A GIS-Based Model for CO_2 Pipeline Transport and Source-Sink Matching Optimization

May 10, 2006

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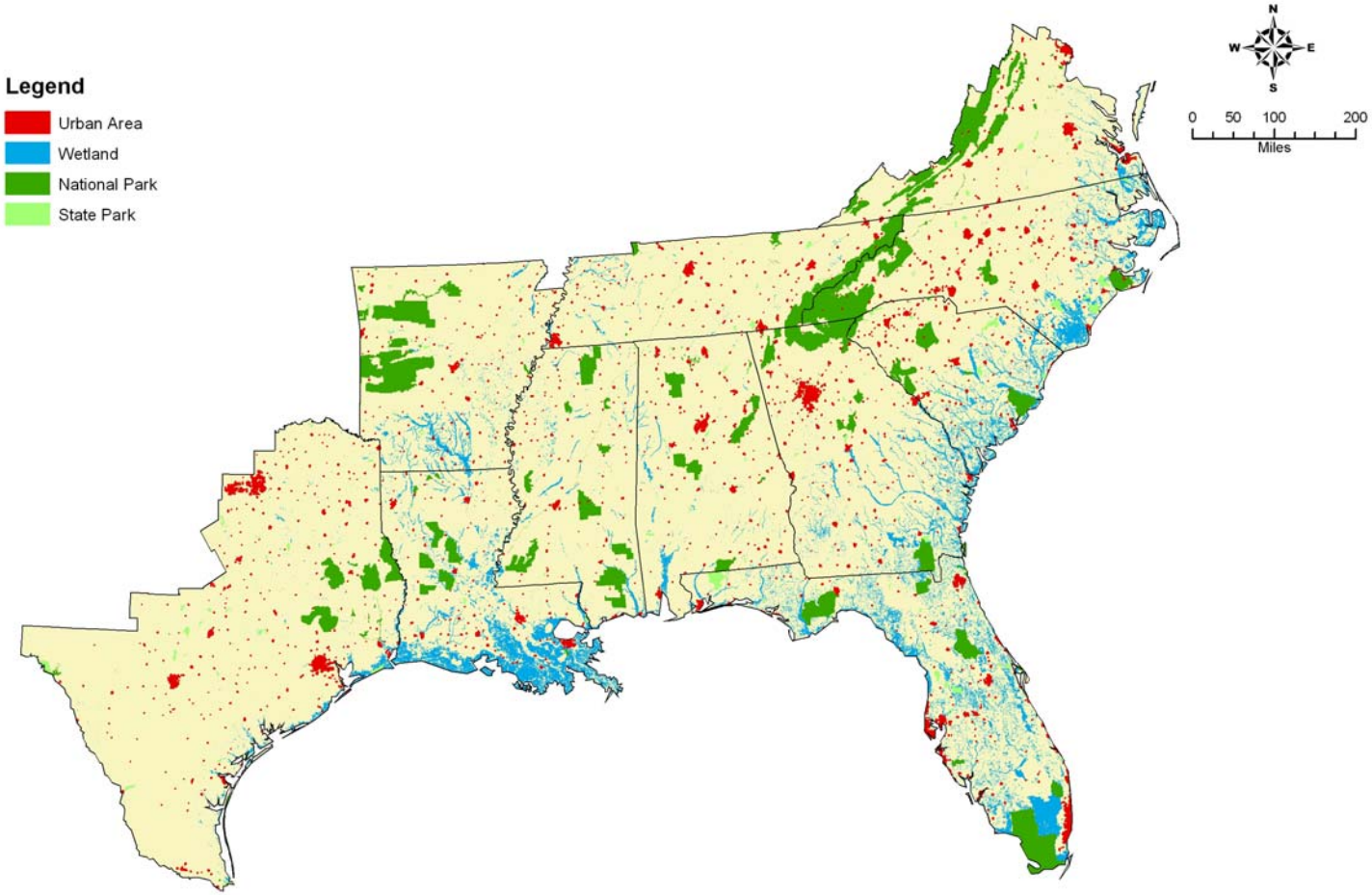
Overview

- CO_2 Pipeline Transport Analysis
- One-to-One Source-sink Matching
  - NATCARB web-based application
- Many-to-Many Source-sink Matching
  - Regional partnership application

CO_2 Pipeline Transport Analysis Options

- **Straight-line Distance Matching**
- **Least-cost Path Matching**
- **Existing Right-of-way**

Terrain


Legend
Urban Area
Wetland
National Park
State Park
N
W
E
S
0 50 100 200
Miles

Data Source and Relative Cost Factor for Obstacle Layers

Construction Condition		Raw Data Source	Cost Factor
Base Case			1
Slope		ESRI Digital Elevation Model	
	10-20%		0.1
	20-30%		0.4
	>30%		0.8
Protected Area			
	Populated Place	ESRI Data & Maps	15
	Wetland	USGS LULC Data	15
	National Park	ESRI Data & Maps	30
	State Park	ESRI Data & Maps	15
Crossing			
	Wateway Crossing	ESRI Data & Maps	10
	Railroad Crossing	ESRI Data & Maps	3
	Highway Crossing	ESRI Data & Maps	3

Note: The relative weights are calculated as the ratios of the additional construction costs to cross those obstacles and the base case construction cost for an 8 inch pipeline.

Aggregate Crossing Cost Factor Map

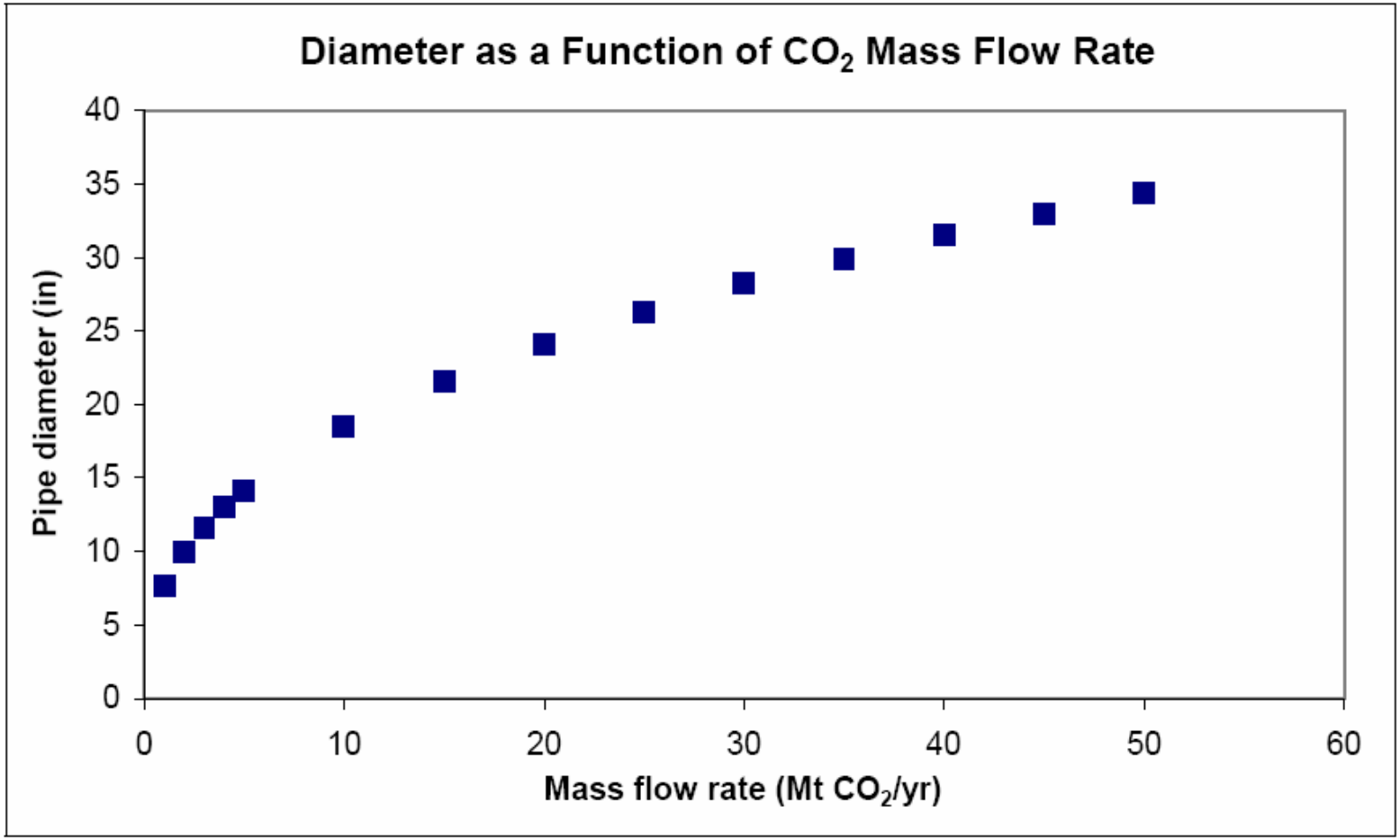
Pipeline Diameter Calculation (1)

$$\frac{\Delta P}{\Delta L} = \frac{32 f \dot{m}^2}{\pi^2 \rho D^5}$$

$\Delta P / \Delta L$:	Pressure drop per length unit
f :	Fanning friction factor
$\dot{m}$:	CO_2 mass flow rate
ρ :	CO_2 density
D:	Pipeline diameter

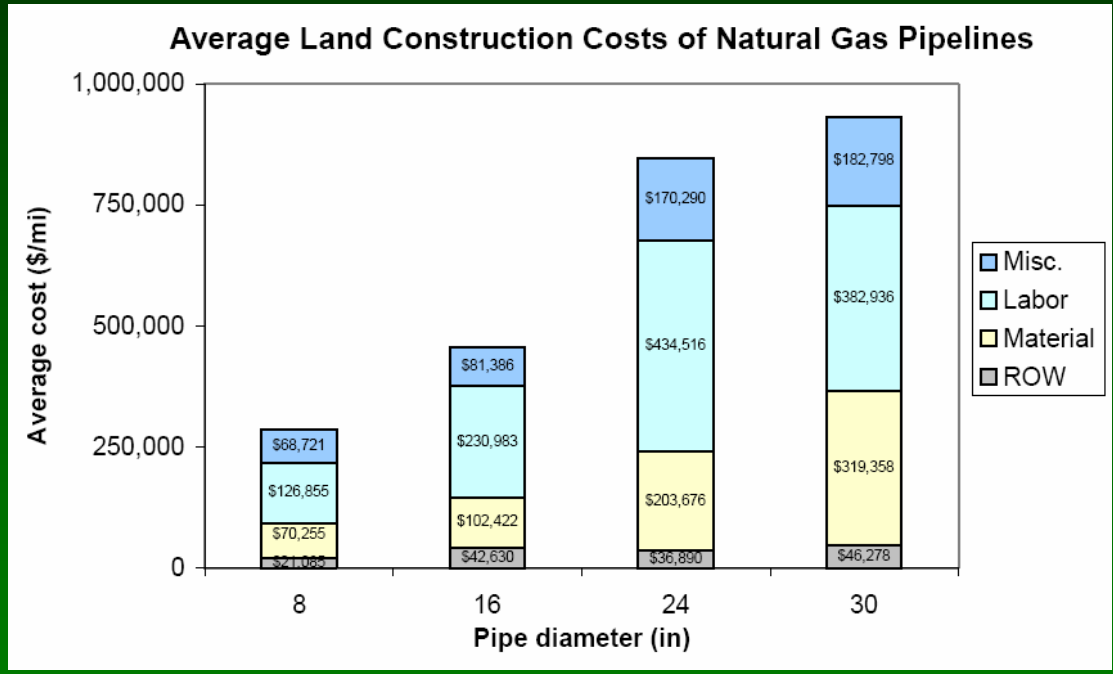
Doubling the CO_2 mass flow rate will increase the pipeline diameter to increase by 32 percent.

Pipeline Diameter Calculation (2)

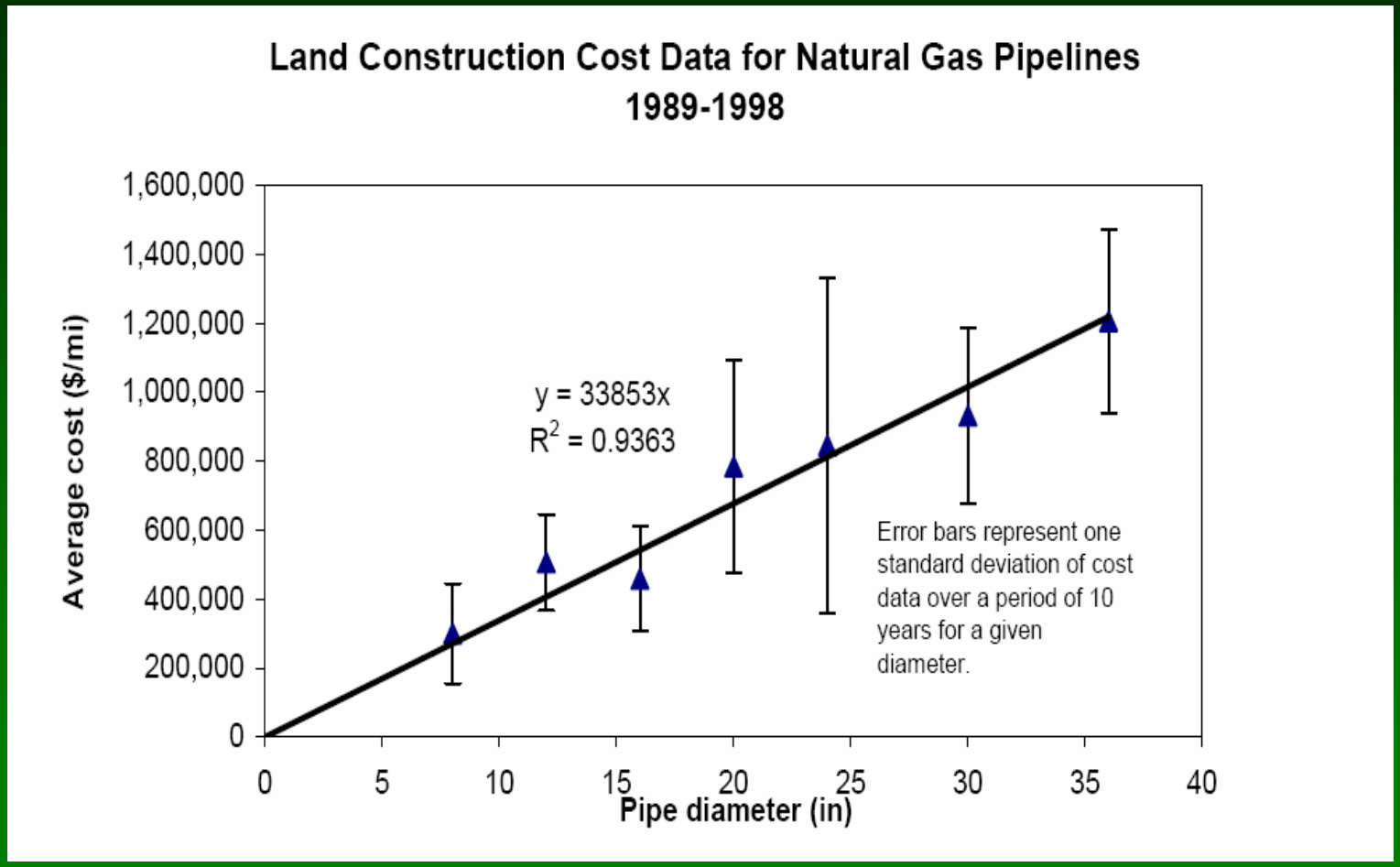


Pipeline Land Construction Cost

- Land Construction Cost
  - Material
  - Labor
  - ROW
  - Misc.
- O&M Cost



Pipeline Land Construction Cost Model



Disaggregated CO_2 Pipeline Transportation Cost Model

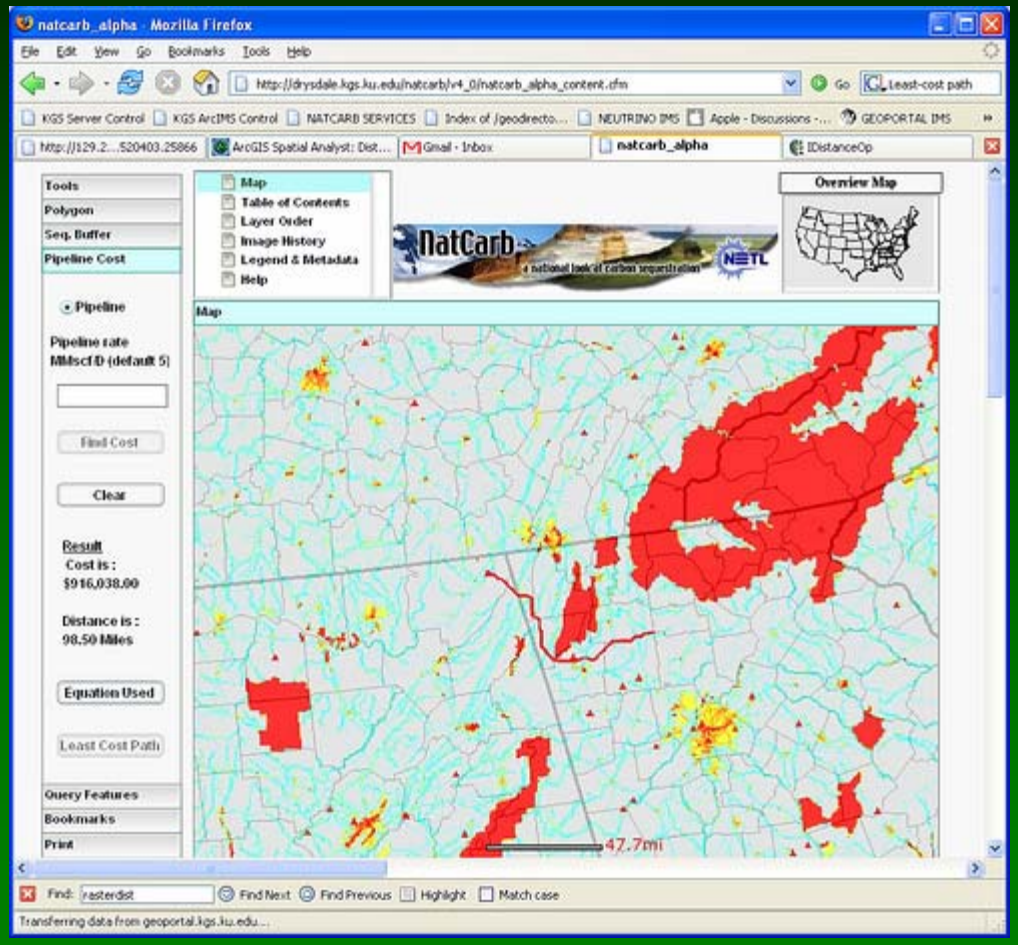
- Base Case Construction Cost (diameter-dependent)
  - The average pipeline construction cost is $33,900/in/mile.
  - Using an average relative cost factor of 1.75, this can be converted to a base case pipeline construction cost of $19,300/in/mile.
- Obstacle Crossing Construction Cost (diameter-independent)
  - The obstacle crossing cost is calculated as the product of the relative weight and the base case construction cost for an 8 inch pipeline, but is assumed to be the same for pipelines of any diameter
- Operation and Management Cost (diameter-independent)
  - The O&M cost is estimated to be $5,000/mile per year, independent of pipeline diameter

One-to-One Matching

- Web-based Pipeline Tool Implementation (www.natcarb.org)
- One-to-One Matching Least-cost Route Selection
- Pipeline Construction Cost Estimation

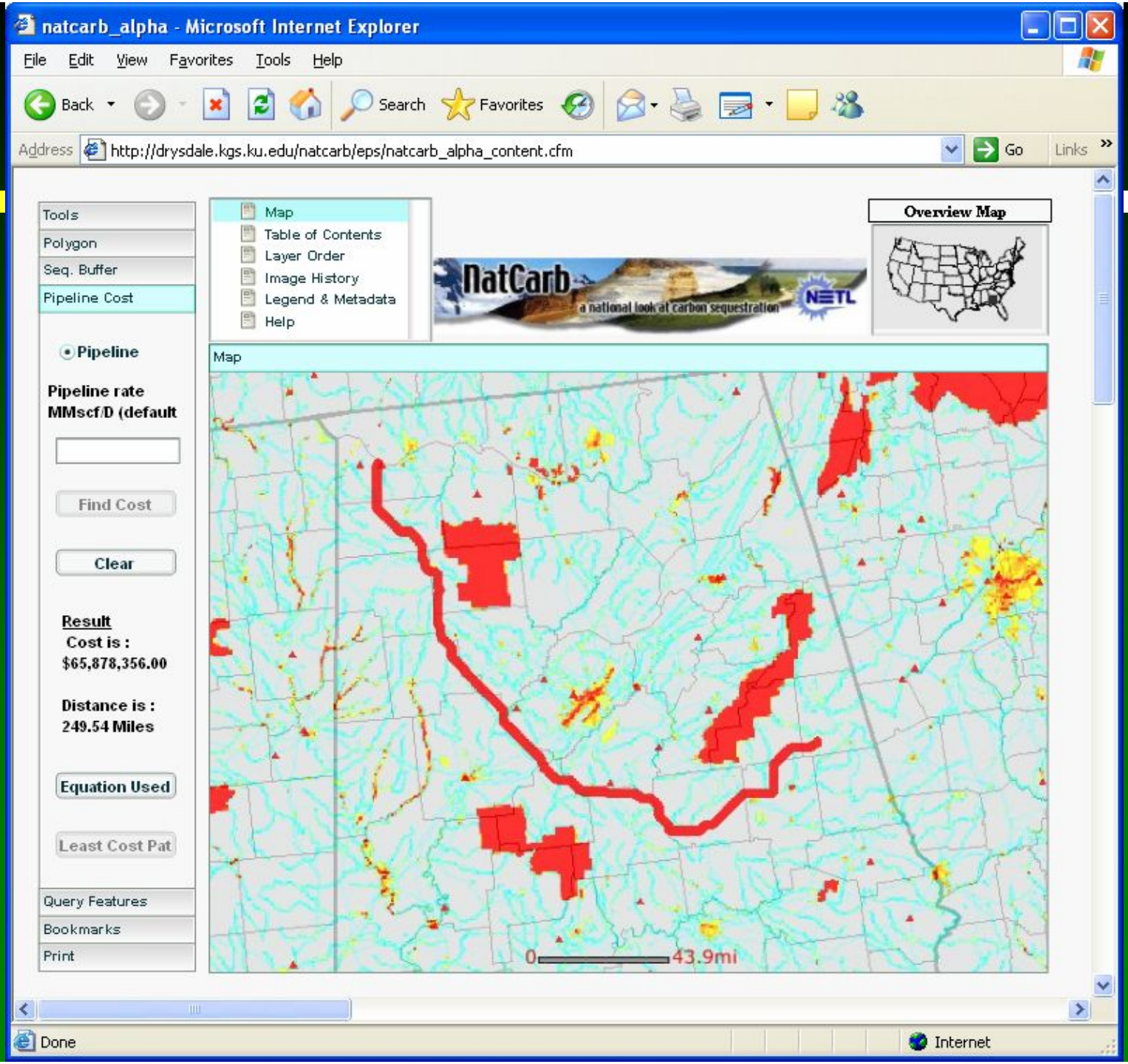
Natcarb Web-based Tool

- Goal: Allow the user to perform a least-cost path function in real time between two distinct locations.



Natcarb Point to Point

- Technology, Data, and User Input Required:
  - ESRI's ArcGIS Server 9.1
  - Custom built Java servlet
  - ESRI's ArcIMS map server
  - MIT cost raster dataset
  - Two points selected by the user over any area in the region within the cost raster
- Basic Model:
  - Generate cost distance raster from the first point to all cells in the cost raster
  - Generate the least-cost path from the data generated above and the second point
  - Calculate the distance of the least-cost path
  - Estimate the pipeline construction cost


natcarb_alpha - Microsoft Internet Explorer
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Go Links
Tools
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Seq. Buffer
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Find Cost
Clear
Result
Cost is :
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Distance is :
249.54 Miles
Equation Used
Least Cost Pat
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Bookmarks
Print
Map
Table of Contents
Layer Order
Image History
Legend & Metadata
Help
NatCarb
a national look at carbon sequestration
NETL
Overview Map
Map
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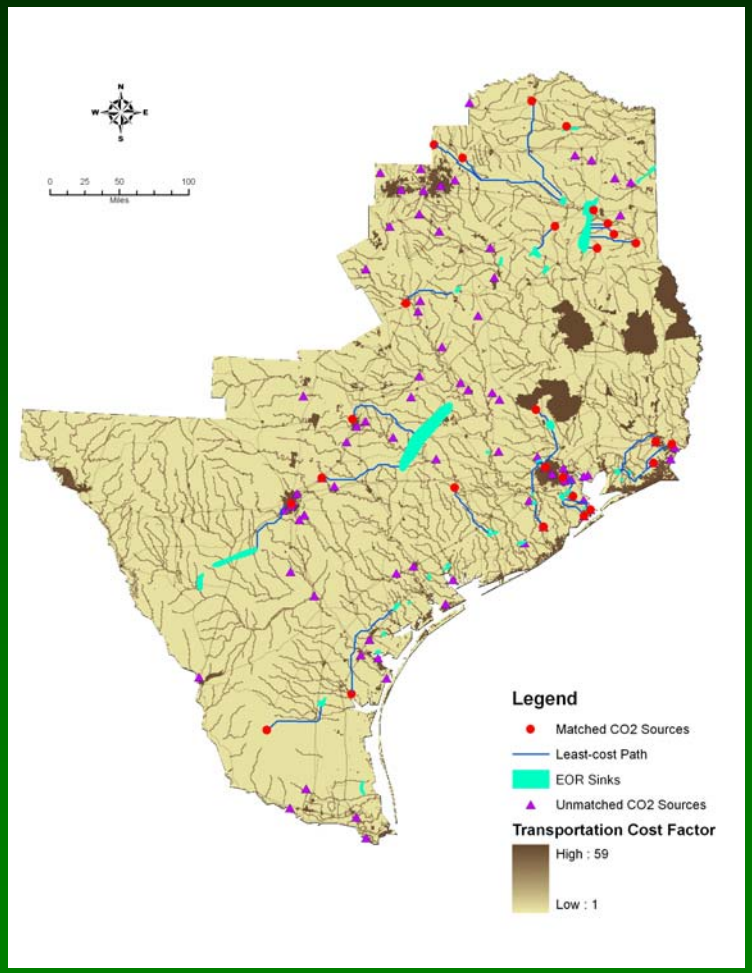
Internet

Many-to-Many Matching: System Optimization

- CO_2 Source Set
  - 130 sources with a 25-year CO_2 flow for storage of 8.9 Gt
    - Fossil-fuel power plants (98)
    - Ammonia (1)
    - Cement (8)
    - Gas processing (8)
    - Refineries (15)
- Storage Sink Set
  - 34 oil fields with EOR potential with an overall CO_2 Storage Capacity of 1.2 Gt
    - Depth > 800m
    - CO_2 Storage Capacity > 5 Mt
- Constant CO_2 –EOR Credit
- Optimize Transportation Network
  - Take into account the storage capacity constraint of each sink

Regional Application: Eastern Texas

- 29 sources with a 25-year CO_2 flow of 1.0 Gt are matched to EOR sinks.
- 101 sources remain unmatched.



Transportation Cost to EOR Sinks

Marginal Transportation Cost by Annual CO_2 Storage Rate in Oil Fields with EOR Potential, eastern Texas