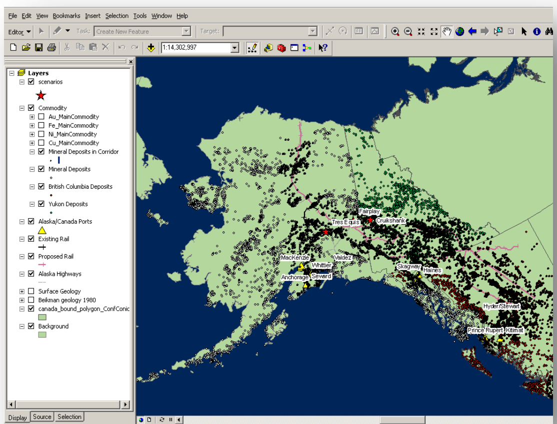
MOREV Tool

Mineral Occurrence Revenue Estimation & Visualization Tool

A System for Evaluating Potential Revenue and Carbon Emissions from Mineral Resources for Existing and Expanded Rail Networks in the Alaska - Northwest Canada region



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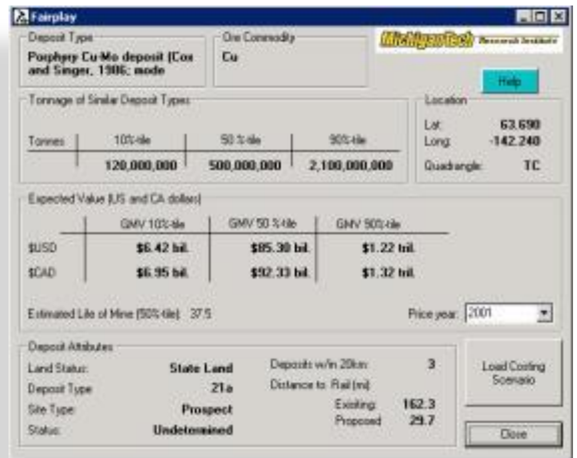
September 2011



www.mtri.org
www.mtri.org/mineraloccurrence.html

Presentation Outline

- **Background & Motivation**
- **Current Capabilities & Upcoming Developments**
- **Screen Shot Demo**
- **Tool Methodology**
  - **Revenue Estimation Methodology**
    - Calculation of Gross Metal Value
    - Estimation of potential freight volumes
  - **Cost Estimation Methodology**
    - Capacity, Mining cost (Capital Expense, Operating)
    - Transportation cost (multimodal)
  - **Carbon Accounting: Transportation Carbon Accounting Module (TCAM)**
    - Rail, Truck, Waterborne (OGV & barge)
  - **Dynamic Network Routing Module**
- **Detailed Screen Shot Walk-through**
  - **Visualization examples**
  - **Step-by-step tool usage**

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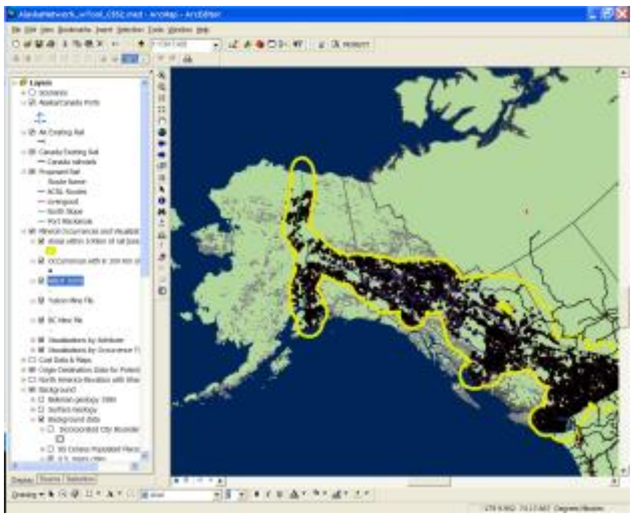
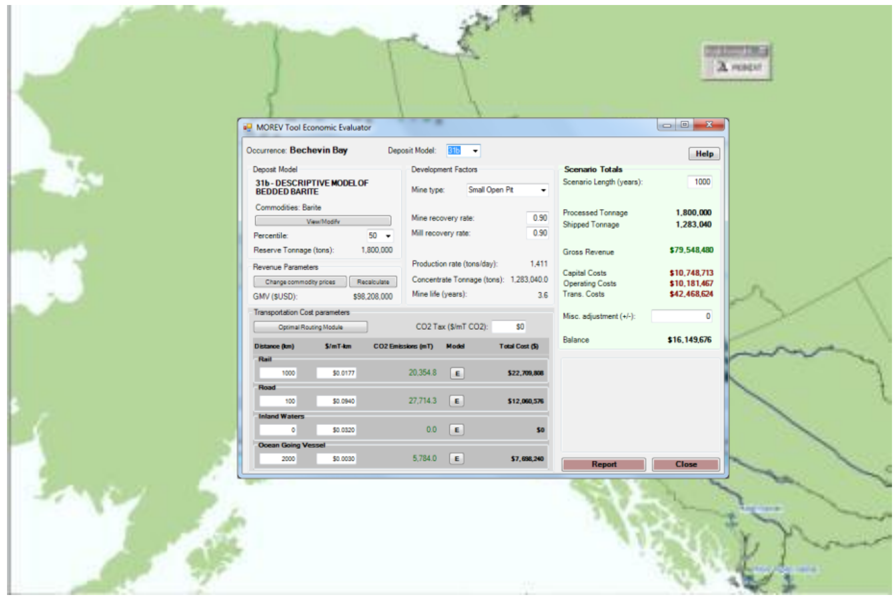
MOREV: Purpose

- Provide **GIS-based visualization** for decision makers to **evaluate revenue potential** from **mineral exploitation** in **Alaska**, **Yukon**, and **BC**
  - *Especially in light of new proposed & potential rail transportation links*

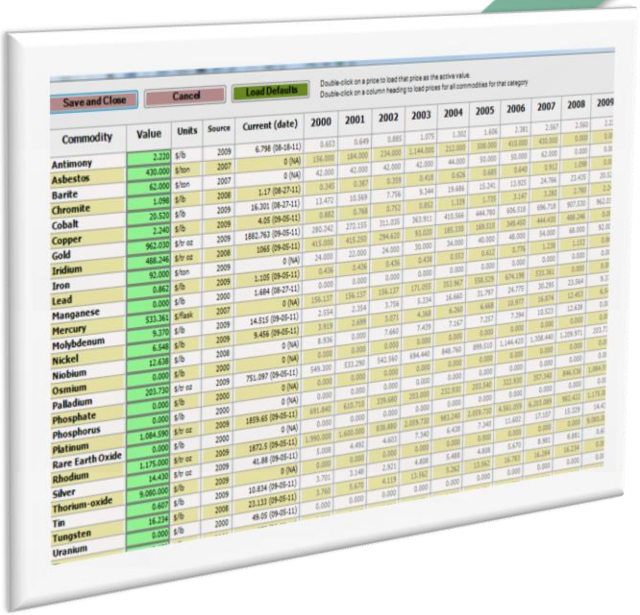


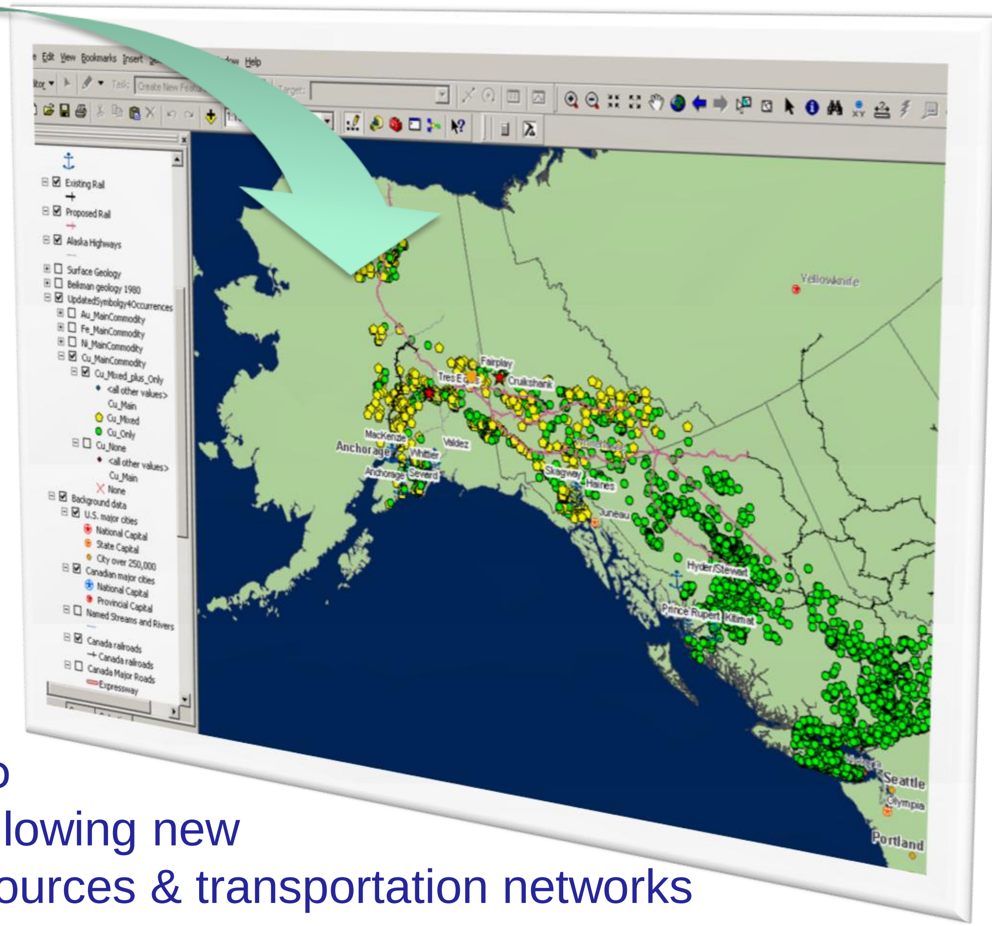


MOREV: Background

Starting point: **Gross Metal Value of Identified Major Mineral Occurrences in ARR Extension Corridor in Alaska** (P. Metz, full ARDF version, revised 2010 from 2007 ACRL Phase I study)

…but, to be useful it is desirable to make resource databases available to more users in **resource development** & **transportation** communities, so…





…we implemented Metz's methodology into ARDF, BC mine file, and Yukon mine file, allowing new ways of exploring scenarios for mineral resources & transportation networks

MOREV: Key Points

- Spatializing the mineral occurrence database allows integration of disparate data important to resource development & transportation decision makers, example uses:
  - → Calculate potential revenue & freight volumes from occurrences within 100-km of a proposed transport link
  - → Visualize proximity to existing infrastructure, historic mines, nearby deposits
  - → Visualize land use patterns, watersheds, political boundaries
  - → Track CO_2 in transportation segment for a proposed mine
  - → Calculate and visualize most efficient multi-modal transportation route.
- Sensitivity analyses can be performed, for example:
  - Transportation costs with and without a new rail link
  - Carbon impact of multimodal routing options (truck/rail/OGV)
- Inputs and assumptions are transparent to and modifiable by the user
  - e.g. modal shift costs, carbon cost per ton-mile, port charges, mineral occurrence tonnage, costs per ton-mile, commodity price, mine recovery rate, etc.
- Occurrence data are updateable

MOREV: Potential Users

- Small to midsized exploration interests in pre-feasibility stages of project planning for new mining projects
- Transportation & infrastructure planners
  - State & local government
- Potential for helping in permitting process
  - Example: Preparation of NI 43-101 mineral project disclosures in Canada
- Government agencies & resource database maintainers
- Investment community & lenders
- Researchers (geological, transportation, economic, etc.)

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MOREV: Current Capabilities

- Database Linkage
  - **Gross Metal Value** can be automatically calculated for any ***collection of*** mineral deposits with a valid USGS Deposit Model
    - Currently applies to **67%** of ALL metallic mineral occurrences in the combined ARDF, BC, and Yukon mine files (**73%** of ARDF occurrences)
    - We have added functionality so that the **user can select/change a deposit model** for the occurrences with unidentified deposit types
- Scenario Evaluation
  - Calculates and displays **mine capacity** (tons/day) based on Modified Taylor Rule (updated by Long 2009)
    - From this value, calculate Mine Capital Expense and **Mine Operating Cost**
    - Researching implementation of SEE software – more advanced costing
  - **Dynamically calculates optimal route** from mineral occurrence to user-chosen destination based on transportation costs
    - Derives total multi-modal **transportation cost** and **carbon emissions** associated with transporting minerals along the calculated route

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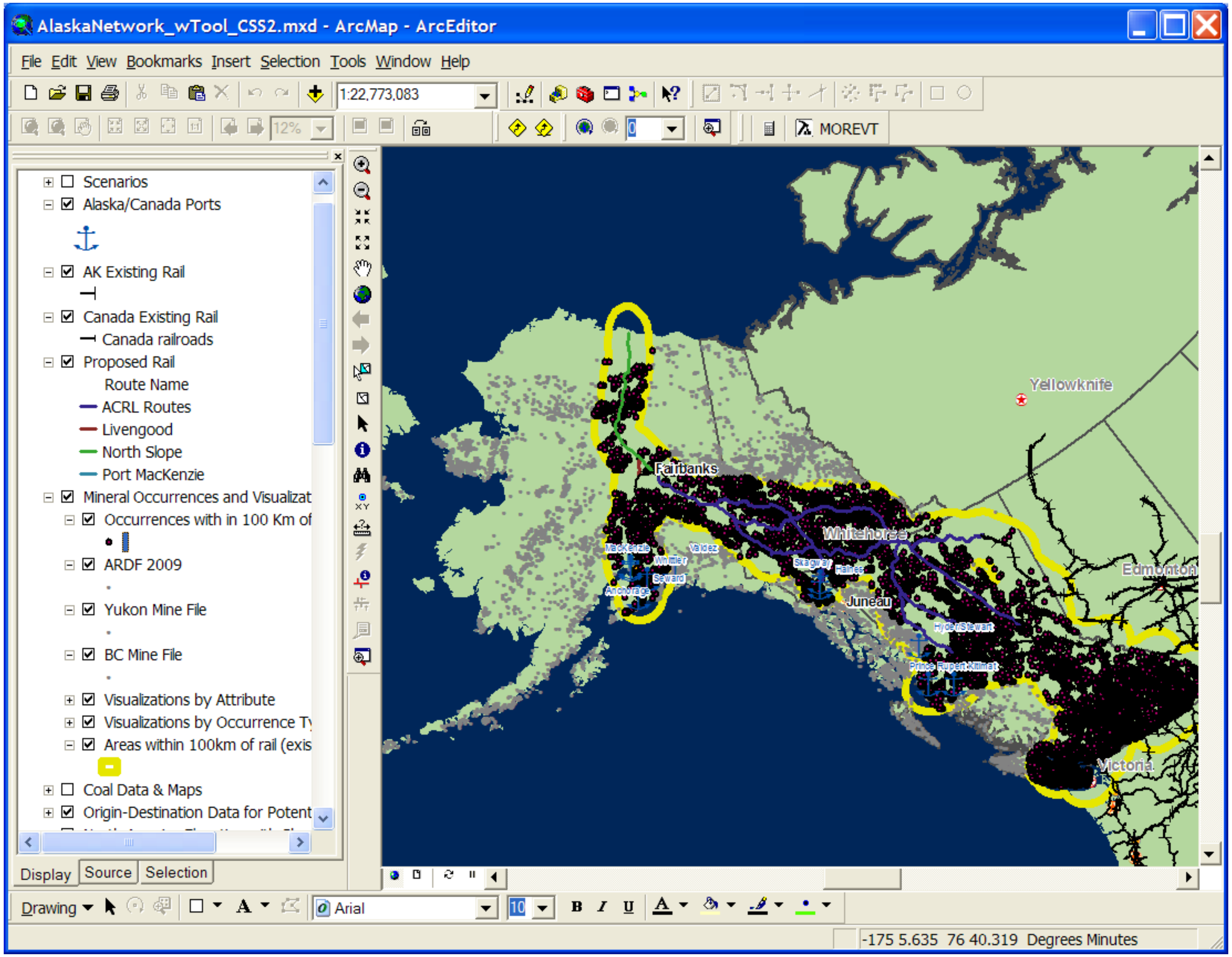
MOREV Workflow Details: Example Scenario Setup

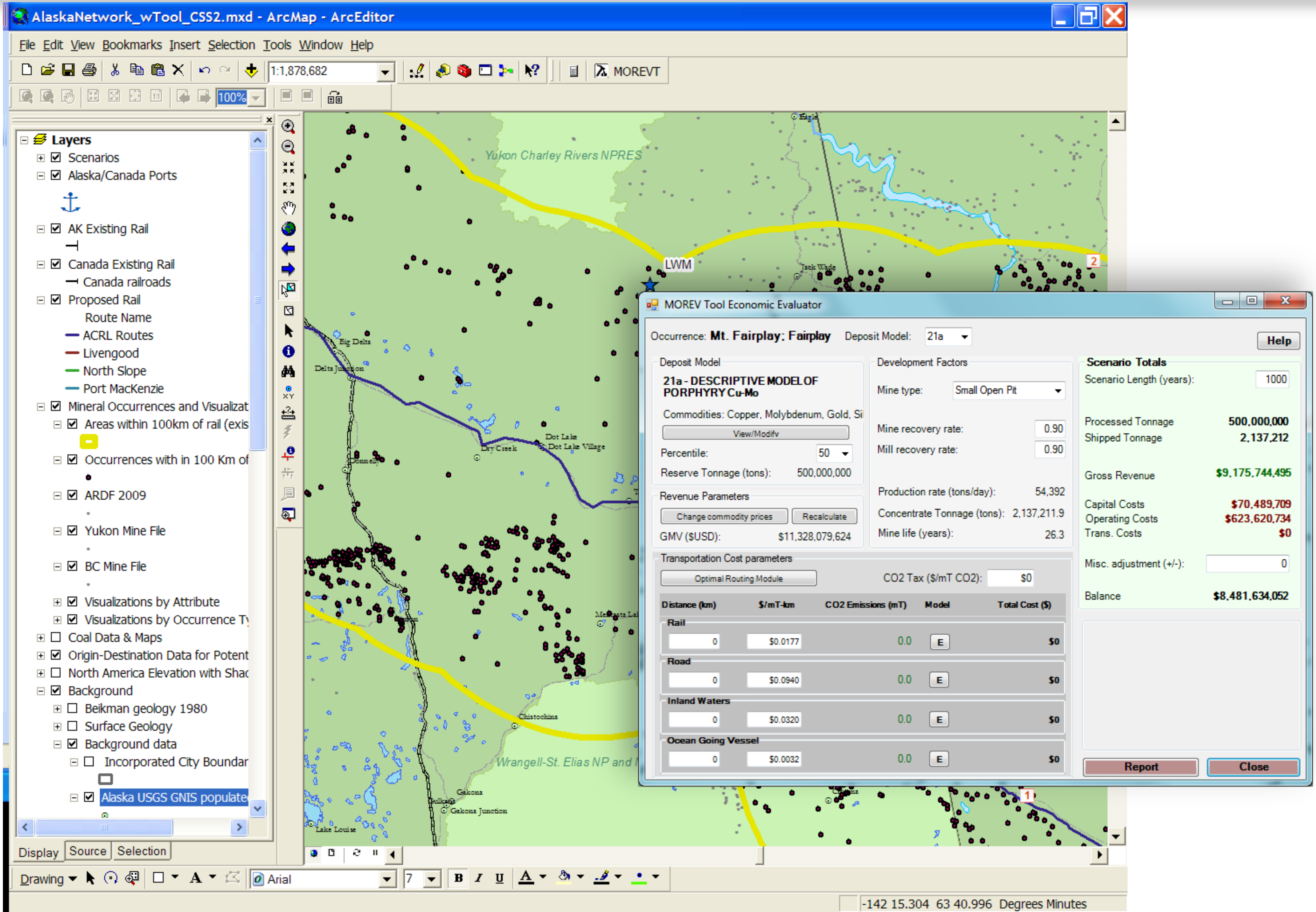
User visualization of geographic context of candidate mineral occurrences (ACRL corridor as well as all AK, Yukon, BC)

- Proximity to existing + proposed rail/road/grid infrastructure
- Transport distance/route selection to port
- Proximity to candidate mineral occurrences, known deposits, existing/historic mines
- Map display options:
  (examples next page)
  – In-corridor occurrences
  – Gross Metal Values*
  – Deposit Type
  – Commodity groupings

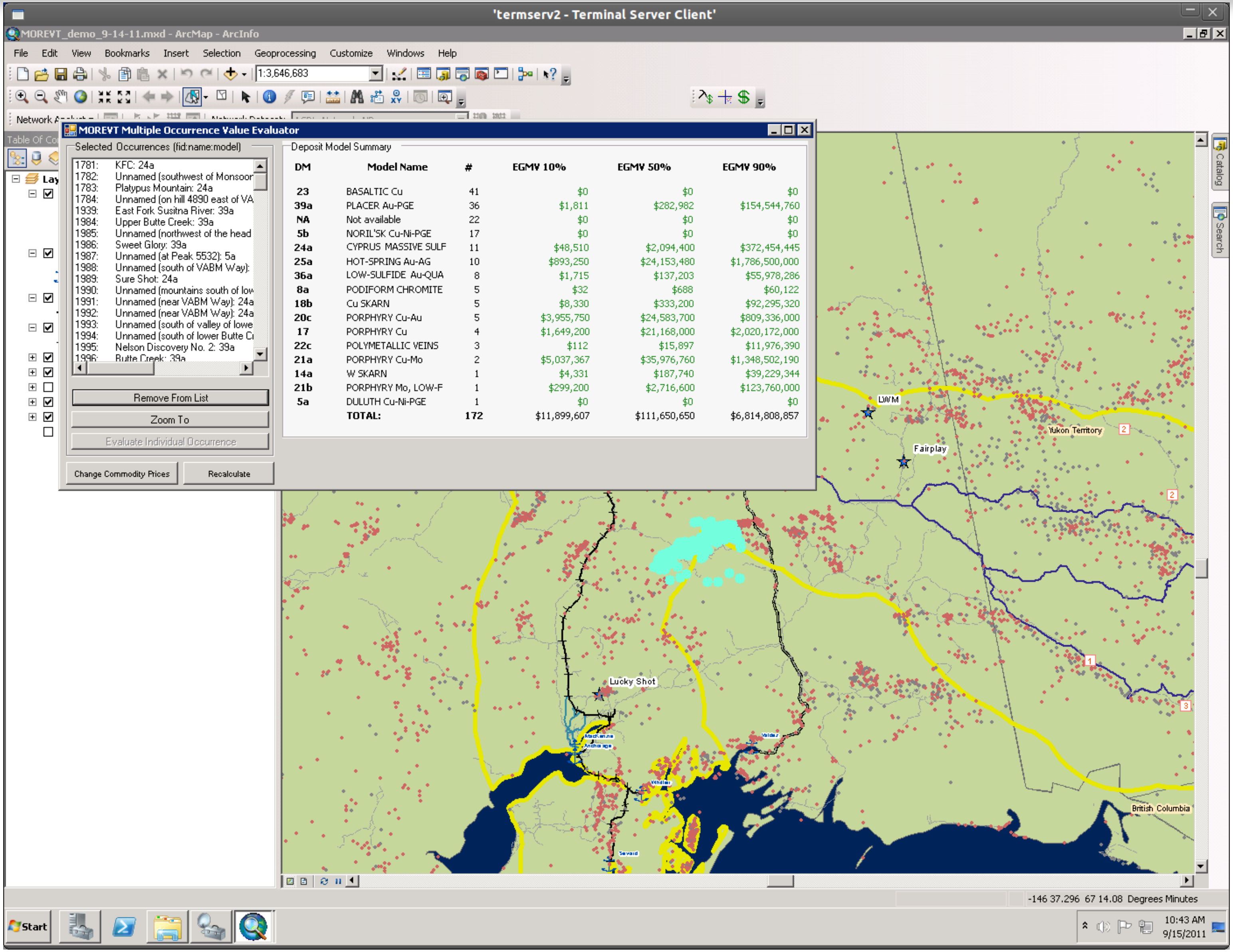


*P. Metz. UAF

Example Single Mineral Occurrence Selection



Example Multiple Mineral Occurrence Selection



DM	Model Name	#	EGMV 10%	EGMV 50%	EGMV 90%
23	BASALTIC Cu	41	$0	$0	$0
39a	PLACER Au-PGE	36	$1,811	$282,982	$154,544,760
NA	Not available	22	$0	$0	$0
5b	NORIL'SK Cu-Ni-PGE	17	$0	$0	$0
24a	CYPRUS MASSIVE SULF	11	$48,510	$2,094,400	$372,454,445
25a	HOT-SPRING Au-AG	10	$893,250	$24,153,480	$1,786,500,000
36a	LOW-SULFIDE Au-QUA	8	$1,715	$137,203	$55,978,286
8a	PODIFORM CHROMITE	5	$32	$688	$60,122
18b	Cu SKARN	5	$8,330	$333,200	$92,295,320
20c	PORPHYRY Cu-Au	5	$3,955,750	$24,583,700	$809,336,000
17	PORPHYRY Cu	4	$1,649,200	$21,168,000	$2,020,172,000
22c	POLYMETALLIC VEINS	3	$112	$15,897	$11,976,390
21a	PORPHYRY Cu-Mo	2	$5,037,367	$35,976,760	$1,348,502,190
14a	W SKARN	1	$4,331	$187,740	$39,229,344
21b	PORPHYRY Mo, LOW-F	1	$299,200	$2,716,600	$123,760,000
5a	DULUTH Cu-Ni-PGE	1	$0	$0	$0
	TOTAL:	172	$11,899,607	$111,650,650	$6,814,808,857

New functionality added to MOREV tool in 2011; expanded help as well

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Revenue Estimation Methodology

- Calculation of **Gross Metal Value**
  - Tonnage from USGS Mineral Deposit Models for occurrence (after Cox & Singer); *or user can input known or measured tonnages and commodity prices*

- Installation and operating cost estimates from statistical models from historical economic mines (after USGS, Camm)

- Multimodal transportation costs of shippable tonnage derived from US Transportation Statistics database

- *Parameters are user-updateable*

Revenue Estimation Methodology: Significance of GMV

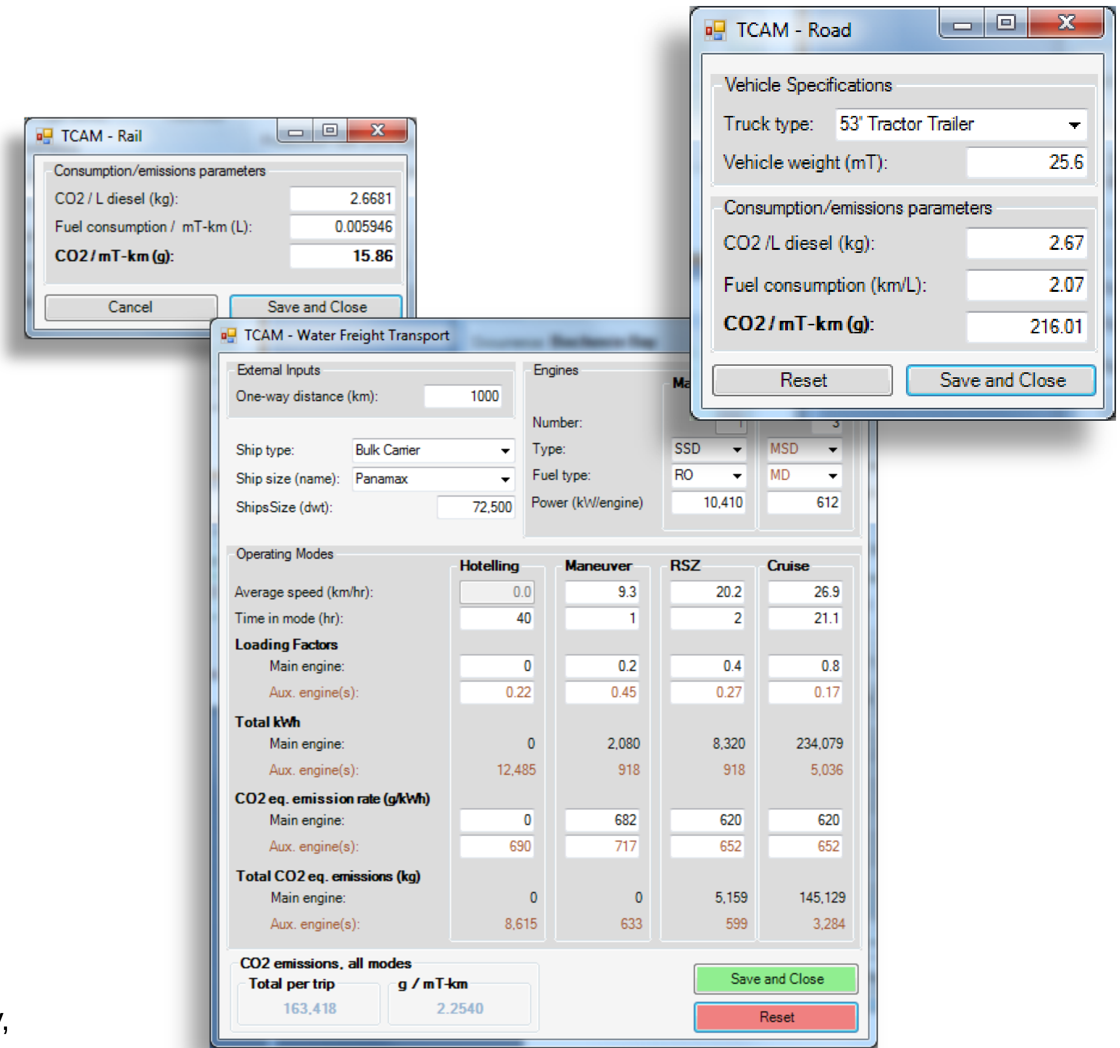
- Multiplier effect in local economy – new wealth generation from development of mineral resources
- Fort Knox Gold Mine - $104 million per year during 12 year estimated life of mine
  - 1999 Information Insights report for the Fairbanks North Star Borough
  - Through multiplier effect - wages, supplies, property taxes, reduced energy costs
- Estimated GMV = $1.2 billion
- The value to communities of mineral resource development can be equal to the GMV

Fort Knox operation (from www.gov.state.ak.us)

Carbon Accounting

Transportation Carbon Accounting Module (TCAM)

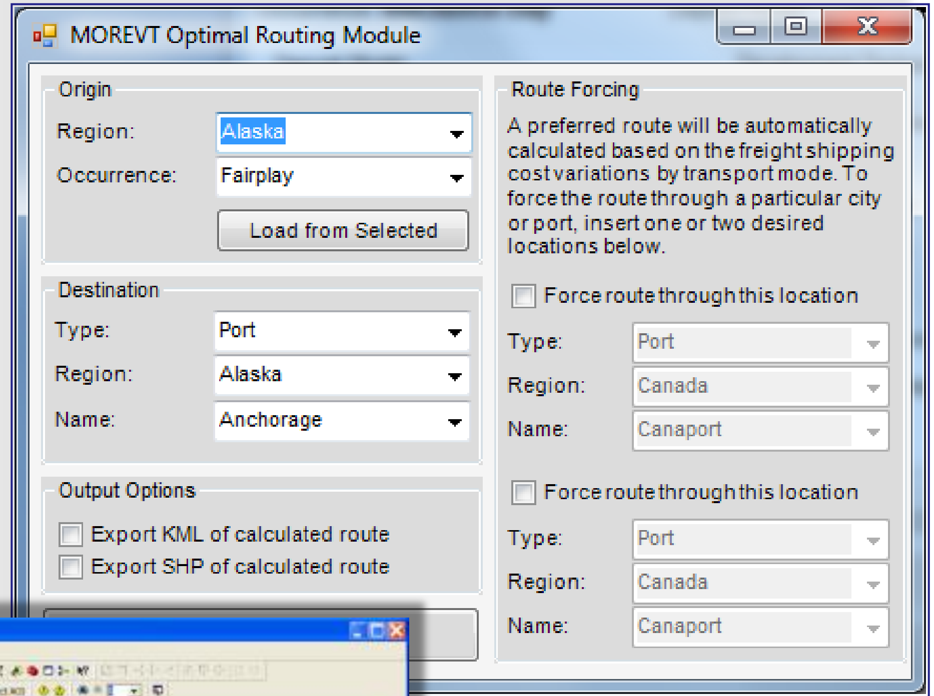
- **Rail**, **truck**, **barge**, and **OGV** (ocean going vessel) emissions models (based on fuel usage estimates) are incorporated
- Mode-specific calculator forms show model assumptions and allow user-modification of default parameters
- Interacts with dynamic routing module to enable user to select most carbon efficient shipping logistics route
- **CO2 equivalent** (which includes:CO2, CH4, and N2O) values are used
- Sources for fuel consumption/emissions model data:
  - **Rail**: Association of American Railroads, US EPA
  - **Truck**: USDOT Federal Highway Administration, Vehicle Inventory and Use Survey (VIUS) 2002, US EPA
  - **Water**: MAN Diesel, European Environment Agency, US EPA, ICF International, Lloyd's Register

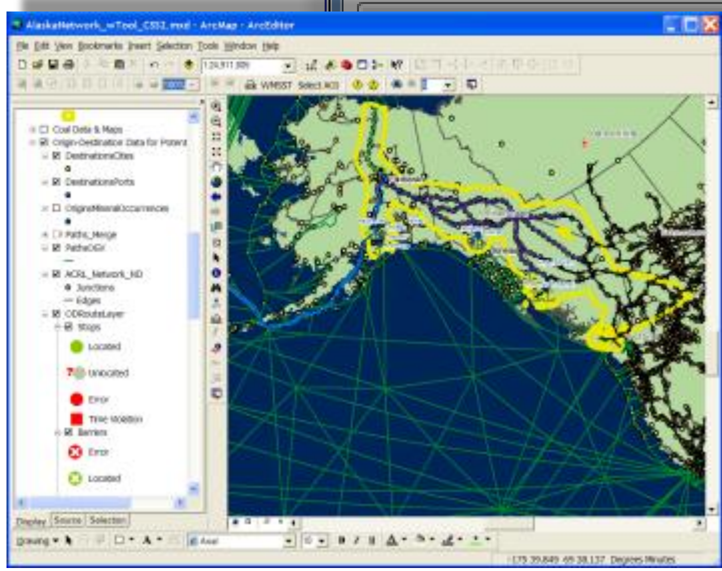


Dynamic Network Routing

Users can choose origins & destinations

- Routing is dynamically calculated from user-defined mineral occurrence origin and specified destination points (port, cities, or facilities; U.S., Canada or overseas for destination)
- Most cost efficient route is automatically chosen, but user will have the ability to force route through certain locations
- Can select most carbon-efficient means of shipping mineral concentrates
- Modal distances and intermodal transition points that were calculated will be loaded directly into the transportation costing calculations w/ option for exported KML visualization of route as well





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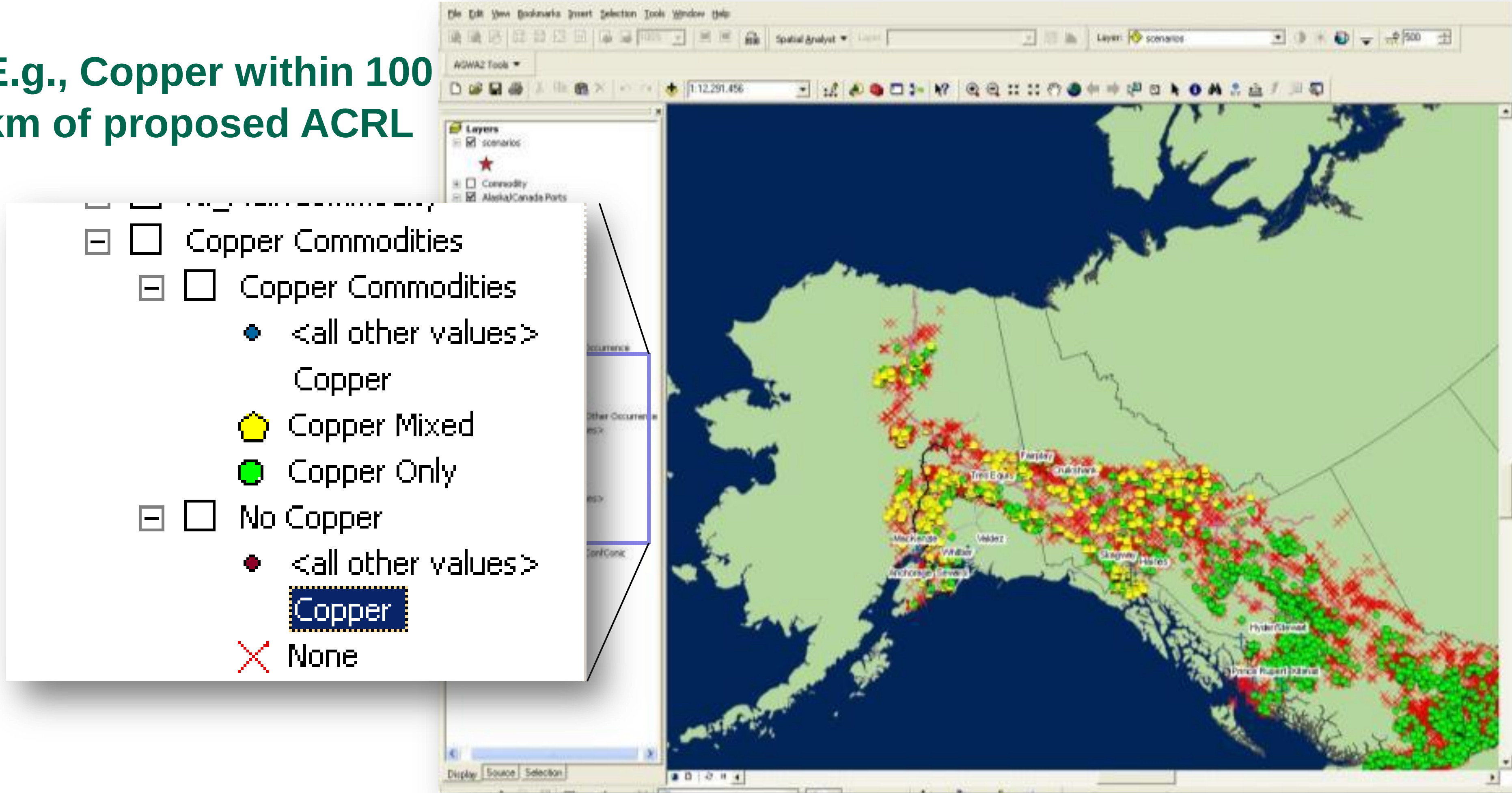
Map Display Examples

- Allow Filtering by Attribute, Commodity Type

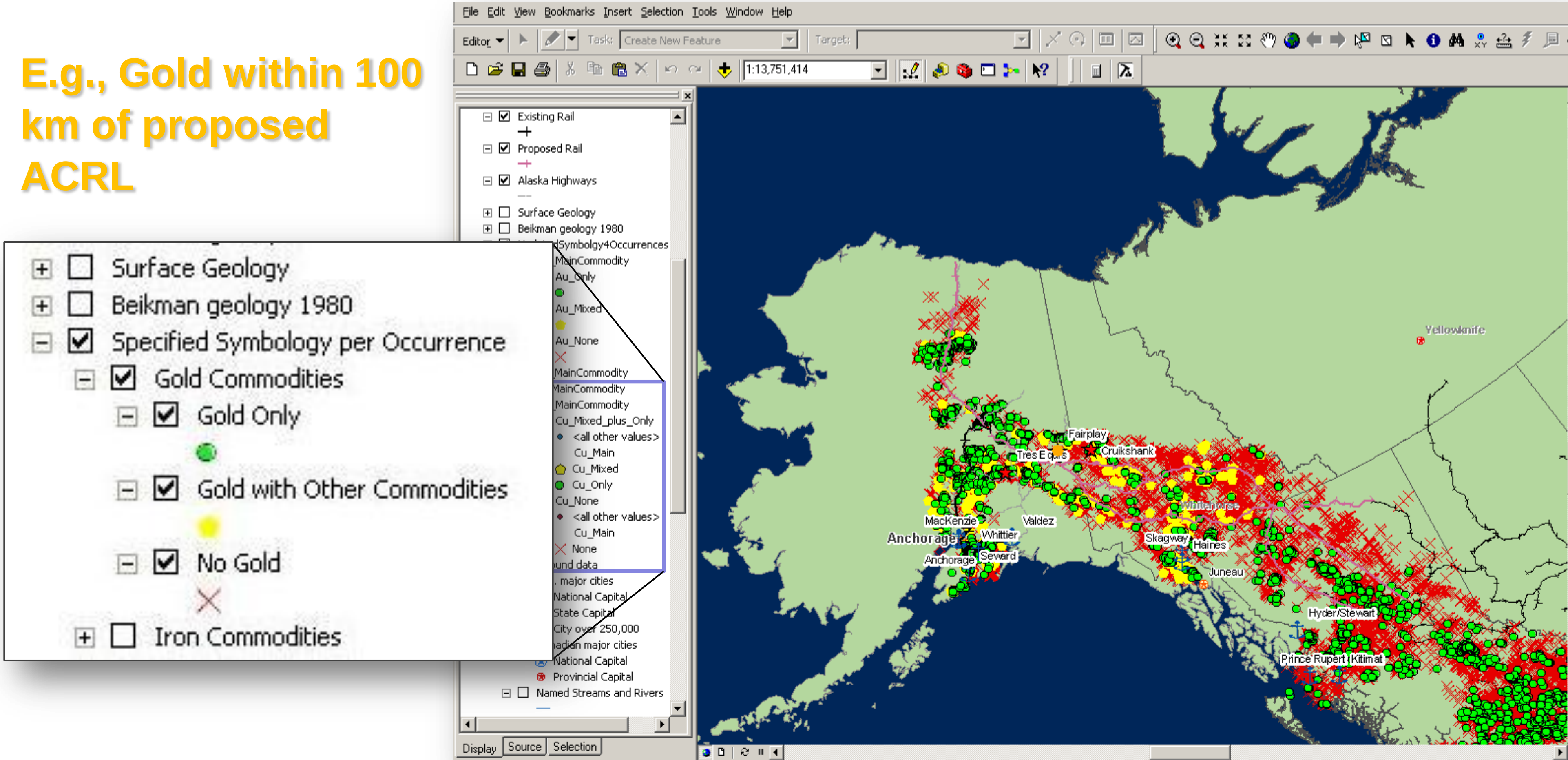
E.g., Copper within 100 km of proposed ACRL



Map Display Examples

- Allow Filtering by Attribute, Commodity Type

E.g., Gold within 100 km of proposed ACRL



Transportation Expenses

Transportation expense calculation: Freight volumes

- Freight volume is estimated from concentrate tonnage (which is dependent on reserve tonnage, commodity grades, and mine and mill recovery rates; deposit model) and distance traveled for each of four transportation modes: **Rail**, **Road**, **Inland Water**, and **Ocean Going Vessel**
  - ***We calculate daily freight volume of concentrate (& summarize as total shippable tonnage)***

Processed Tonnage	1,800,000
Shipped Tonnage	1,283,040

- Cost per revenue tonne-kilometer for each mode were derived from literature review of Bureau of Transportation Statistics publications

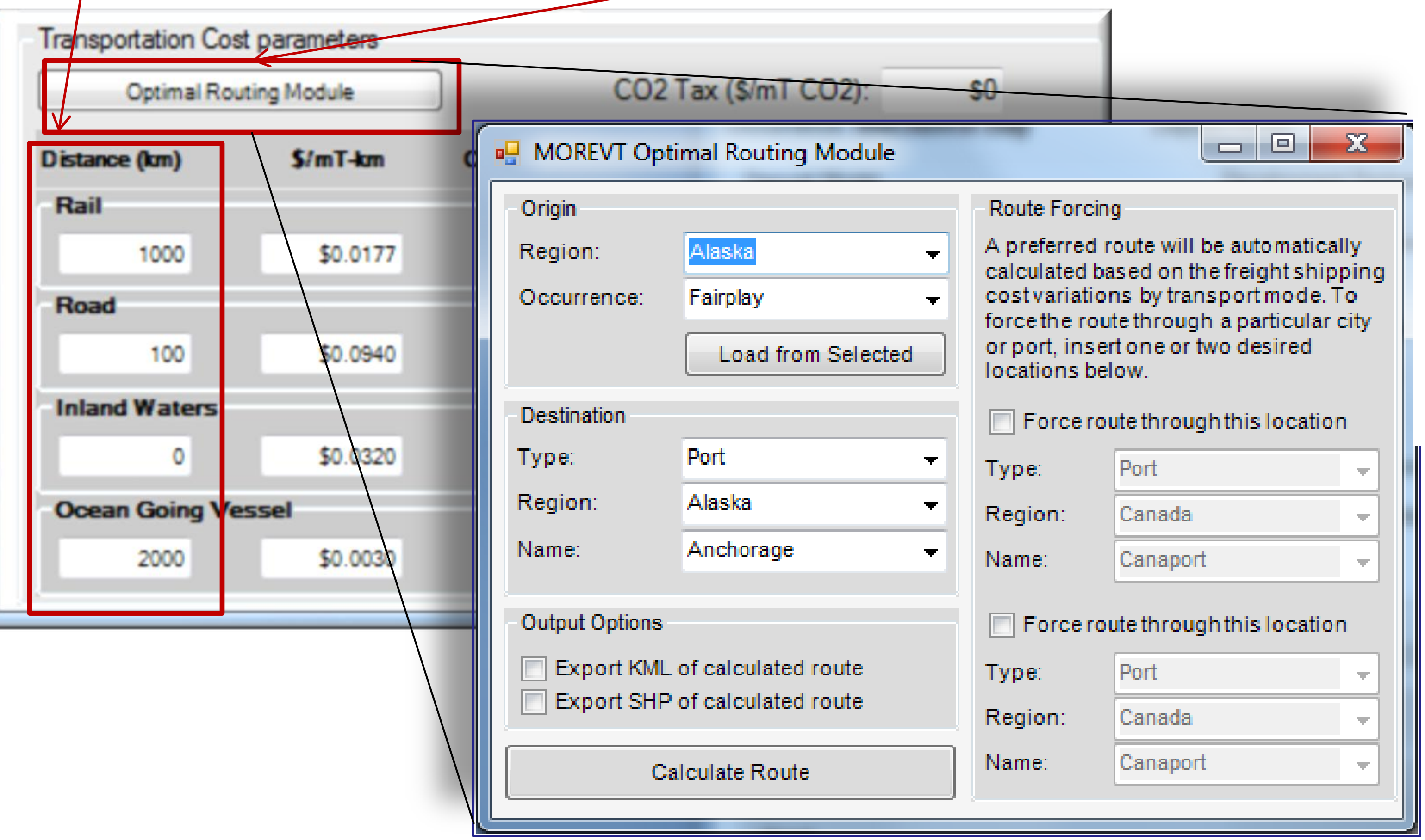
	Distance (km)	$/mT-km	CO2 Emissions (mT)	Model	Total Cost ($)
Rail	1000	$0.0177	20,354.8	E	$22,709,808
Road	100	$0.0940	27,714.3	E	$12,060,576
Inland Waters	0	$0.0320	0.0	E	$0
Ocean Going Vessel	2000	$0.0030	5,784.0	E	$7,698,240

Transportation Expenses & Dynamic Routing Form

Transportation expense calculation: Routing

The user can choose to use a preset ore destination and route

……….or can set their own



This routing module will automatically calculate a route the minimizes transportation costs.

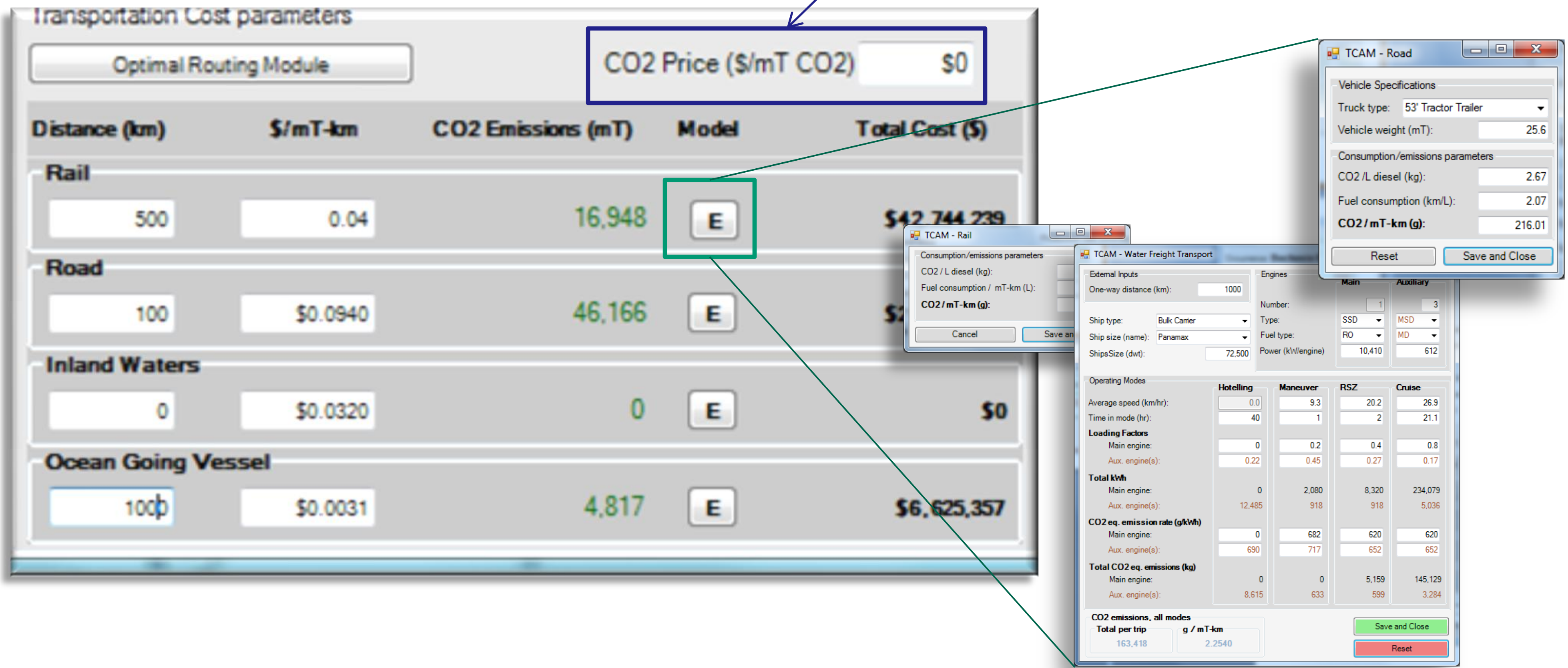
The user can also force the route through a particular port or city if desired.

CO2 emissions: TCAM module

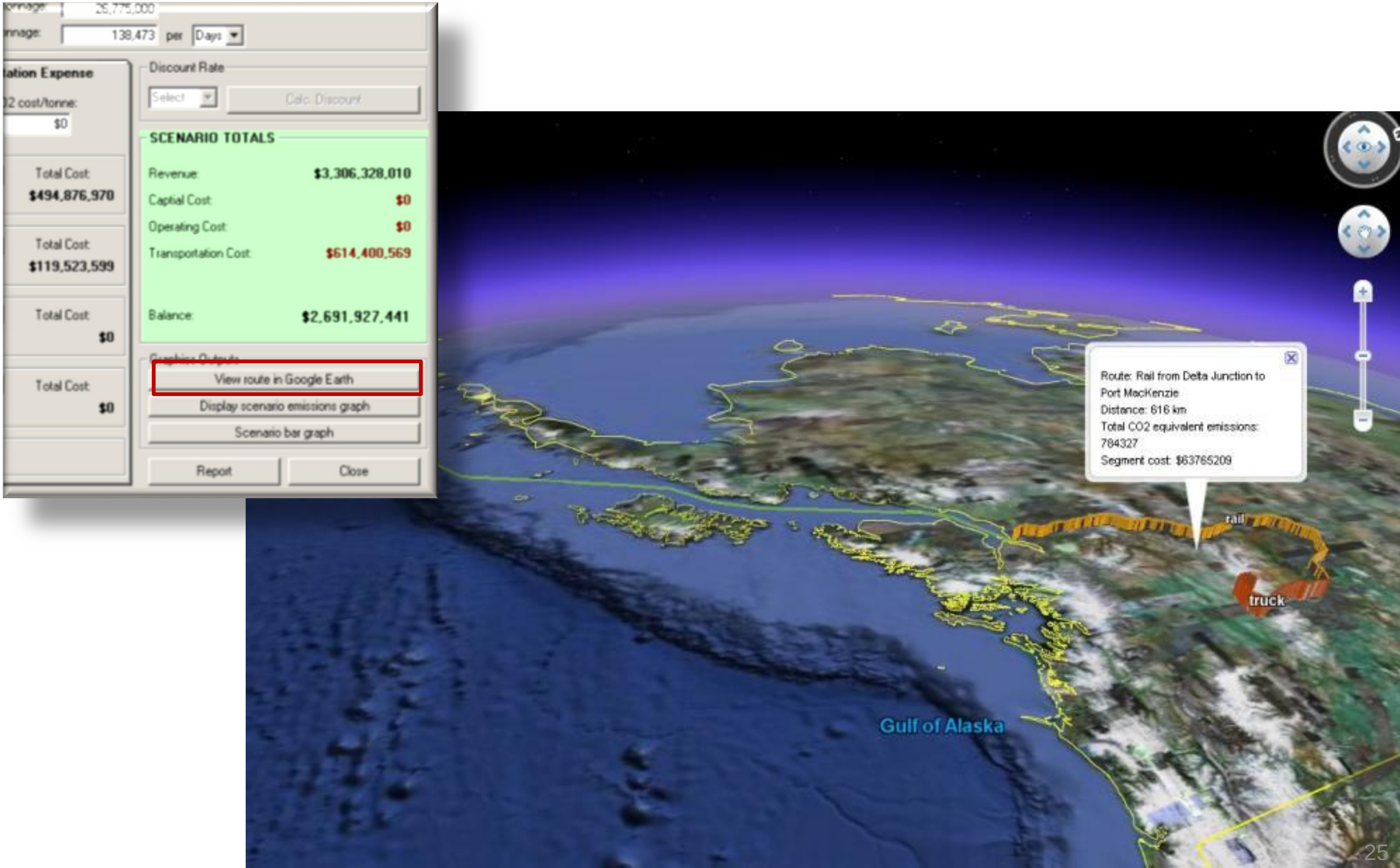
Transportation expense calculation: CO_2 emissions

Total CO_2 equivalent emissions for each transportation mode are calculated from mode-specific emissions models, with the option to set an offset price that will be incorporated into transportation costs

Mode-specific emissions calculators have been incorporated so that users can modify default parameters

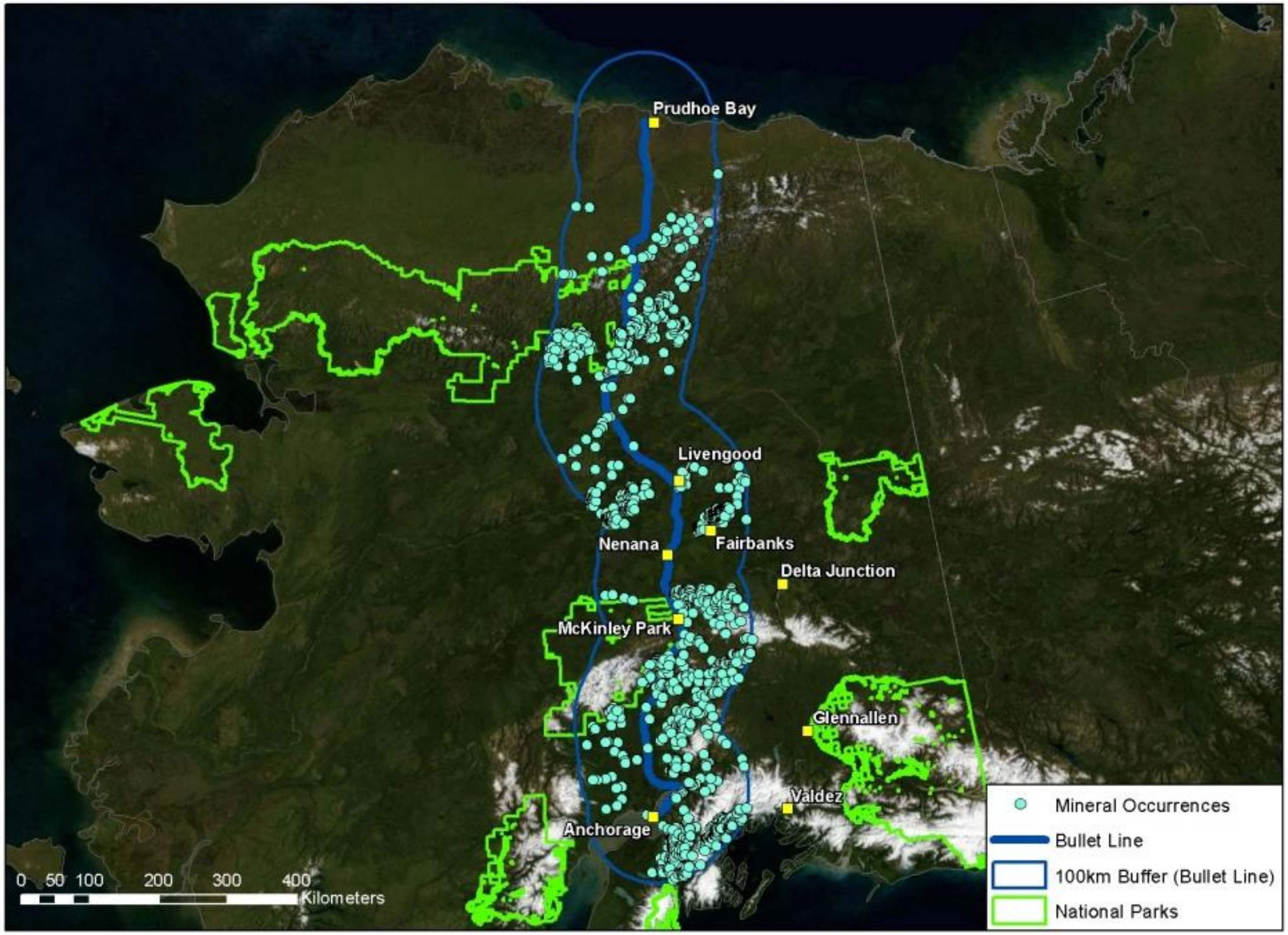


Tool Outputs:
Route KML in Google Earth



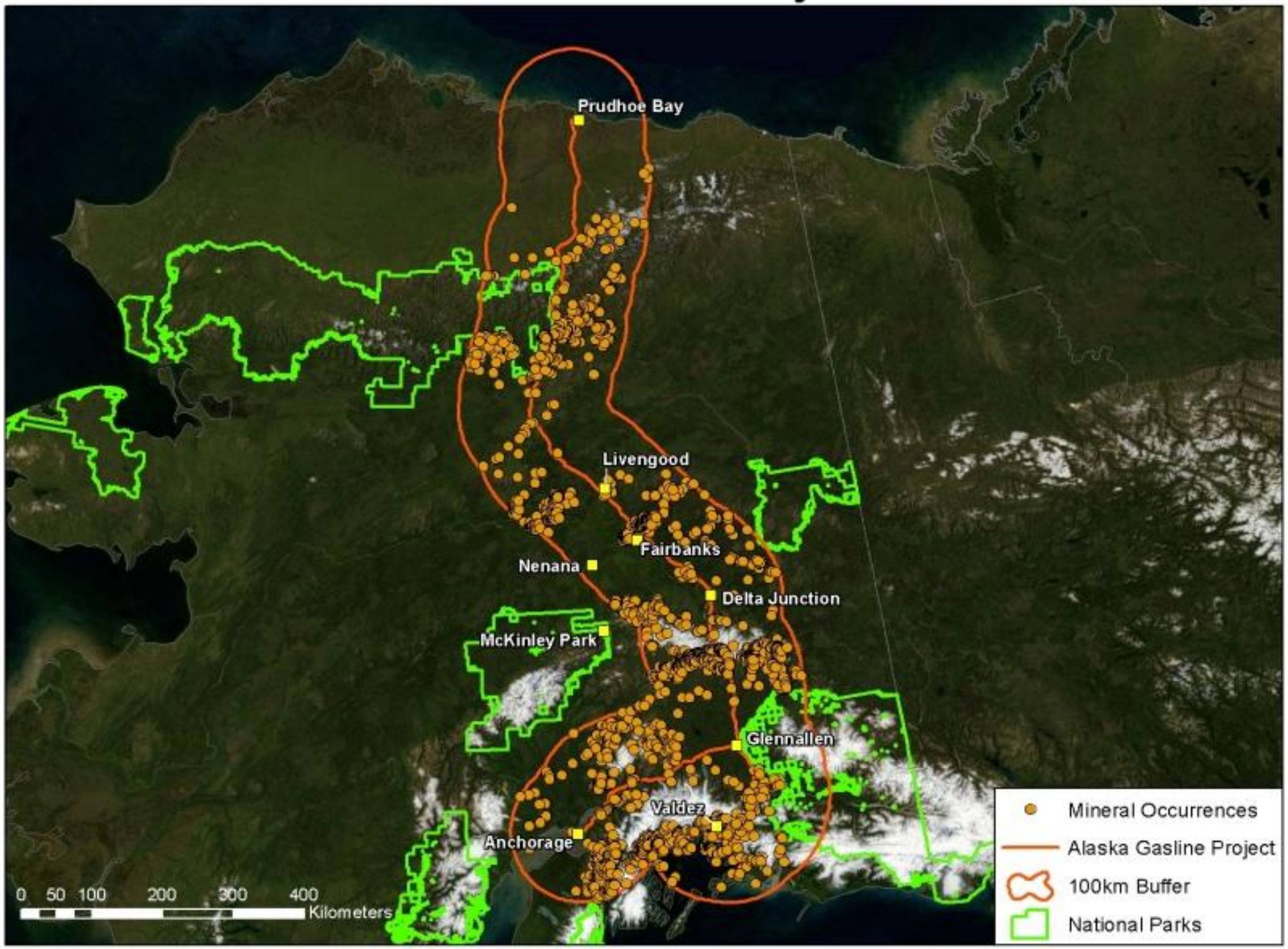
Scenario: Alternative Pipeline Route

ENSTAR Bullet Line



Proposed Bullet Line (from Prudhoe Bay to Anchorage) with mineral occurrences within 100-kilometers of pipeline.

Alaska Gasline Project



Proposed Alaska Pipeline Project (from Prudhoe Bay to Valdez) with mineral occurrences within 100-kilometers of pipeline.

Pipeline Scenario: Potential Revenue Evaluation

Tabulated Estimated Gross Metal Value (EGMV) statistics for mineral resources in100-km pipeline corridor

- EGMV: GMV x Probability of Development (Metz) – 0.001 for 10th & 50th percentile, 0.0005 for 90th

Alaska Pipeline Project - Updated 11/2/2010 with Development Probability						
Model Code	Name	Metals	Amt	GMV (10th Perc.)	GMV (50th Perc.)	GMV (90th Perc.)
10	Carbonatite	Niobium - Rare Earth	1	$771,795,431	$9,329,300,739	$38,420,308,164
26a	Carbonate-Hosted Au-Ag	Au-Ag	1	$277	$4,707	$33,641
27b	Almaden Hg	Hg	1	$0	$0	$0
30a	Sandstone-Hosted Pb-Zn	Pb-Zn-Ag	1	$9,896	$304,823	$4,793,022
31b	Bedded Barite	Barite	1	$1,489	$30,713	$260,597
38a	Lateritic Ni	Ni-Co	1	$1,247,069	$9,779,654	$38,216,657
39b	Placer PGE-Au	Pt-Au-Os-Ir-Pl	1	$157	$11,918	$253,611
9	Alaskan PGE and Epiterthermal Veins	Pt	1	$0	$0	$0
14b	Sn Skarn	Sn	2	$45,007	$630,525	$4,768,965
15b	Sn Veins	Sn	2	$1,818	$67,510	$1,119,755
25g	Epithermal Mn	Mn	2	$2,523	$39,424	$275,968
39c	Shoreline Placer Ti	Zr-Ti	2	$149,486	$7,742,151	$152,147,019
6a	Komatitic Ni-Cu	Ni-Au-Cu	2	$31,998	$540,902	$6,552,870
15c	Sn Greisen	Sn	3	$44,141	$654,326	$4,957,754
20b	Sn-polymetallic veins	Au-Ag-Pb-Zn	3	$0	$0	$0
32a	Mississippi Valley Zn-Pb	Pb-Zn	3	$0	$0	$0
24c	Volcanogenic Mn	Mn	4	$7,065	$207,528	$2,343,891
31a	Sedimentary Exhalative Zn-Pb	Zn-Pb	4	$469,315	$9,963,579	$106,186,580
18a	Porphyry Cu Skarn	Cu-Ag-Au-Mo	5	$3,135,635	$23,837,669	$90,867,849
8d	Serpentine-Hosted Asbestos	Asbestos	6	$61,078	$588,154	$2,950,605
18d	Fe Skarn	Fe	7	$654,326	$19,828,066	$277,592,918
19a	Polymetallic Replacement	Pb-Zn-Cu-Ag-Au	7	$57,062	$1,872,126	$30,815,076
18c	Zn-Pb Skarn	Zn-Pb-Cu	8	$72,529	$1,594,558	$17,322,805
21a	Porphyry Cu-Mo	Cu-Mo-Au-Ag	8	$15,788,676	$110,237,308	$397,001,891
21b	Porphyry Mo, Low F	Mo	9	$1,789,382	$16,246,773	$74,015,336
25a	Hot Spring Au-Ag	Au-Ag	12	$0	$0	$0
17	Porphyry Cu	Cu-Ag-Au-Mo	19	$6,709,091	$86,823,819	$632,182,850
34c	Phosphates	P2O5-P	19	$0	$0	$0
20c	Porphyry Cu-Au	Cu-Au-Ag-Mo	23	$11,927,285	$67,332,511	$202,579,108
14a	W Skarn	W	24	$9,738	$422,162	$8,821,286
24b	Besshi Massive Sulphide	Cu-Ag-Au-Pb-Zn	28	$13,550	$574,074	$11,034,567
8a	Podiform Chromite	Cr	33	$82,492,478	$10,453,592,312	$59,085,521,764
18b	Cu Skarn	Cu-Ag-Au	34	$35,981	$1,442,311	$27,864,929
27d	Simple Sb Deposits	Sb-Ag-Au	34	$138	$7,222	$186,206
5b	Noril'sk Cu-Ni-PGE	Au-Pd-Pt	50	$0	$0	$0
24a	Cyprus Massive Sulphide	Cu-Ag-Au-Pb-Zn	52	$206,510	$8,853,963	$115,958,480
28a	Kuroko Massive Sulphide	Cu-Pb-Zn-Au-Ag	79	$344,782	$14,664,440	$285,809,883
23	Basaltic Copper	Au-Ag-Cu-Ni-Zn-Co	88	$0	$0	$0
22c	Polymetallic Veins	Ag-Au-Pb-Zn-Cu	115	$1,596	$152,342	$7,481,083
36a	Low Sulfide Au-Quartz Veins	Au-Ag	367	$591	$47,265	$6,399,194
	No Description		405	$0	$0	$0
39a	Placer Au-PGE	Au-Ag	520	$3,309	$39,426	$2,150,505
	TOTALS		1987	$897,109,410	$20,167,434,999	$100,018,774,830

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APPENDIX -TCAM Equations & Data Sources

Overview

Rail

- Based on US freight fleet-wide fuel economy as reported by American Association of Railroads

Road

- Fuel economy regression equation based on total vehicle weight derived from US DOT VIUS and FHA *Highway Statistics*.

Water

- Methodology adopted from ICF/EPA port emission inventory best practices. Utilizes emission factors based on engine power output (g/kWh) instead of fuel consumption. Data sources include: ICF Consulting, US EPA, Swedish Methodology for Environmental Data, Lloyd's Register, MAN Diesel.

Total Rail CO_2 (kg) = F * R * C

Where:

F = Revenue tonne-kilometers of freight: *distance(km) * tonnes of freight,* both figures being derived from the user-defined scenario

R = Fuel consumption rate (L diesel/tonne-km): default value = **0.005946**, following American Association of Railroads (AAR) *Railroad Facts 2008* (p. 40), which provides the following fleet-wide average: 436 revenue-ton-miles / gallon fuel consumed for 2007. This figure was converted to L/tonne-km using the following equation:

*L/tonne-km = 1 / (436 * 0.264 gallons/liter * 1.609 km/mile * 0.907 tonnes/ton)*

C = CO_2/L of diesel (kg); default value = **2.6681**, according to US EPA

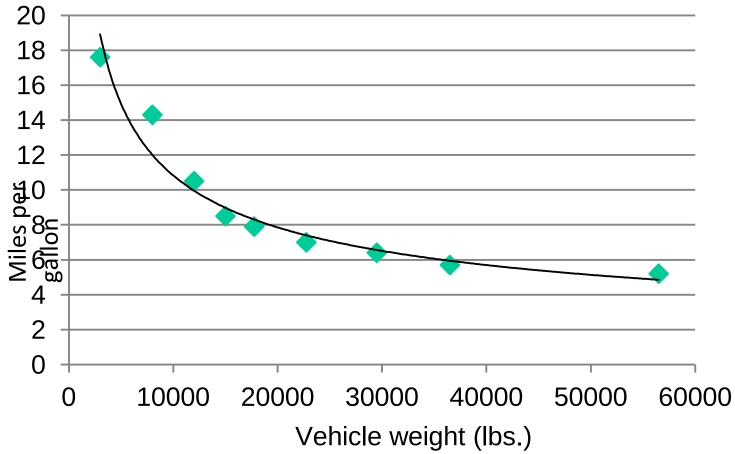
Total Road CO_2 (kg)= F * R * C / W

Where:

F = Revenue tonne-kilometers of freight: *distance(km) * tonnes of freight,* both figures being derived from the user-defined scenario

R = Fuel consumption rate (L diesel/km, or 1/*e* where *e* is *fuel economy*). Fuel economy is based on total vehicle weight. Data on vehicle weight from the **US Department of Commerce Bureau of the Census** *2002 Vehicle Inventory and Use Survey* and the **US DOT Federal Highway Administration** *Highway Statistics 2007 (*for Class 8 combination trucks) was used to derive a regression equation to calculate fuel economy from combined vehicle and cargo weight (converted to metric units afterwards):

miles-per-gallon= $772.04 * w^{-0.463}$, where ***w*** = *total vehicle weight (lbs.),* $r^2 = 0.9605$



C = CO_2/L of diesel; default value = **2.6681**, according to US EPA

W = Total vehicle weight (tonnes), defined here as equal to *curb weight* (weight of empty vehicle) plus *freight tonnage*. *Curb weight* values for each truck Class are derived from the FHA's Development of Truck Payload Equivalent Factor (TPEF)

APPENDIX -TCAM Equations & Data Sources

Water Freight

$$\textbf{Total Water } CO_2 \text{ (kg)} = \sum_t \left(\sum_m \left(H_{m,v} * L_{m,t,v} * P_{t,v} * N_{t,v} * E_{m,t} \right) \right) \text{ for vessel type } v$$

Where:

t = engine type (2 total) (*propulsion/main*, *auxiliary*)

m = activity mode (4 total) (*cruise*, *reduced-speed-zone* (*RSZ*), *maneuvering*, *hotelling*)

v = vessel type (8 options) (auto carrier, bulk carrier, container ship, cruise ship, general cargo, RORO, reefer, tanker)

H = average or expected amount of time (hrs) a vessel of type *v* spends in activity mode *m*. Default values: *hotelling* = 40, *maneuvering* = 1, *RSZ* = 2. Values for *cruise* activity mode are automatically calculated from scenario-derived *distance* (km), and *average cruise speed* for a vessel of type *v*. Sources: *Thesing and Edwards 2006, Lloyd's Register, ICF/EPA 2006*

L = loading factor (percent). The percentage of the maximum continuous rating (MCR) used by engine type *t* in mode *m* for vessel type *v*. Source: US EPA Analysis of Marine Vessel Emissions and Fuel Consumption Data

P = Maximum Continuous Rating (MCR) for engine type *t* in kW. Auxiliary engine power is based on ICF/EPA fleet averages.

Main engine power is derived from ship domestic weight tonnage (DWT) and vessel type *v* based on the following EPA regression equation and table:

*Main engine power (kW) = (a * DWT) + b*

Vessel Type	a	b	r^2
Auto Carrier	0.4172	7602	0.17
Bulk Carrier	0.0985	6726	0.55
Container Ship	0.8000	-749.4	0.59
Cruise Ship	6.810	-4877	0.72
General Cargo	0.2880	3046	0.56
RORO	0.5264	4358	0.76
Reefer	1.007	1364	0.58
Tanker	0.1083	6579	0.66

N = number of engines of type *t*, which varies by vessel type *v*. Generally, *N* =1 for main engines, and *N* < 6 for auxiliary.

Source: ICF/EPA 2006: Current Methodologies and Best Practices for Preparing Port Emission Inventories

E = CO2 equivalent emissions rate in grams per kilowatt hour (g/kWh), specific to *m* and *t*.

Source: SMED Methodology for Calculating Emissions from Ships

APPENDIX -TCAM Equations & Data Sources

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