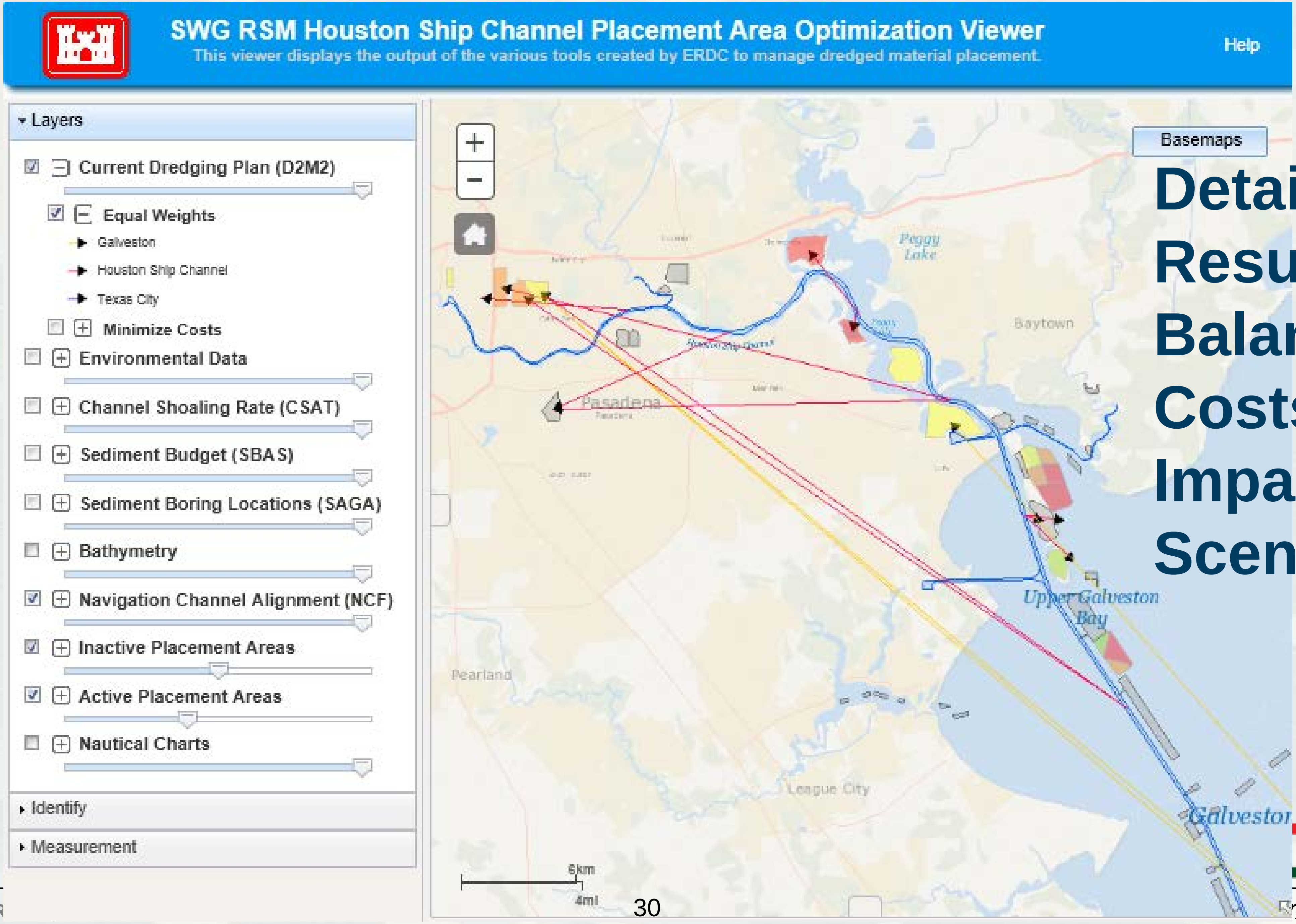
	HS_03_BMP_3	HS_04_MPE_4	HS_05_ECB_5	HS_06_C	
ALEXANDER ISLAND PLACEMENT AREA	0	0	1336836 2030 / 2033	0	
ATKINSON IS MARSH CELL M10	0	0	0	0	
ATKINSON IS MARSH CELL M7/M8/M9	0	0	0	0	
CLINTON EAST PLACEMENT AREA	0	0	0	0	
CLINTON WEST PLACEMENT AREA	0	0	0	0	
FILTERBED PLACEMENT AREA	0	0	0	0	
GLENDALE PLACEMENT AREA	0	0	0	0	
HOUSE TRACT PLACEMENT AREA	0	0	0	0	
LOST LAKE PLACEMENT AREA	0	0	0	8222 2014 / 2	
MID BAY PLACEMENT AREA	0	0	0	0	
PA 14	0	0	0	0	
PA 15	9573400 2014 / 2033	0	0	0	
PA 15 - PA 14 CONNECTION PLACEMENT AREA	0	0	0	0	
PEGGY LAKE PLACEMENT AREA	0	0	6149044 2014 / 2030	0	
PELICAN ISLAND BENEFICIAL USE SITE	0	0	0	0	0



If costs and impacts are considered equally important, the optimal routing costs 50% more than the minimize cost scenario, and has a significant relative impact savings for oysters and oil/gas leases

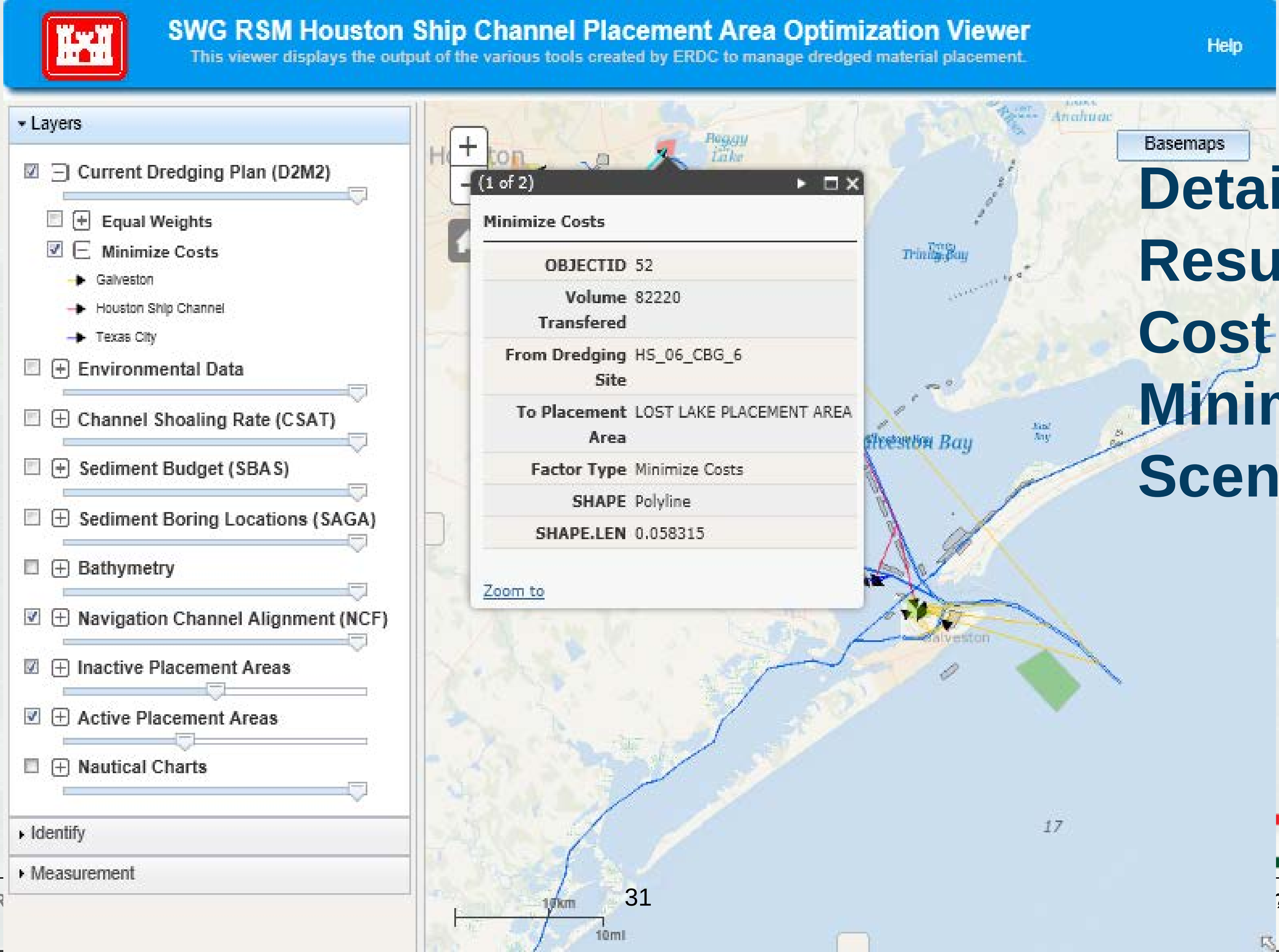


Detailed Results: Cost Minimizing Scenario

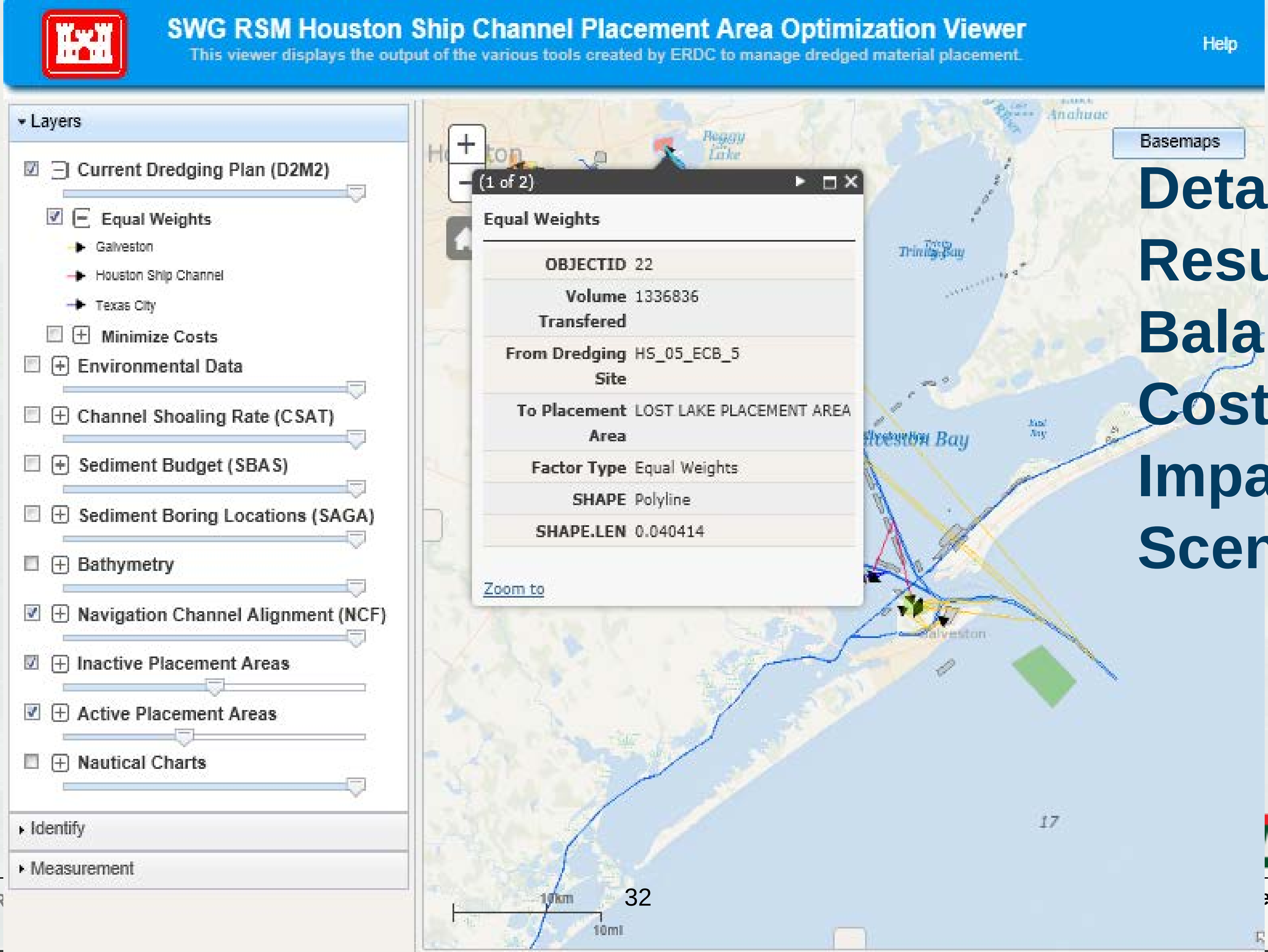


Detailed Results: Balanced Costs & Impacts Scenario

Detailed Results: Cost Minimizing Scenario



Detailed Results: Balanced Costs & Impacts Scenario



Conclusions

D2M2 is a spatial Multi-Objective Optimization tool that helps solve complex & multifaceted material management problems:

- Enables exploration of large sets of potential solutions.
- Enables explicit consideration of multiple objectives (e.g., economic, environmental, stakeholder, etc.).
- Shows opportunity cost/benefit of policy scenarios, etc.
- Adds transparency & replicability to help justify analyses.
- Enables easy scenario & “what if” analysis for future conditions.

Thank You!

Any Questions?

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Available at: http://el.erdc.usace.army.mil/dots/models.html