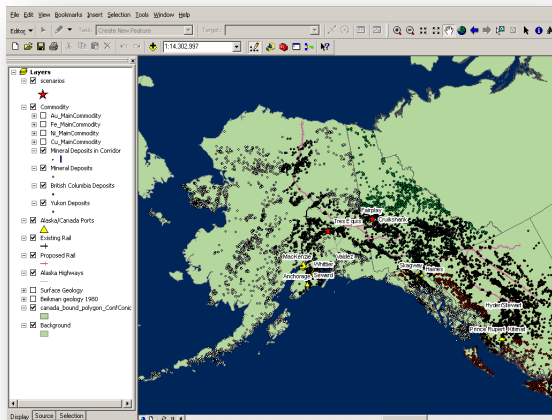


Mineral Occurrence Revenue Estimation & Visualization Tool

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

***Colin Brooks, MTRI
Paul Metz, UAF
Robert Shuchman, MTRI
Michael Billmire, MTRI
Helen Kourous-Harrigan, MTRI***

September 2011



Fairplay			
Deposit Type	One Commodity		
Porphyry Cu Mo deposit (Cot and Singer, 1986; mode)	Cu		
Help			
Tonnage of Single Deposit Types			
Tonnes	100-ile	50-ile	500-ile
	120,000,000	500,000,000	2,100,000,000
Location			
Lat	63.690		
Long	-142.240		
Quadrangle	TC		
Expected Value (US and CA dollar)			
	GMV 100-ile	GMV 50-ile	GMV 500-ile
\$USD	\$6.42 bil.	\$05.30 bil.	\$1.22 bil.
\$CAD	\$6.95 bil.	\$92.33 bil.	\$1.32 bil.
Estimated Life of Mine (500-ile): 37.5			
Price year: 2001			
Deposit Attributes			
Land Status:	State Land	Deposits w/in 20km:	3
Deposit Type:	21a	Distance to Rail (mi):	
Site Type:	Prospect	Existing:	162.3
Status:	Undetermined	Proposed:	29.7
Load Costing Scenario			
Close			

www.mtri.org

www.mtri.org/mineraloccurrence.html

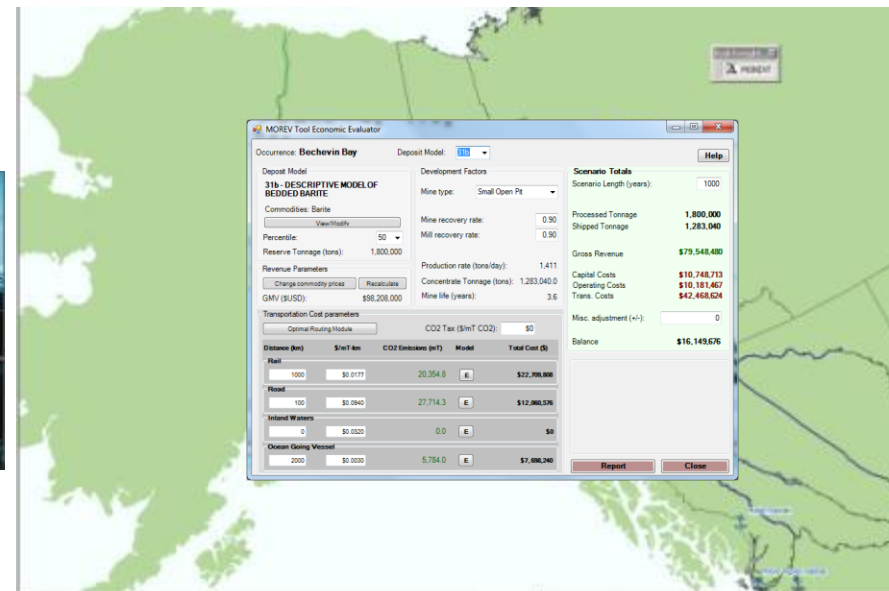
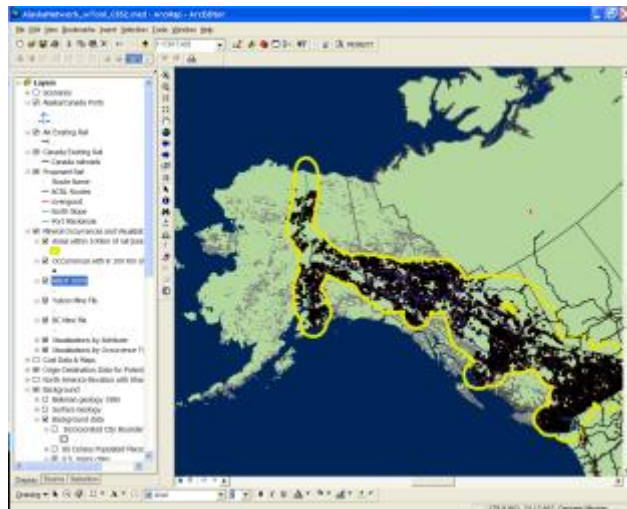
- **Background & Motivation**
- **Current Capabilities & Upcoming Developments**
- **Screen Shot Demo**
- **Tool Methodology**
 - **Revenue Estimation Methodology**
 - Calculation of Gross Metal Value
 - Estimation of potential freight volumes
 - **Cost Estimation Methodology**
 - Capacity, Mining cost (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*

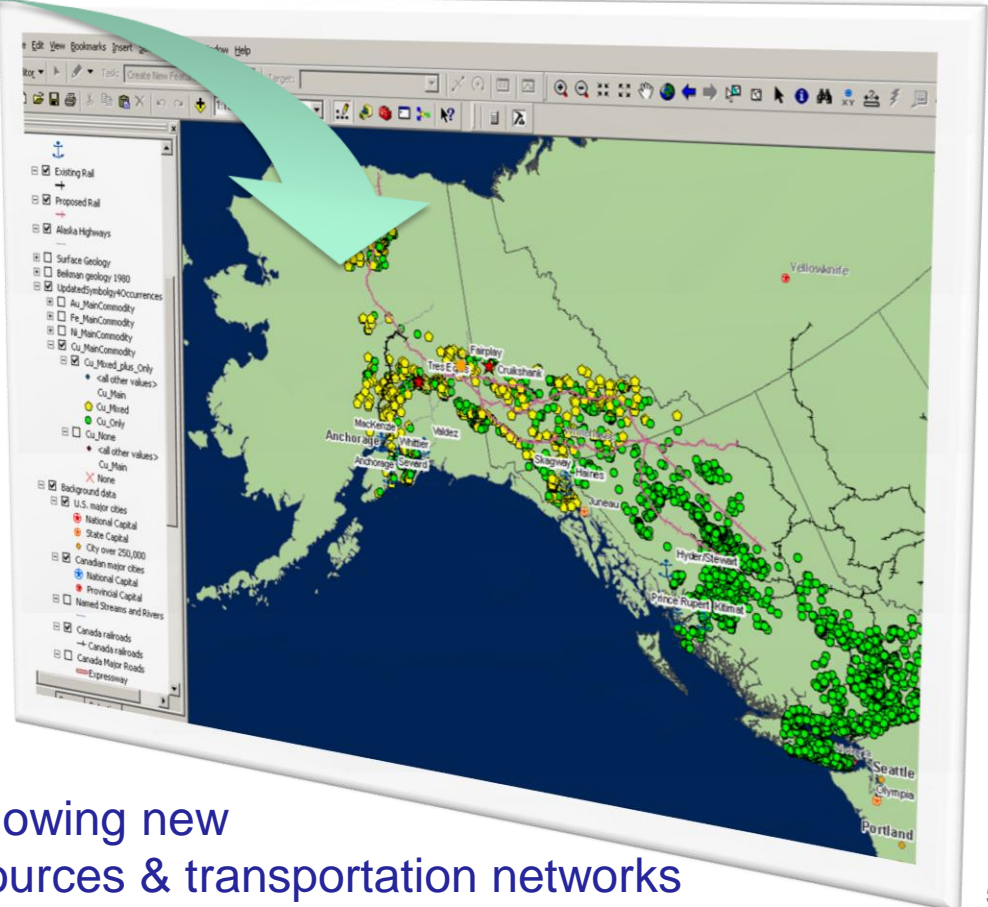


MOREV: Background

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...

Commodity	Value	Units	Source	Current (date)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Antimony	2,220	\$/b	2009	6,798 (08-18-11)	0.033	0.049	0.065	1.075	1.302	1.606	3.393	2.047	2.090	2.2	
Asbestos	430,000	\$/ton	2007	0 (NA)	126,000	184,000	234,000	1,144,000	222,000	309,000	410,000	430,000	0.00	0.0	
Bavite	62,000	\$/ton	2007	0 (NA)	42,000	42,000	42,000	44,000	53,000	53,000	62,000	62,000	0.00	0.0	
Barite	1,098	\$/b	2008	1,17 (08-27-11)	0.345	0.387	0.500	0.518	0.626	0.685	0.848	0.912	1,048	0.0	
Chromite	20,520	\$/b	2009	16,30 (09-05-11)	13,472	10,949	9,794	9,944	19,666	15,242	13,925	34,768	13,453	10.5	
Cobalt	2,240	\$/b	2009	4,05 (09-05-11)	0.862	0.788	0.732	0.82	1.139	1.178	2,007	2,330	2,781	2.2	
Copper	92,039	\$/b	2009	180,763 (09-05-11)	205,242	271,150	311,038	303,811	420,566	444,700	509,650	444,658	468,261	5.0	
Gold	482,240	\$/oz	2008	198 (09-05-11)	402,000	425,000	294,000	93,000	185,000	188,000	309,000	48,000	14,000	48,000	0.0
Iridium	92,000	\$/ton	2009	0 (NA)	24,000	22,000	24,000	30,000	34,000	40,000	48,000	54,000	62,000	0.0	
Iron	0,862	\$/b	2009	1,105 (08-27-11)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Lead	0,000	\$/b	2009	1,404 (08-27-11)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Manganese	531,361	\$/b	2007	14,511 (09-05-11)	2,034	2,034	3,074	4,368	6,000	8,000	10,000	10,000	10,000	0.0	
Mercury	9,370	\$/b	2009	9,435 (09-05-11)	3,918	2,000	7,640	7,429	9,147	7,357	7,394	10,000	10,000	0.0	
Molybdenum	6,540	\$/b	2008	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Nickel	12,630	\$/b	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Niobium	0,000	\$/b	2009	751.097 (09-05-11)	649,350	533,290	542,960	684,440	896,760	895,510	1,144,420	1,208,440	1,209,971	201.7	
Osmium	203,720	\$/oz	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Palladium	0,000	\$/b	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Phosphate	2,000	\$/b	2009	189.46 (09-05-11)	691,640	659,720	378,640	202,000	222,500	222,500	222,500	222,500	222,500	0.0	
Phosphorus	1,084,590	\$/oz	2009	189.46 (09-05-11)	691,640	659,720	378,640	202,000	222,500	222,500	222,500	222,500	222,500	0.0	
Platinum	0,000	\$/b	2009	187.5 (09-05-11)	1,090,000	4,452	4,452	4,452	3,942	3,942	3,942	3,942	3,942	0.0	
Rare Earth Oxide	1,175,000	\$/oz	2009	41.88 (09-05-11)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Rhodium	14,430	\$/oz	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Silver	9,080,000	\$/b	2009	18,824 (09-05-11)	1,090,000	4,452	4,452	4,452	3,942	3,942	3,942	3,942	3,942	0.0	
Thorium-oxide	0,667	\$/b	2008	23.13 (09-05-11)	3,760	5,672	4,333	13,562	5,242	13,562	16,781	16,781	16,781	0.0	
Tin	16,230	\$/b	2009	49.07 (09-05-11)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Tungsten	0,000	\$/b	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	
Uranium	0,000	\$/b	2009	0 (NA)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	



...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 CO₂ 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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■ 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

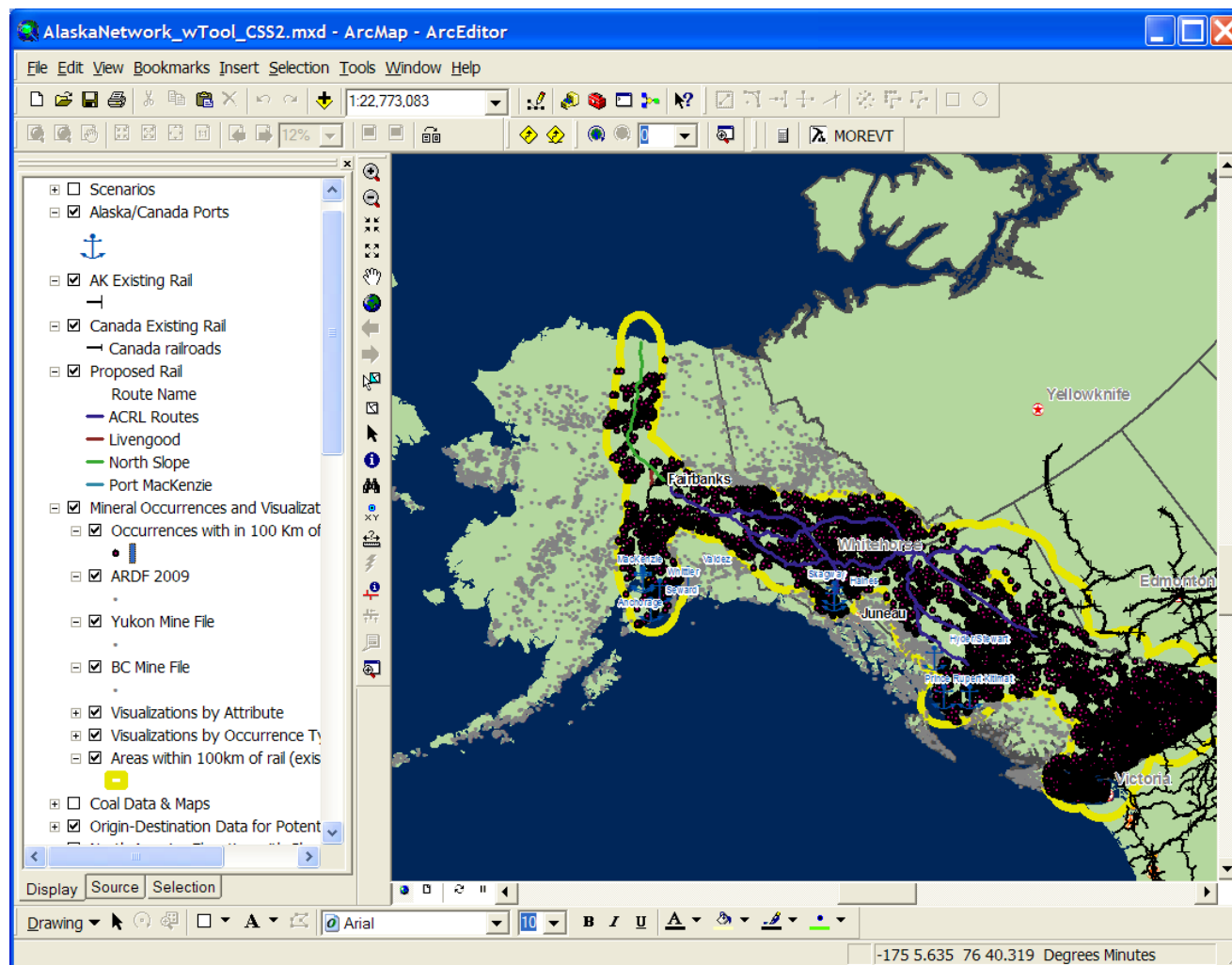
- Calculates and displays **mine capacity** (tons/day) based on Modified Taylor Rule (updated by Long 2009)
 - From this value, calculate Mine Capital Expense and **Mine Operating Cost**
 - Researching implementation of SEE software – more advanced costing
- **Dynamically calculates optimal route** from 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



Example Single Mineral Occurrence Selection

AlaskaNetwork_wTool_CSS2.mxd - ArcMap - ArcEditor

File Edit View Bookmarks Insert Selection Tools Window Help

1:1,878,682

100%

MOREVT

Layers

- Scenarios
- Alaska/Canada Ports
- AK Existing Rail
- Canada Existing Rail
- Canada railroads
- Proposed Rail
 - Route Name
 - ACRL Routes
 - Livgood
 - North Slope
 - Port MacKenzie
- Mineral Occurrences and Visualizat
- Areas within 100km of rail (exis
- Occurrences with in 100 Km of
- ARDF 2009
- Yukon Mine File
- BC Mine File
- Visualizations by Attribute
- Visualizations by Occurrence Ty
- Coal Data & Maps
- Origin-Destination Data for Potent
- North America Elevation with Sha
- Background
 - Beikman geology 1980
 - Surface Geology
 - Background data
 - Incorporated City Boundar
 - Alaska USGS GNIS populat

MOREV Tool Economic Evaluator

Occurrence: **Mt. Fairplay: Fairplay** Deposit Model: 21a

Deposit Model: **21a - DESCRIPTIVE MODEL OF PORPHYRY Cu-Mo**

Commodities: Copper, Molybdenum, Gold, Si

Percentile: 50

Reserve Tonnage (tons): 500,000,000

Revenue Parameters

GMV (\$USD): \$11,328,079,624

Development Factors

Mine type: Small Open Pit

Mine recovery rate: 0.90

Mill recovery rate: 0.90

Production rate (tons/day): 54,392

Concentrate Tonnage (tons): 2,137,211.9

Mine life (years): 26.3

Scenario Totals

Scenario Length (years): 1000

Processed Tonnage: 500,000,000

Shipped Tonnage: 2,137,212

Gross Revenue: \$9,175,744,495

Capital Costs: \$70,489,709

Operating Costs: \$623,620,734

Trans. Costs: \$0

Misc. adjustment (+/-): 0

Balance: \$8,481,634,052

Report Close

Display Source Selection

Drawing

Arial

-142 15.304 63 40.996 Degrees Minutes

Example Multiple Mineral Occurrence Selection

'termserv2 - Terminal Server Client'

MOREVT_demo_9-14-11.mxd - ArcMap - ArcInfo

File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help

1:3,646,683

Network ArcToolbox

MOREVT Multiple Occurrence Value Evaluator

Selected Occurrences (fid.name.model)

- 1781: KFC: 24a
- 1782: Unnamed (southwest of Monsoor)
- 1783: Platypus Mountain: 24a
- 1784: Unnamed (on hill 4890 east of VA
- 1939: East Fork Susitna River: 39a
- 1984: Upper Butte Creek: 39a
- 1985: Unnamed (northwest of the head
- 1986: Sweet Glory: 39a
- 1987: Unnamed (at Peak 5532): 5a
- 1988: Unnamed (south of VABM Way):
- 1989: Sure Shot: 24a
- 1990: Unnamed (mountains south of low
- 1991: Unnamed (near VABM Way): 24a
- 1992: Unnamed (near VABM Way): 24a
- 1993: Unnamed (south of valley of lowe
- 1994: Unnamed (south of lower Butte Cr
- 1995: Nelson Discovery No. 2: 39a
- 1996: Rutte Creek: 39a

Remove From List

Zoom To

Evaluate Individual Occurrence

Change Commodity Prices Recalculate

Deposit Model Summary

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

Yukon Territory

Lucky Shot

Fairplay

British Columbia

-146 37.296 67 14.08 Degrees Minutes

10:43 AM 9/15/2011

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

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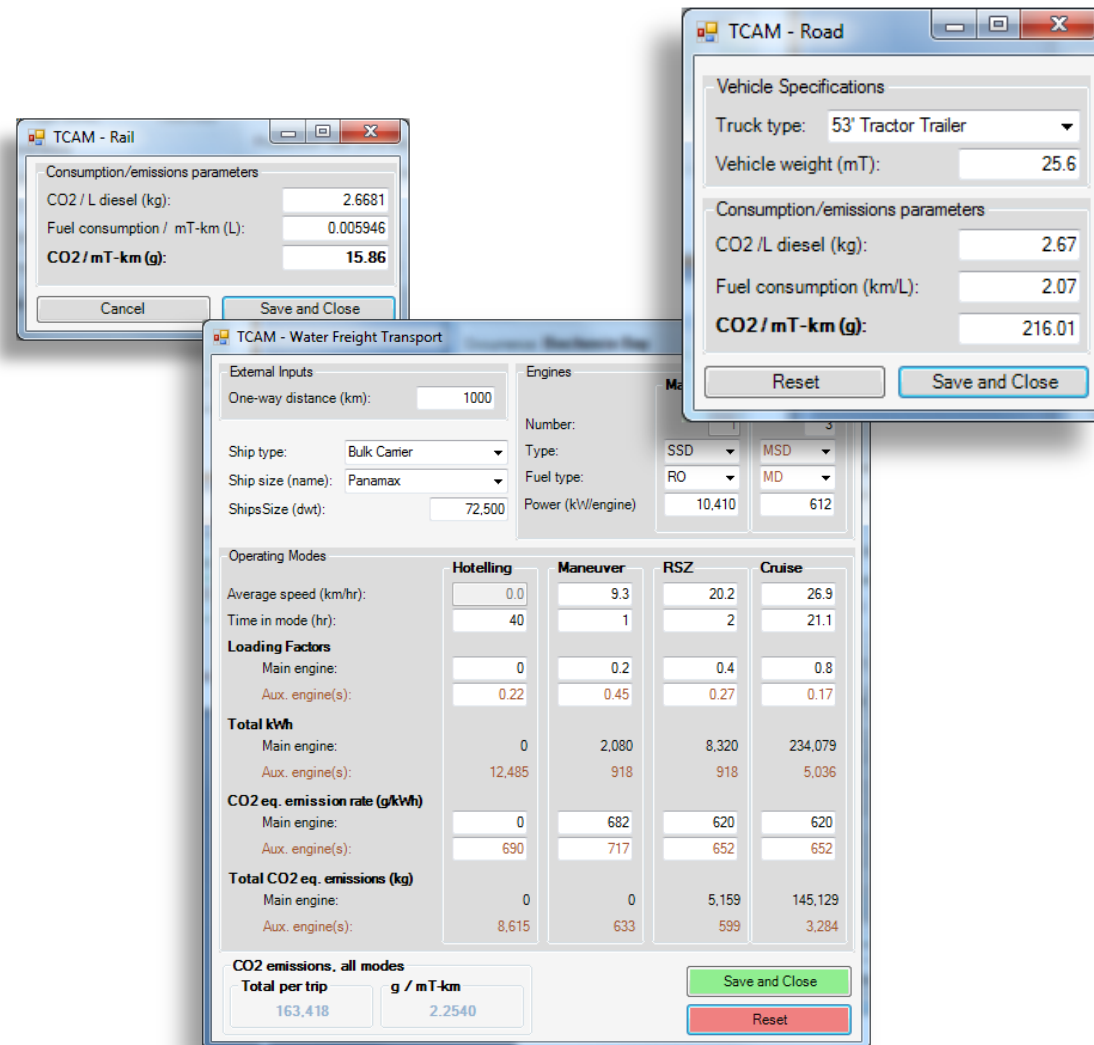
- Calculation of **Gross Metal Value**
 - Tonnage from USGS Mineral Deposit Models for occurrence (after Cox & Singer); *or user can input known or measured tonnages and commodity prices*
- Installation and operating cost estimates from statistical models from historical economic mines (after USGS, Camm)
- Multimodal transportation costs of shippable tonnage derived from US Transportation Statistics database
- *Parameters are user-updateable*

- 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)

- 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



TCAM - Rail

Consumption/emissions parameters

CO2 / L diesel (kg): 2.6681

Fuel consumption / mT-km (L): 0.005946

CO2 / mT-km (g): 15.86

Cancel Save and Close

TCAM - Road

Vehicle Specifications

Truck type: 53' Tractor Trailer

Vehicle weight (mT): 25.6

Consumption/emissions parameters

CO2 /L diesel (kg): 2.67

Fuel consumption (km/L): 2.07

CO2 / mT-km (g): 216.01

Reset Save and Close

TCAM - Water Freight Transport

External Inputs

One-way distance (km): 1000

Ship type: Bulk Carrier

Ship size (name): Panamax

ShipsSize (dwt): 72,500

Engines

Number: 3

Type: SSD MSD

Fuel type: RO MD

Power (kW/engine): 10,410 612

Operating Modes

	Hotelling	Maneuver	RSZ	Cruise
Average speed (km/hr):	0.0	9.3	20.2	26.9
Time in mode (hr):	40	1	2	21.1
Loading Factors				
Main engine:	0	0.2	0.4	0.8
Aux. engine(s):	0.22	0.45	0.27	0.17
Total kWh				
Main engine:	0	2,080	8,320	234,079
Aux. engine(s):	12,485	918	918	5,036
CO2 eq. emission rate (g/kWh)				
Main engine:	0	682	620	620
Aux. engine(s):	690	717	652	652
Total CO2 eq. emissions (kg)				
Main engine:	0	0	5,159	145,129
Aux. engine(s):	8,615	633	599	3,284

CO2 emissions, all modes

Total per trip g / mT-km

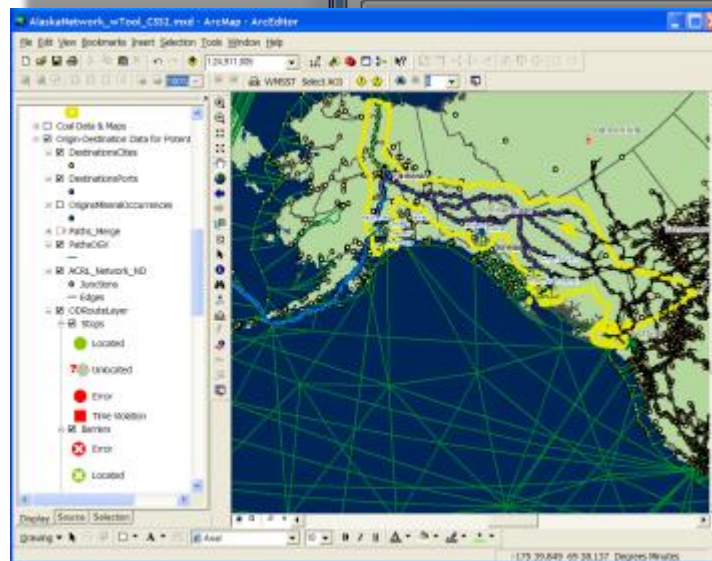
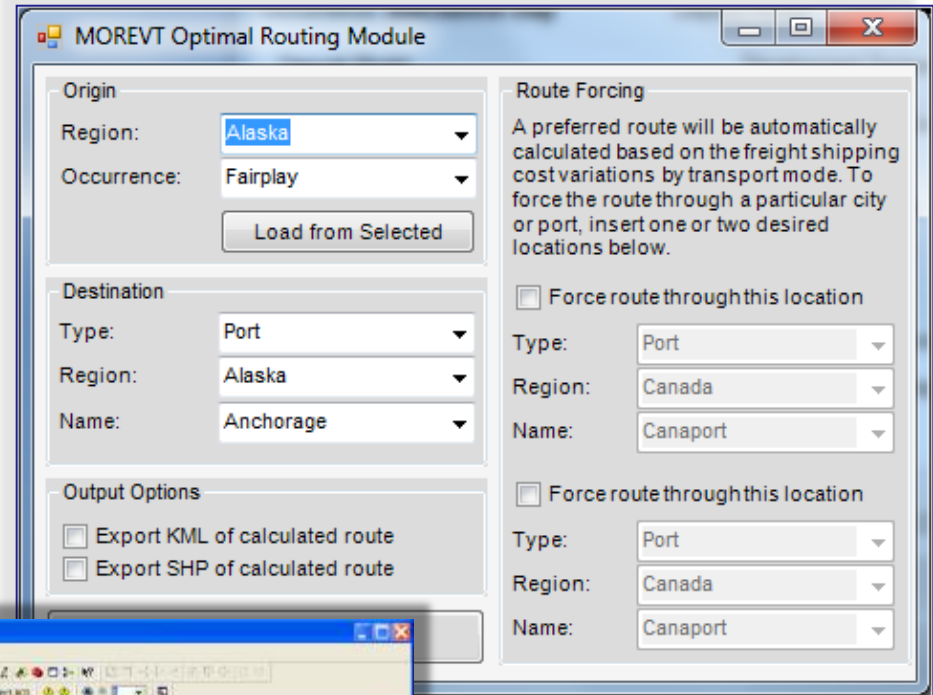
163,418 2,2540

Save and Close Reset

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

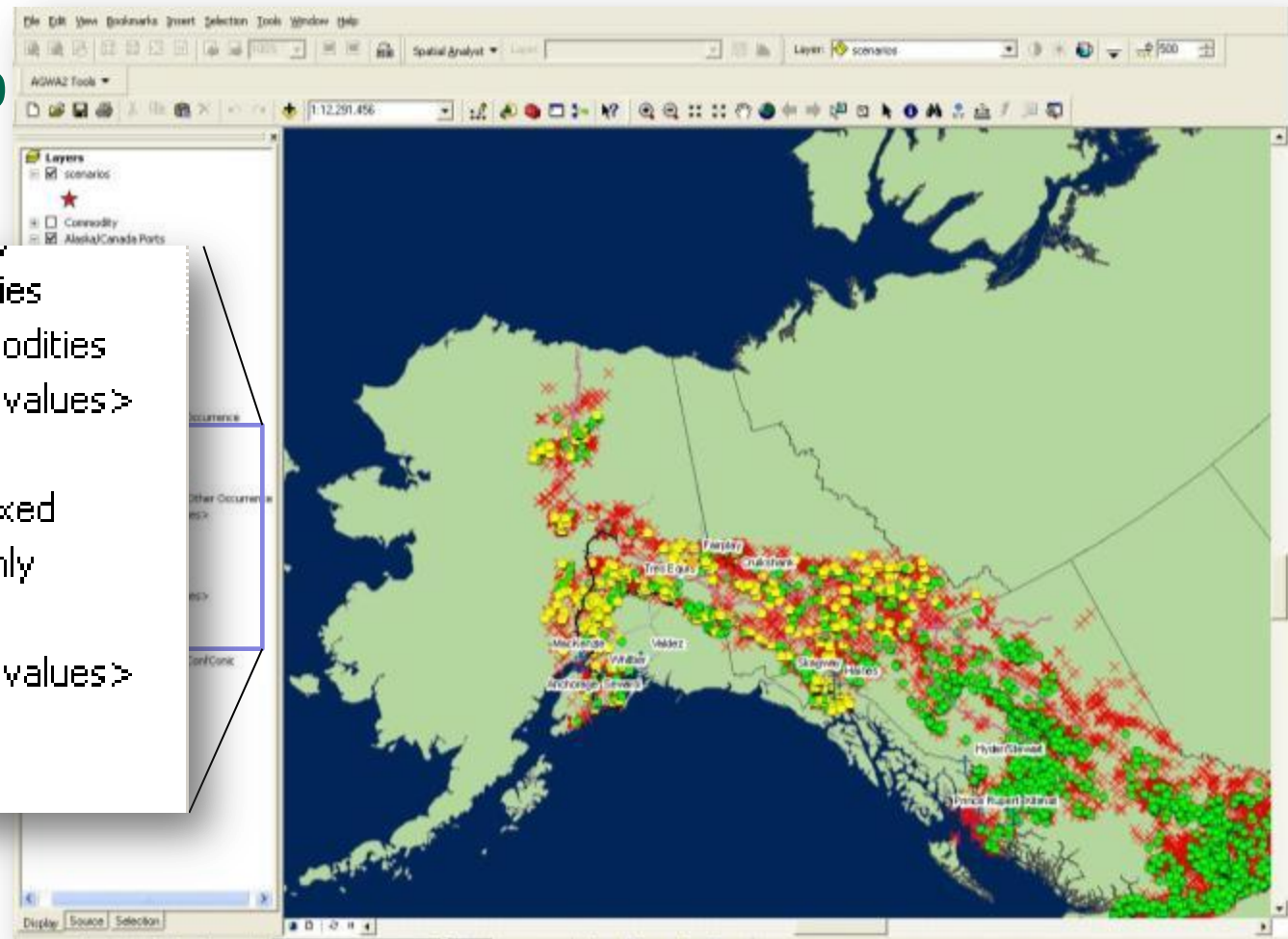


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Map Display Examples

- Allow Filtering by Attribute, Commodity Type

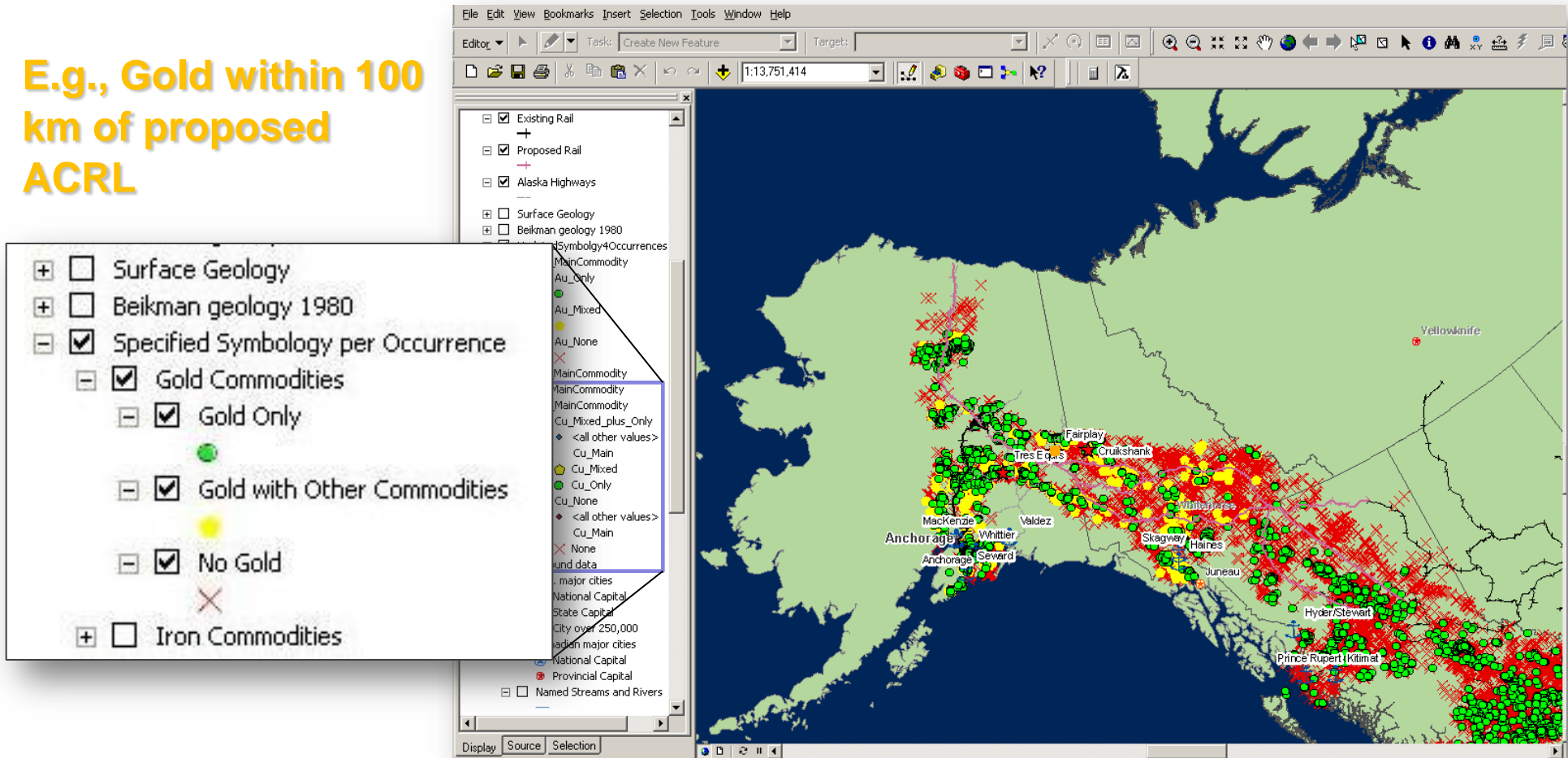
E.g., Copper within 100 km of proposed ACRL



Map Display Examples

- Allow Filtering by Attribute, Commodity Type

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



The screenshot shows a GIS application window with a map of Alaska. The map displays various layers including rail lines, highways, and geology. A legend is open, showing the following options:

- Surface Geology
- Beikman geology 1980
- Specified Symbology per Occurrence
 - Gold Commodities
 - Gold Only (represented by a green circle)
 - Gold with Other Commodities (represented by a yellow circle)
 - No Gold (represented by a red cross)
 - Iron Commodities

The map shows a network of rail lines (Existing and Proposed) and various commodity occurrences (Gold, Iron) across the state of Alaska. Major cities like Anchorage, Fairbanks, and Juneau are labeled.

■ 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 expense calculation: Routing

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

.....or can set their own

Transportation Cost parameters

CO2 Tax (\$/mT CO2): \$0

Optimal Routing Module

Distance (km)	\$/mT-km
Rail	
1000	\$0.0177
Road	
100	\$0.0940
Inland Waters	
0	\$0.0320
Ocean Going Vessel	
2000	\$0.0030

MOREVT Optimal Routing Module

Origin

Region: **Alaska**

Occurrence: **Fairplay**

Load from Selected

Destination

Type: **Port**

Region: **Alaska**

Name: **Anchorage**

Output Options

Export KML of calculated route

Export SHP of calculated route

Calculate Route

Route Forcing

A preferred route will be automatically calculated based on the freight shipping cost variations by transport mode. To force the route through a particular city or port, insert one or two desired locations below.

Force route through this location

Type: **Port**

Region: **Canada**

Name: **Canaport**

Force route through this location

Type: **Port**

Region: **Canada**

Name: **Canaport**

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.

■ Transportation expense calculation: CO₂ emissions

Total CO₂ 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

Transportation Cost parameters

Optimal Routing Module

CO2 Price (\$/mT CO2) \$0

Distance (km)	\$/mT-km	CO2 Emissions (mT)	Model	Total Cost (\$)
Rail				
500	0.04	16,948	E	\$42,744,239
Road				
100	\$0.0940	46,166	E	\$4,348,100
Inland Waters				
0	\$0.0320	0	E	\$0
Ocean Going Vessel				
1000	\$0.0031	4,817	E	\$6,625,357

TCAM - Rail

Consumption/emissions parameters

CO2 / L diesel (kg):

Fuel consumption / mT-km (L):

CO2 / mT-km (g):

Cancel Save and Close

TCAM - Water Freight Transport

External Inputs

One-way distance (km): 1000

Ship type: Bulk Carrier

Ship size (name): Panamax

ShipsSize (dwt): 72,500

Engines

Number: 3

Type: SSD

Fuel type: FO

Power (kW/engine): 10,410

Operating Modes	Hotelling		Maneuver		RSZ		Cruise	
	1	3	1	3	1	3	1	3
Average speed (km/hr):	0.0	9.3	20.2	26.9				
Time in mode (hr):	40	1	2	21.1				
Loading Factors								
Main engine:	0	0.2	0.4	0.8				
Aux. engine(s):	0.22	0.45	0.27	0.17				
Total kWh								
Main engine:	0	2,080	8,320	234,079				
Aux. engine(s):	12,485	918	918	5,036				
CO2 eq. emission rate (g/kWh)								
Main engine:	0	682	620	620				
Aux. engine(s):	690	717	652	652				
Total CO2 eq. emissions (kg)								
Main engine:	0	0	5,159	145,129				
Aux. engine(s):	8,615	633	599	3,284				
CO2 emissions, all modes								
Total per trip	g / mT-km							
163,418	2,2540							

TCAM - Road

Vehicle Specifications

Truck type: 53' Tractor Trailer

Vehicle weight (mT): 25.6

Consumption/emissions parameters

CO2 / L diesel (kg): 2.67

Fuel consumption (km/L): 2.07

CO2 / mT-km (g): 216.01

Reset Save and Close

Tool Outputs: Route KML in Google Earth

tonnage: 25,775,000
 tonnage: 138,473 per Days

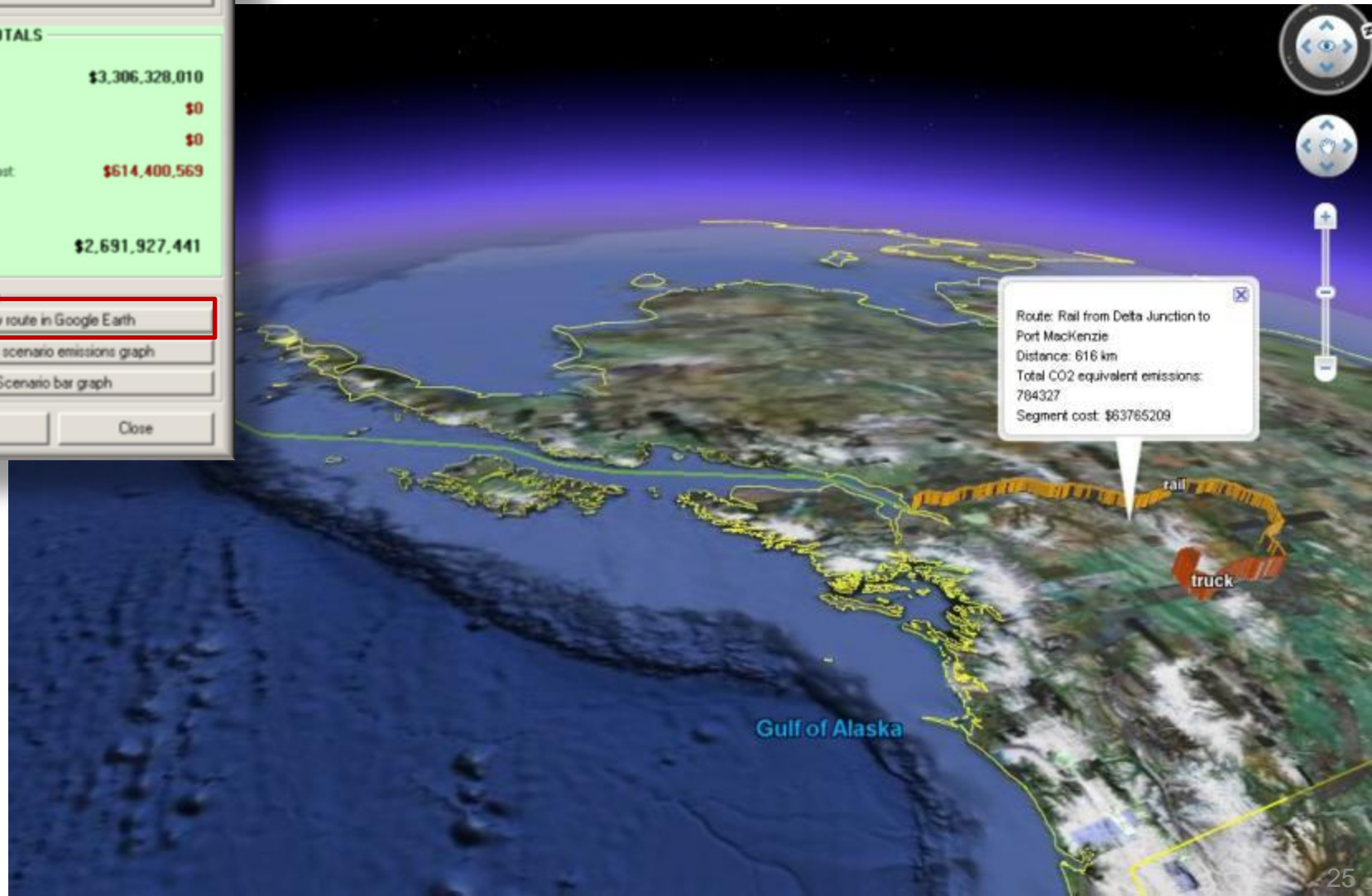
ation Expense
 2 cost/tonne: \$0

Discount Rate
 Select

SCENARIO TOTALS

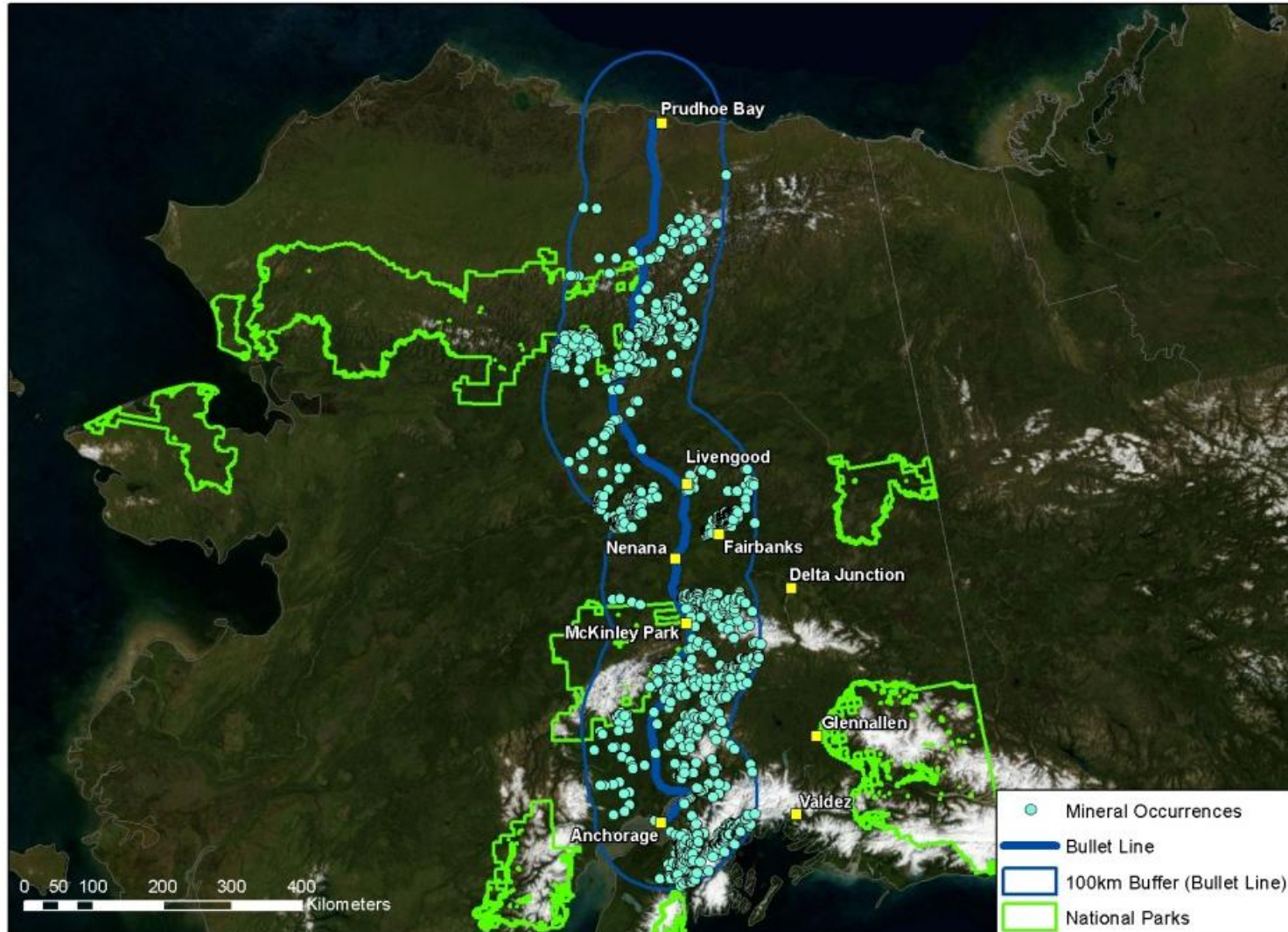
Revenue:	\$3,306,328,010
Capital Cost:	\$0
Operating Cost:	\$0
Transportation Cost:	\$614,400,569
Balance:	\$2,691,927,441

Graphics Outputs:



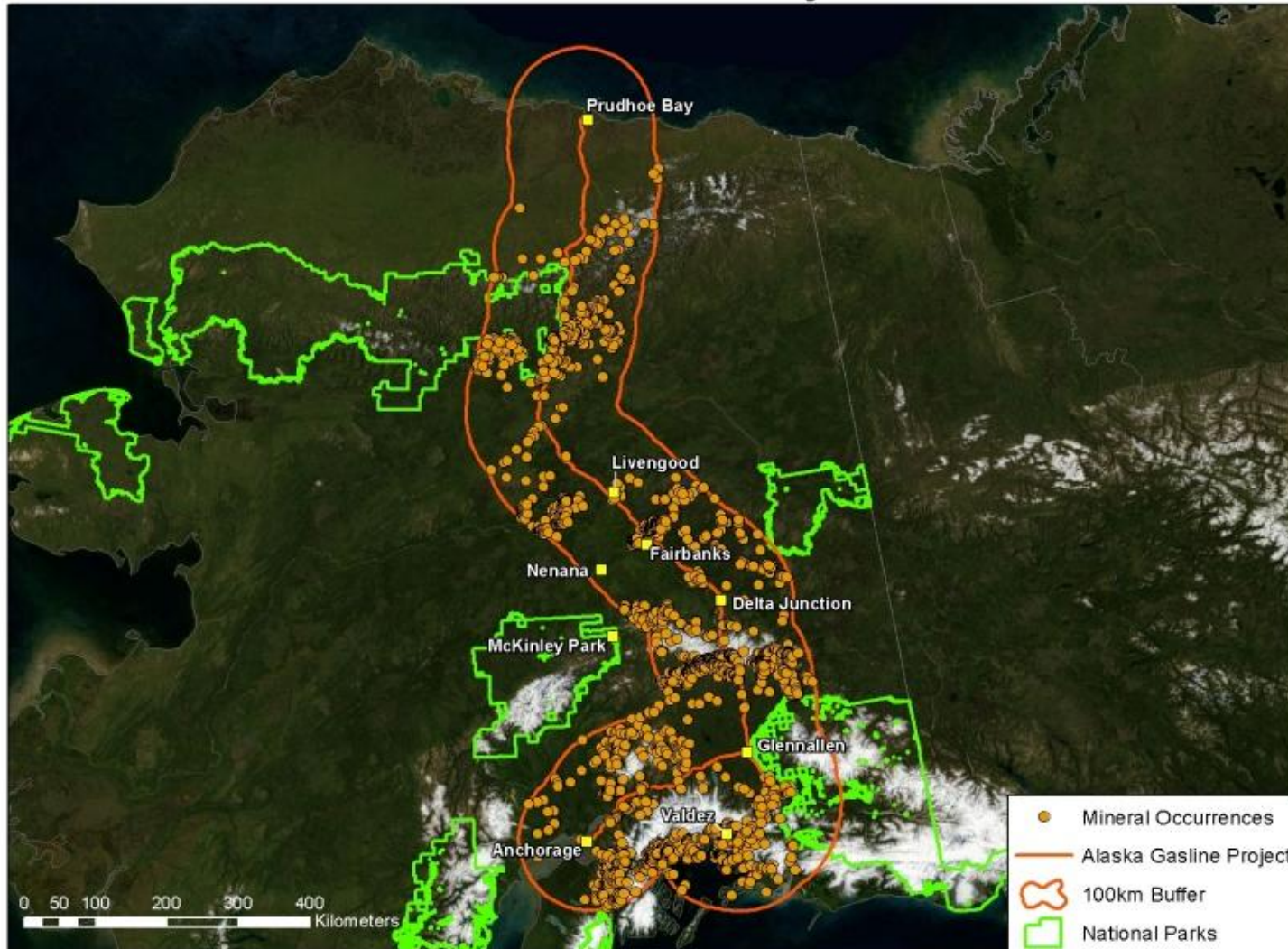
Scenario: Alternative Pipeline Route

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 in 100-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 Epithermal 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	P ₂ O ₅ -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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<http://www.alaska.edu/uaf/cem/ge/people/metz.xml>

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

- Alaska Canada Rail Link Project. 2007. “Rails to Resources to Ports.” ACRL Phase I Feasibility Study. ALCAN RaiLink Inc., Whitehorse, Yukon.
- “Expanding Alaska–Canada Rail: Jointly Visualizing Revenue Freight, Development Cost, Mineral Commodity Value, and Carbon Dioxide Impacts,” Brooks, Billmire, Dobson, Kourous-Harrigan, Keefauver, Michigan Tech Research Institute, for publication in the Transportation Research Record.
- Ballou, R. 1998. Business Logistics Management, 4th Edition, Upper Saddle River, NJ: Prentice Hall.
- Camm, T. W. 1991. “Simplified cost models for prefeasibility mineral evaluations.” Information Circular 9298, U.S. Department of the Interior Bureau of Mines.
- Cox & Singer Mineral Deposit Models
<http://pubs.usgs.gov/of/2004/1344/mainfrms.htm>
- A Test and Re-Estimation of Taylors Empirical Capacity–Reserve Relationship, Keith R. Long Natural Resources Research, Vol. 18, No. 1, March 2009 (2009)

- MAGORMINRailExenCompleteV2.xls (Metz Spreadsheet)
- Gartner Lee report:
http://alaskacanadarail.com/documents/WPA2/WPA2a%20traffic_data_development_mineral_resources2006_04_18.pdf
- A simplified economic filter for open-pit gold-silver mining in the United States, Singer, Menzie, David, Long, USGS Opefile report 98207, 1998
- Course materials website, Prof. Bradley Paul
- Singer, Introduction to Quantitative Mineral Resource Assessments and Required Deposit Models http://pubs.usgs.gov/of/2007/1434/1_Introduction_and_models.pdf
- QCI Logistics Mineral Resources Evaluation
[http://alaskacanadarail.com/documents/WPA2/WPA2d%20MP%20LogisticsEv
aluationMineralResources\(2\)2006_05_17.pdf](http://alaskacanadarail.com/documents/WPA2/WPA2d%20MP%20LogisticsEvaluationMineralResources(2)2006_05_17.pdf)



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.



APPENDIX -TCAM Equations & Data Sources

Rail



$$\text{Total Rail CO}_2 \text{ (kg)} = F * R * C$$

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:

$$L/\text{tonne-km} = 1 / (436 * 0.264 \text{ gallons/liter} * 1.609 \text{ km/mile} * 0.907 \text{ tonnes/ton})$$

C = CO₂/L of diesel (kg); default value = **2.6681**, according to [US EPA](#)

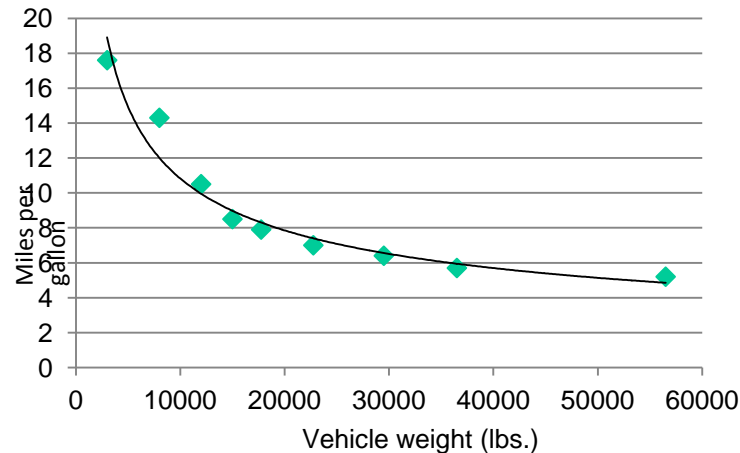
$$\text{Total Road CO}_2 \text{ (kg)} = F * R * C / W$$

Where:

F = Revenue tonne-kilometers of freight: $distance(km) * tonnes \text{ of freight}$, 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):

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



C = CO₂/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



$$\text{Total Water CO}_2 \text{ (kg)} = \sum_t (\sum_m (H_{m,v} * L_{m,t,v} * P_{t,v} * N_{t,v} * E_{m,t})) \text{ for vessel type } v$$

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:

$$\text{Main engine power (kW)} = (a * DWT) + b$$

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 References



American Association of Railroads (AAR). 2008. *Railroad Facts 2008*.

Browning, Louis, and Kathleen Bailey. ICF Consulting and U.S. EPA. 2006. *Current Methodologies and Best Practices for Preparing Port Emission Inventories*. Proc. of 15th International Emission Inventory Conference, New Orleans, LA.

Lloyd's Register of Shipping. 1995. *Marine Exhaust Emissions Research Programme*. London, United Kingdom.

MAN B&W Diesel A/S . 2004. *Propulsion Trends in Bulk Carriers*. Copenhagen, Denmark, September 2004.

MAN B&W Diesel A/S . 2004. *Propulsion Trends in Container Vessels*. Copenhagen, Denmark, December 2004.

MAN B&W Diesel A/S . 2005. *Propulsion Trends in Tankers*. Copenhagen, Denmark, August 2005.

Swedish Environmental Research Institute. 2004. Swedish Methodology for Environmental Data. *Methodology for Calculating Emissions from Ships. 1. Update of Emission Factors*. By David Cooper and Tomas Gustafsson. Norrkoping: Swedish Meteorological and Hydrological Institute (SMHI).

Thesing, Kirstin B. and Alice Edwards. E.H. Pechan & Associates and Alaska Department of Environmental Conservation, Air NonPoint & Mobile Source Program. 2006. *Nine Ports in the 49th State: Commercial Marine Inventory for Alaska*. Proc. of 15th International Emission Inventory Conference, New Orleans, LA.

U.S. Department of Commerce, Bureau of the Census, 2002. *Vehicle Inventory and Use Survey*. Additional information:
<http://www.census.gov/econ/overview/se0501.html>

U.S. Department of Transportation Federal Highway Administration. 2007. Office of Freight Management and Operations. Development of Truck Payload Equivalent Factor (TPEF). By Mohammed Alam and Gayathri Rajamanickam. Washington, D.C.

U.S. Department of Transportation Federal Highway Administration. 2007. Office of Highway Policy Information. *Highway Statistics 2007*. Washington, D.C.

U.S. Environmental Protection Agency. Office of Transportation and Air Quality. 2000. *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data*. Energy and Environmental Analysis Inc. EPA420-R-00-002.

U.S. Environmental Protection Agency. Office of Transportation and Air Quality . 2005. *Emission Facts: Average Carbon Dioxide Emissions*