Operations and Maintenance Funding Allocation via Navigation Systems Optimization

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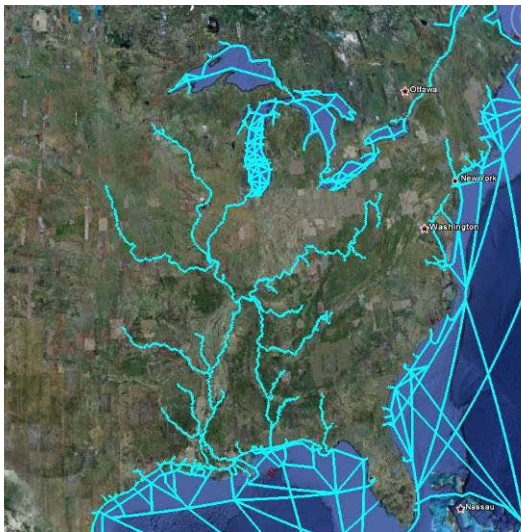

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Scarce O&M Funding

- **Fiscal constraints are forcing the Corps to make difficult decisions concerning allocation of limited Operations and Maintenance (O&M) funds across the vast portfolio of inland navigation projects.**

- **This is driving the push towards system-based methods to ensure that limited resources are optimally distributed and benefits to the Nation are maximized.**

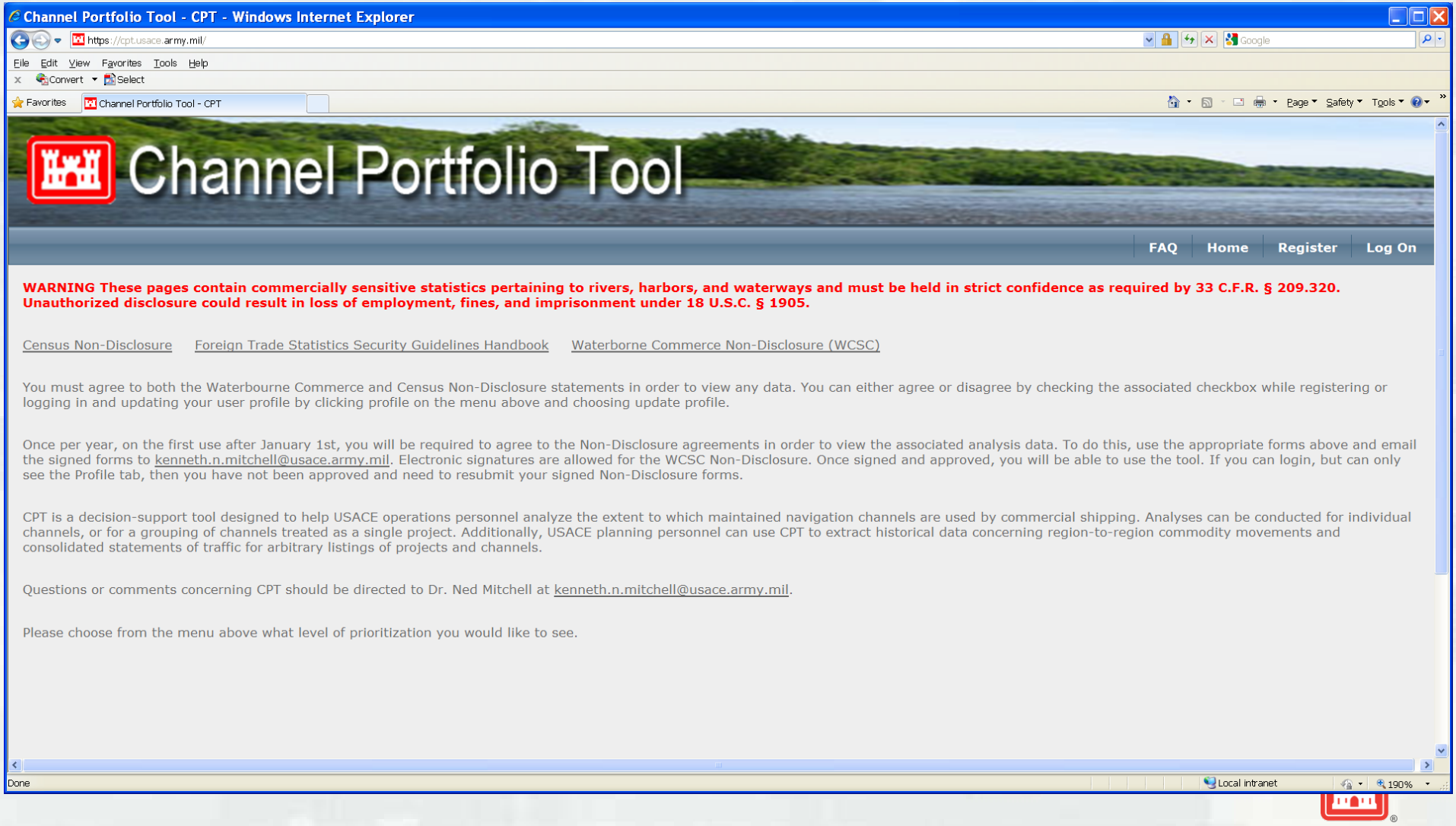
Waterborne Commerce Data

- The Corps' Waterborne Commerce Statistics Center (WCSC) collects and collates data from several sources concerning commercial use of US waterways.
  - ► Dock-level, origin-to-destination routing (Corps-use-only)
  - ► Includes tons, commodity types, vessel counts, drafts
  - ► Aggregated data already published at project level

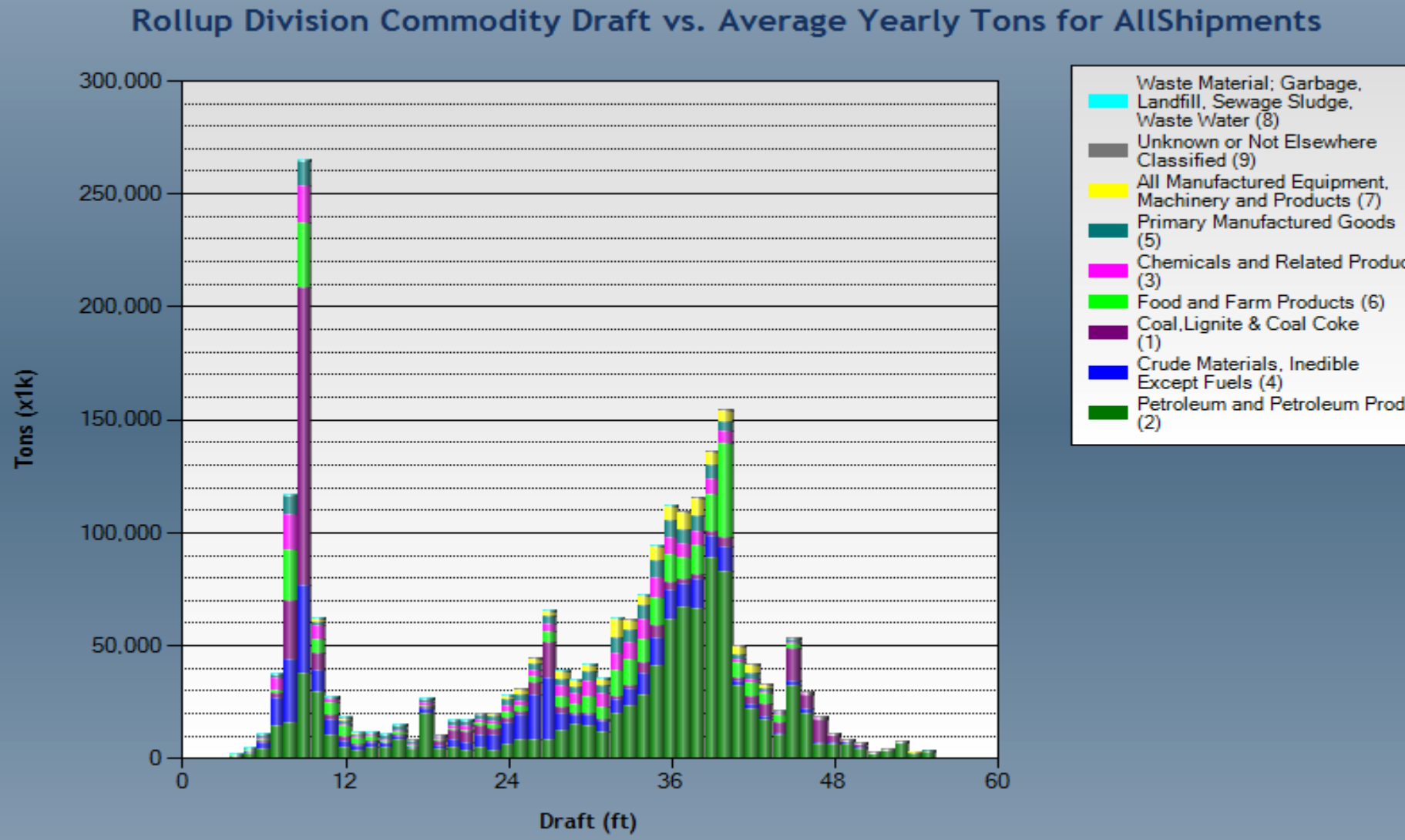
  http://www.ndc.iwr.usace.army.mil/wcsc/wcsc.htm

- Corps Ops community has not consistently used this data beyond project-level tonnage and ton-mile metrics for O&M budget development.
- Richness of data source enables advanced, systems-based approaches over and above project-based metrics.

Channel Portfolio Tool (CPT)



Depth-Utilization Profiles



CPT and Navigation Systems

New York Harbor: budgeted as separate navigation projects… yet functions as a navigation system.

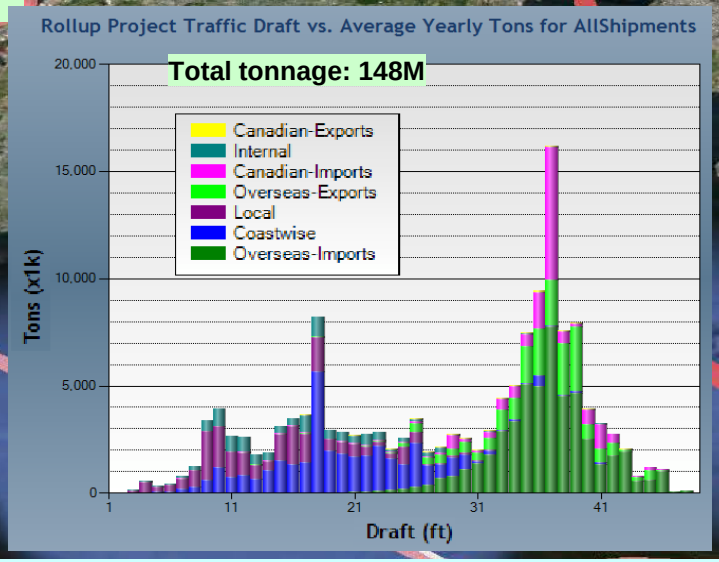
Hudson River: 14.2M tons, 2009

East River: 24.3M tons, 2009

Newark Bay: 39.5M tons, 2009

NY-NJ Channels (Arthur Kill-Kill van Kull): 121.0M tons, 2009

Buttermilk Channel: 23.8M tons, 2009

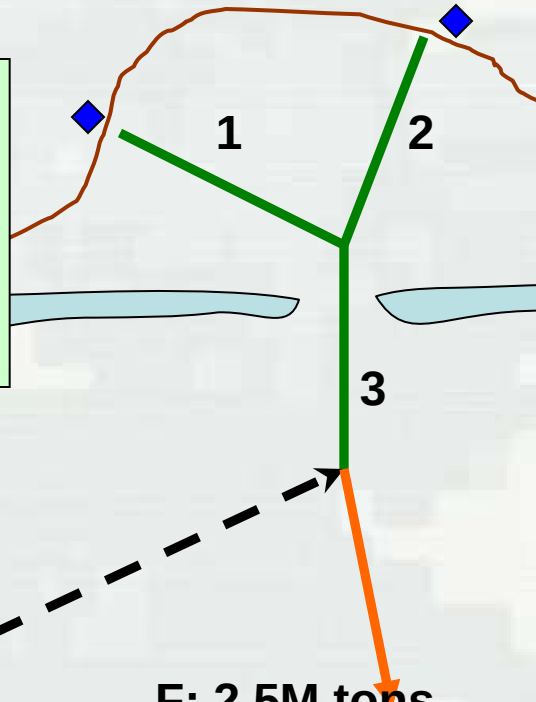


New York Lower Entrance Channels: 135.4M tons, 2009

CPT is helping to ensure that Project O&M budgeting considers interdependencies across projects in addition to channel depth-utilization.

Reach	Foreign Tons	Domestic	O&M Dredging Cost
5	1.5M	500k	$9.0M

Consider a simple “system” of two navigation projects. Dredging in each sub-reach will clear channel depths that have historically carried the tonnage levels shown.

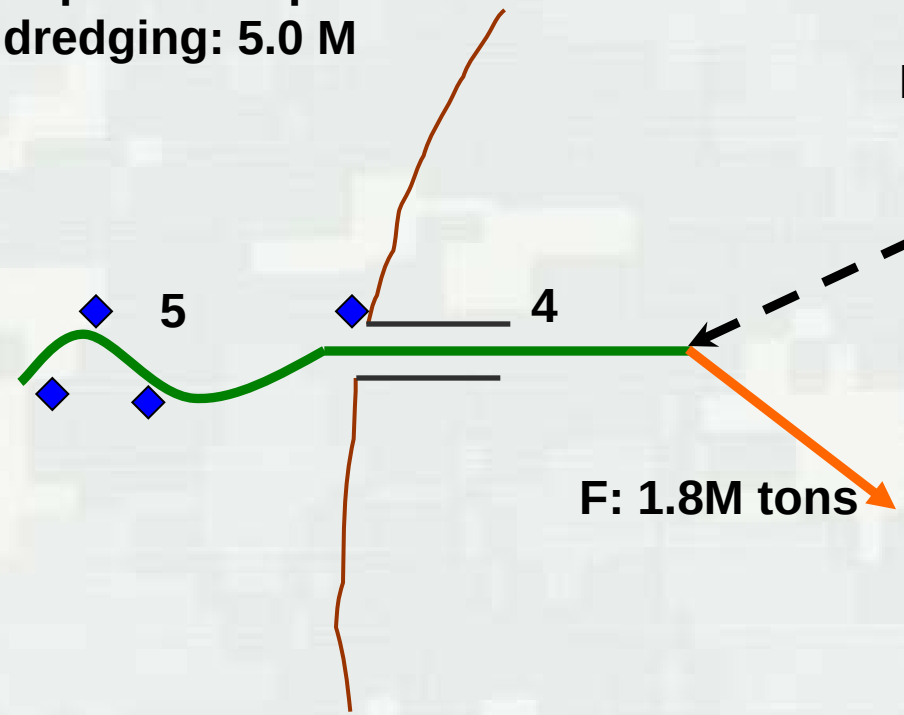


Total system tonnage dependent upon dredging: 5.0 M

O&M Budget Ceiling: $20M

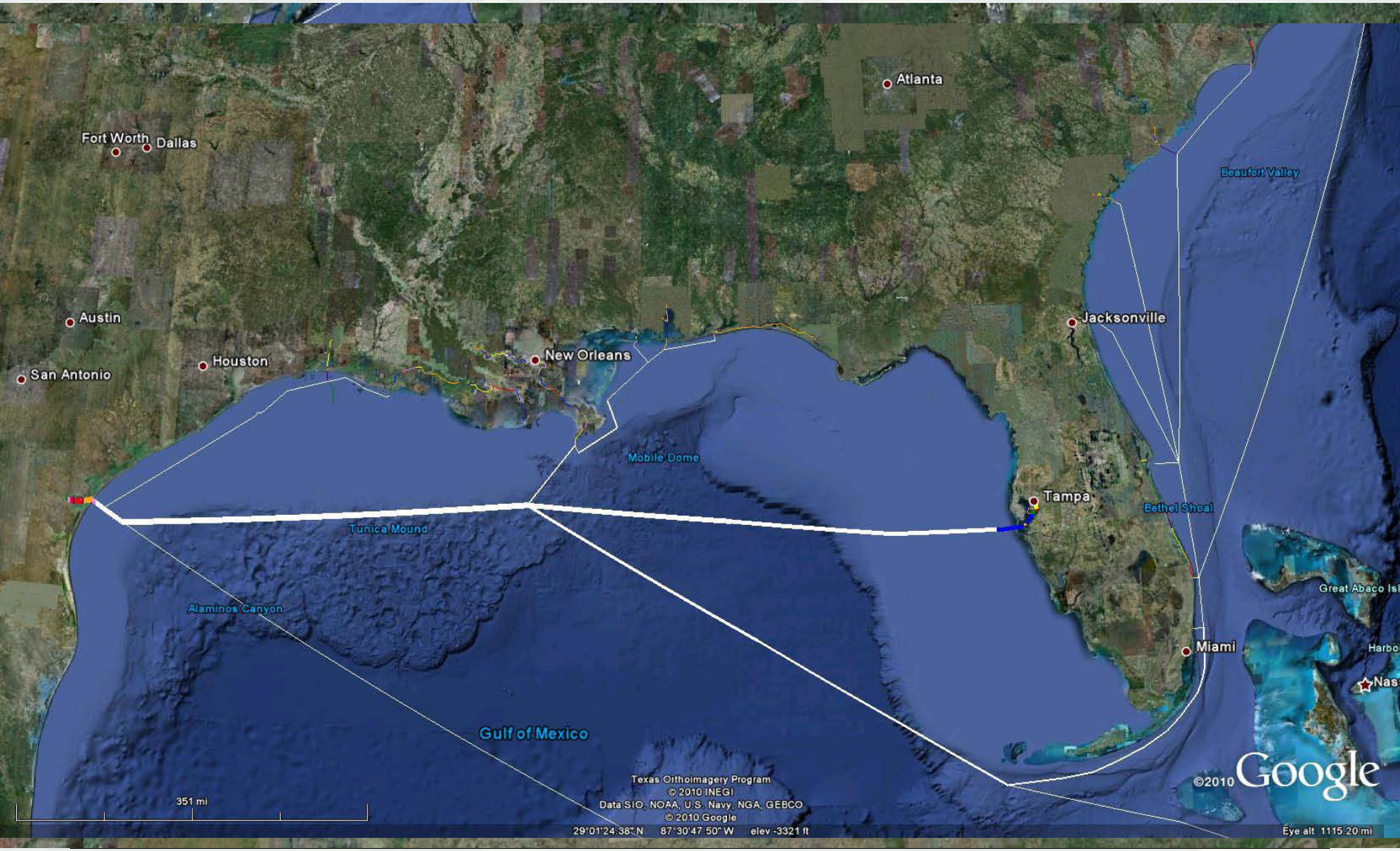
D: 700k tons

F: 2.5M tons

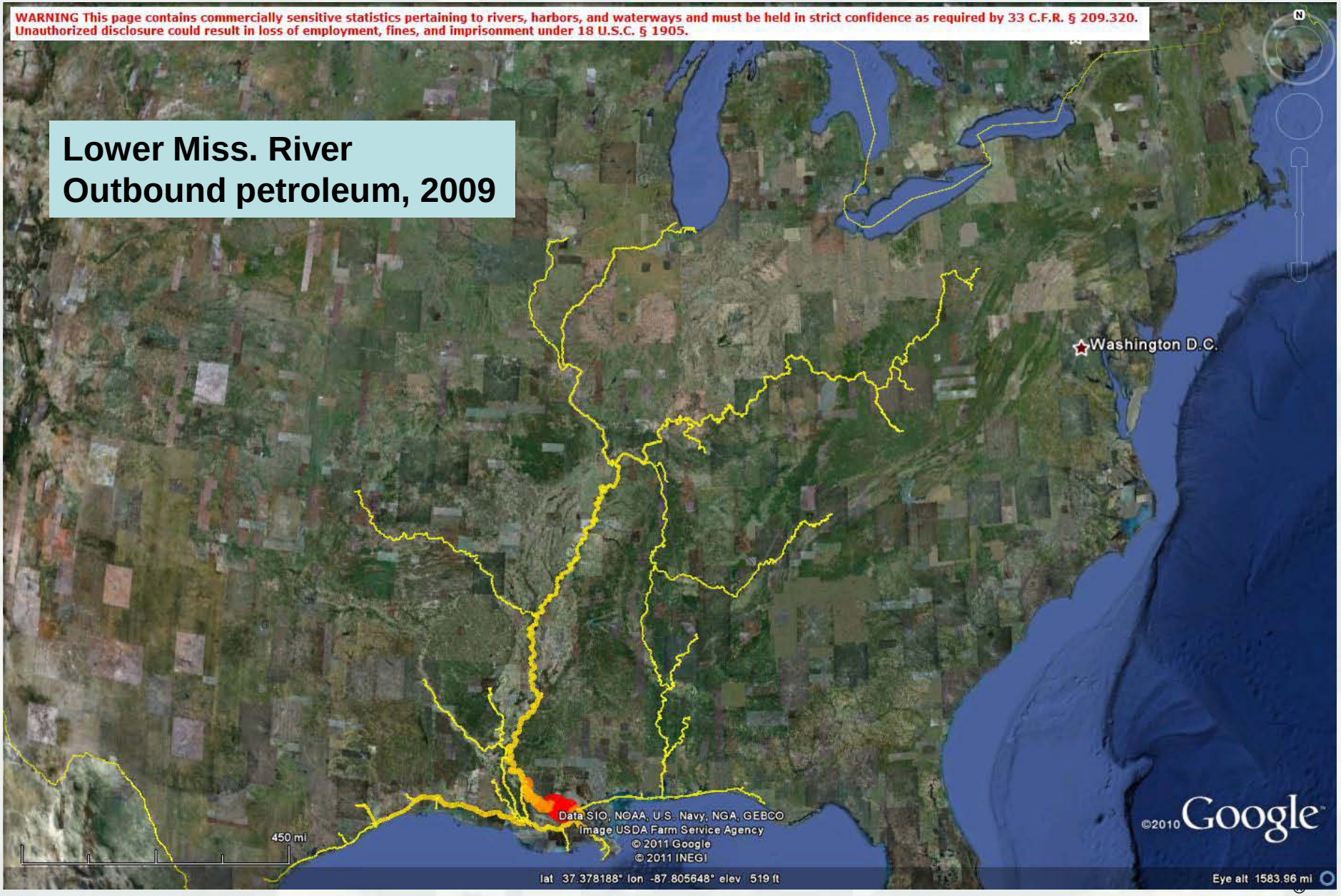


Alternatives	Supported Tonnage
Fund: 1,2,3,4 ($19M); Don’t Fund: 5	3.0M
Fund: 1,2,4,5 ($20M); Don’t Fund: 3	1.8M
Fund: 1,3,5 ($20M); Don’t Fund: 2,4	500k
Fund: 2,3,4 ($16M); Don’t Fund: 1,5	2.5M
Fund: 3,5 ($17M); Don’t Fund: 1,2,4	0.0M
Fund: 1,3,4 ($15M); Don’t Fund: 2,5	1.1M

Cargo Shared Across Projects



Visualizing Commodity Flows



Understanding Navigation Systems

Mixed-Integer Program

$$Max \quad \sum_i \sum_{j<i} b_{ij} x_{ij} \text{ (Program ORD)} \qquad (1.0)$$

$$s.t.$$

$$x_{ij} \le d_k, \qquad \forall i,j: i<j, \text{ and } k \in S(i,j) \qquad (1.1)$$

$$\sum_k d_k \le x_{ij} + \left|S(i,j)\right| - 1 \qquad \forall i,j: i<j, \qquad (1.2)$$

$$\sum_i d_i c_i \le B \qquad \forall i,j: i<j \qquad (1.3)$$

$$d, binary \ \ for\ all\ i\ ; \ \ x_{ij} \ge 0, \text{ for all } i, j. \qquad (1.4)$$

x_{ij} = Objective function variable, which is 1 when both port *i* and *j* are dredged for the improved benefits; 0, otherwise, where $i \neq j$,

d_i = Binary decision variable, which is 1 when port *i* is selected to dredge; 0, otherwise ,

b_{ij} = The maximum increase in the direct capacity between i and j by dredging both port *i* and *j*,

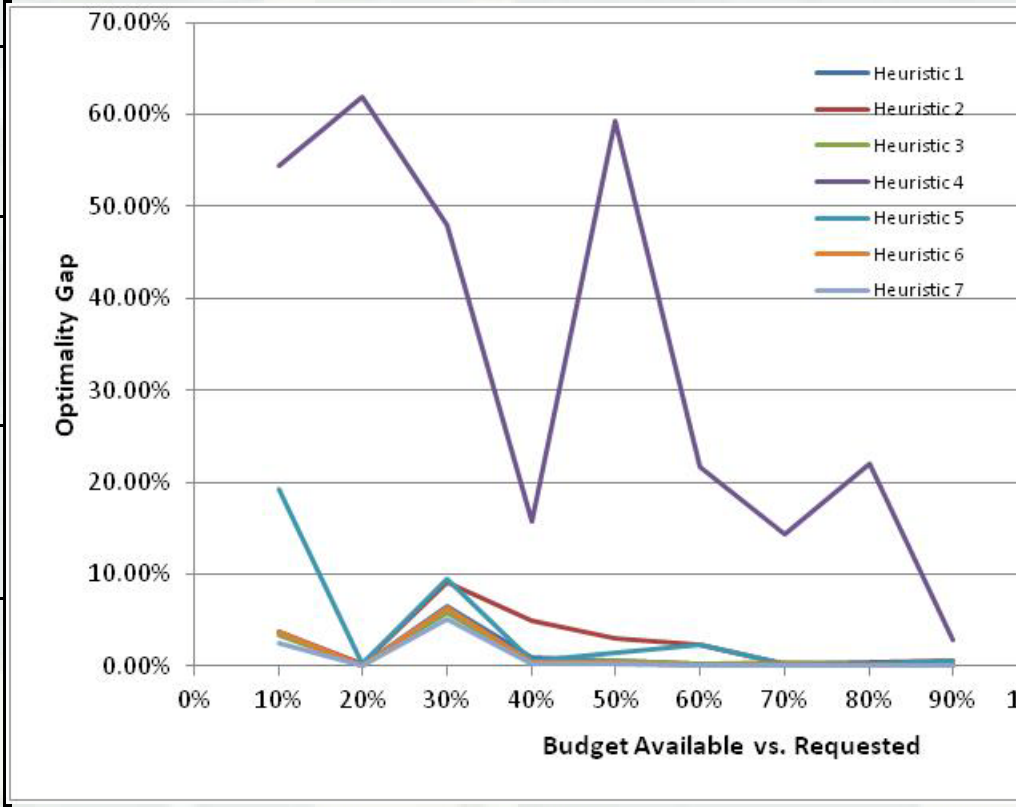
c_j = The cost for dredging port *j*,

B = The total amount of budget available for dredging projects for a planning period.

S(i,j)= Set of all projects that are necessary to realize the benefit of b_{ij}. {i,j} \in S(i,j). For example, if a flow from I to j goes through port I,k,m,j, S={i,k,m,j}.

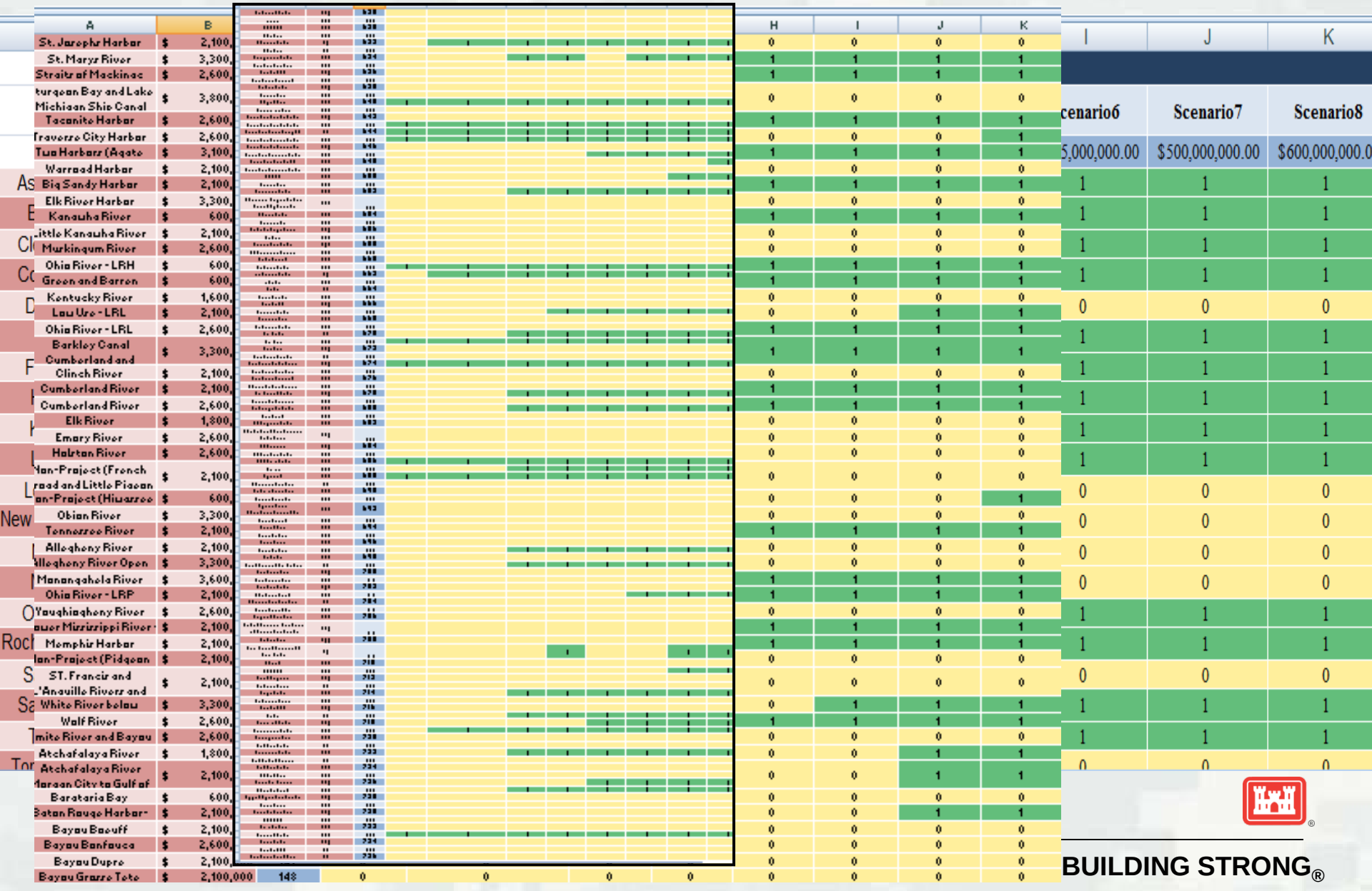
Heuristic Measures

Heuristic	Benefit/cost Ratio or other criteria for project k
1	$\frac{\sum_{(i,j):k\in S(i,j)} b_{ij}}{2c_k}$
2	$\frac{\sum_{(i,j):k\in S(i,j)} b_{ij}}{c_k + \sum_{(i,j):k\in S(i,j),i\neq k,j\neq k} (c_i + c_j)}$
3	$\sum_{(i,j):k\in S(i,j)} \frac{b_{ij}}{\sum_{m\in S(i,j)} c_m}$
4	$\frac{c_k \cdot \sum_{(i,j):k\in S(i,j)} b_{ij}}{(c_k + \sum_{\substack{m\neq k \\ m,k\in S(i,j)}} c_m)}$
5*	Dynamic H2
6*	Dynamic H3
7*	MAX{H1,H2,…,H6}



Budget
Scenario: 6

Alternate Budget Scenarios



A	B	H	I	J	K
St. Joseph Harbor	$ 2,100,000	0	0	0	0
St. Marys River	$ 3,300,000	1	1	1	1
Straits of Mackinac	$ 2,600,000	1	1	1	1
Sturgeon Bay and Lake Michigan Ship Canal	$ 3,800,000	0	0	0	0
Taconite Harbor	$ 2,600,000	1	1	1	1
Traverse City Harbor	$ 2,600,000	0	0	0	1
Two Harbors (Agate	$ 3,100,000	1	1	1	1
Warroad Harbor	$ 2,100,000	0	0	0	0
Big Sandy Harbor	$ 2,100,000	1	1	1	1
Elk River Harbor	$ 3,300,000	0	0	0	0
Kanauha River	$ 600,000	1	1	1	1
Little Kanauha River	$ 2,100,000	0	0	0	0
Muskingum River	$ 2,600,000	0	0	0	0
Ohio River - LRH	$ 600,000	1	1	1	1
Green and Barren	$ 600,000	1	1	1	1
Kentucky River	$ 1,600,000	0	0	0	0
Lau Ure - LRL	$ 2,100,000	0	0	1	1
Ohio River - LRL	$ 2,600,000	1	1	1	1
Barkley Canal	$ 3,300,000	1	1	1	1
Cumberland and Clinch River	$ 2,100,000	0	0	0	0
Cumberland River	$ 2,100,000	1	1	1	1
Cumberland River	$ 2,600,000	1	1	1	1
Elk River	$ 1,800,000	0	0	0	0
Emory River	$ 2,600,000	0	0	0	0
Holston River	$ 2,600,000	0	0	0	0
Non-Project (French Broad and Little Pigeon	$ 2,100,000	0	0	0	0
Non-Project (Hiwassee	$ 600,000	0	0	0	1
Obian River	$ 3,300,000	0	0	0	0
Tennessee River	$ 2,100,000	1	1	1	1
Alleghany River	$ 2,100,000	0	0	0	0
Alleghany River Open	$ 3,300,000	0	0	0	0
Monongahela River	$ 3,600,000	1	1	1	1
Ohio River - LRP	$ 2,100,000	1	1	1	1
Youghiogheny River	$ 2,600,000	0	0	0	0
Lower Mississippi River	$ 2,100,000	1	1	1	1
Memphis Harbor	$ 2,100,000	1	1	1	1
Non-Project (Pidgeon	$ 2,100,000	0	0	0	0
ST. Francis and L'Anguille Rivers and	$ 2,100,000	0	0	0	0
White River below	$ 3,300,000	0	1	1	1
Wolf River	$ 2,600,000	1	1	1	1
Yazoo River and Bayou	$ 2,600,000	0	0	0	0
Atchafalaya River	$ 1,800,000	0	0	1	1
Atchafalaya River Morgan City to Gulf of	$ 2,100,000	0	0	1	1
Barataria Bay	$ 600,000	0	0	0	0
Baton Rouge Harbor-	$ 2,100,000	0	0	1	1
Bayou Boeuff	$ 2,100,000	0	0	0	0
Bayou Bonfouca	$ 2,600,000	0	0	0	0
Bayou Dupre	$ 2,100,000	0	0	0	0
Bayou Grosse Tete	$ 2,100,000	148	0	0	0	0	0	0	0

I	J	K
cenario6	Scenario7	Scenario8
5,000,000.00	$500,000,000.00	$600,000,000.0
1	1	1
1	1	1
1	1	1
1	1	1
0	0	0
1	1	1
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0	0	0
0	0	0

Frequently-Funded Projects

Ashtabula Harbor
Buffalo Harbor
Conneaut Harbor
Erie Harbor
Sandusky Harbor
Toledo Harbor
Indiana Harbor
Channels in Lake St. Clair
Detroit River
Duluth-Superior Harbor
Rogers City, MI
Rouge River, MI
St. Clair River
St. Marys River
Straits of Mackinac
Two Harbors (Agate Bay)
Big Sandy Harbor
Kanawha River
Ohio River – LRH
Ohio River - LRL
Cumberland River Nashville
Tennessee River
Monongahela River
Ohio River - LRP
Lower Mississippi River - MVM
Calcasieu River and Pass
GIWW - MVN
Lower Mississippi River – MVN
Illinois Waterway
Upper Mississippi River -MVR
Upper Mississippi River - MVS
Upper Mississippi River - MVP

Baltimore Harbor
Boston Harbor
Kennebec River, ME
New Haven Harbor
Portland Harbor
Portsmouth Harbor
Buttermilk Channel
New York and New Jersey Channels
New York Harbor
Channel to Newport News
Newport News
Norfolk Harbor
Thimble Shoal Channel
York River
Delaware River Between Philadelphia
Delaware River, Philadelphia to the Sea
Missouri River - NWK
Columbia and Lower Willamette Rivers
Columbia River above The Dalles Dam,
Columbia River between Vancouver, WA
and The Dalles, OR
Multnomah Channel
Oregon Slough
Yaquina Bay and Harbor
Grays Harbor and Chehalis River
Tacoma Harbor
Columbia R. and Trib above Mcnary
Snake River
Homer
Humboldt Harbor
Kodiak Harbor
Unalaska Island

Honolulu Harbor
Charleston Harbor
(Puerto Rico) - Fajardo Harbor
(Puerto Rico) - Ponce Harbor
Canaveral Harbor
Jacksonville Harbor
Miami Harbor
Palm Beach Harbor
Port Everglades Harbor
Tampa
Bayou La Batre
Black Warrior and Tombigbee Rivers
Gulfport Harbor
Mobile
Pascagoula Harbor
Pensacola Harbor
Three Mile Creek
Brunswick Harbor
Savannah Harbor
Morehead City Harbor
Northeast (Cape Fear) River
Wilmington Harbor
Los Angeles - Long Beach Harbors
Port Hueneme
San Diego Harbor
Brownsville
Corpus Christi Ship Channel
Freeport Harbor
Galveston Harbor and Channel
Houston Ship Channel
Matagorda Ship Channel
Sabine-Neches Waterway

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Questions?

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