Great Lakes Maritime Research Institute

A University of Wisconsin - Superior and University of Minnesota Duluth Consortium

ERIE PIER RE-USE FACILITY PHASE II: AN OPTIMIZED COST-EFFECTIVE STRATEGY FOR INCREASED TRANSPORT AND HANDLING OF DREDGED MATERIALS

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GLMRI 2009 AFFILIATE MEETING

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Bureau of Business and Economic Research

Swenson College of Science & Engineering
NATURAL SCIENCES, MATHEMATICAL SCIENCES, ENGINEERING, & TECHNOLOGY

Labovitz School
OF BUSINESS AND ECONOMICS

University of Minnesota Duluth

PROJECT OVERVIEW

- Removal of dredged materials from Erie Pier—A Re-Use Facility based in Duluth.
- Feasible Customers
  - Fines
    - 7 Short-Term and Recurring Projects
    - 4 Long-Term Projects
  - Coarse
    - Many (MN/DOT, Wis DOT)
- Transportation Options
  - Trucking
  - RailMate™
  - Rail + Trucking

Project Objective

- Identify transportation costs for each potential customer in each transportation mode.
- Select optimal long-term and short-term project options.
  - Minimize total costs associated with the removal of fine materials.
  - Depreciate currently accumulated and recurring fine materials.
    - At least 90% of total fine materials.
- Determine the year-by-year project plan for the removal of fines.
- Analyze alternative scenarios.

TRANSPORTATION OPTIONS

- Option 1

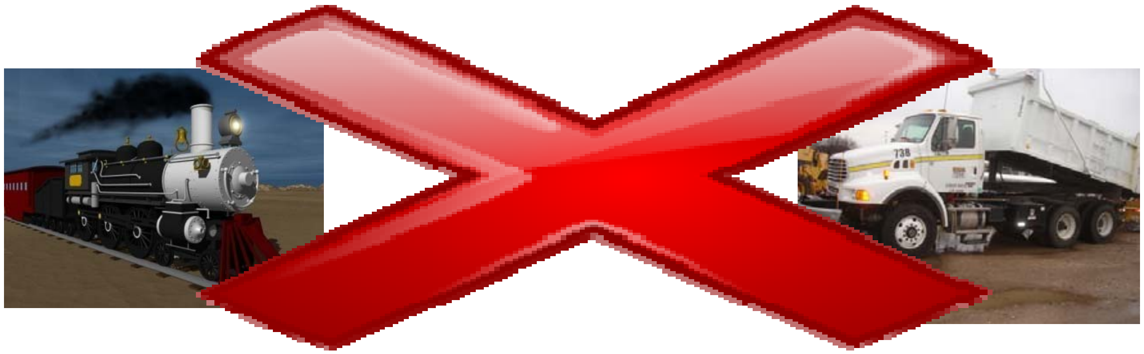
or

- Option 2

- Option 3

+

TRANSPORTATION OPTIONS PRE-SCREENING



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- Higher unit transportation cost
- Huge loading and unloading cost
- Huge transfer yard cost and long application time

TRANSPORTATION OPTIONS PRE-SCREENED

- Option 1

or

- Option 2

SCENARIOS ANALYZED

Transportation Option(s)	Dredged Materials	Customer Options	Time Frame
RailMate™ + Truck	Fines only (Most concerned)	All customers included	21 years in total (Deplete 90%)
Truck only (Less optimal)	Fines + Coarse	One long term project only	Short term projects recurring for 1-12 years
		Based on the likelihood of customers	Short term projects recurring for 5 years (Optimal)—Year by year plan

Analysis (Cont.)

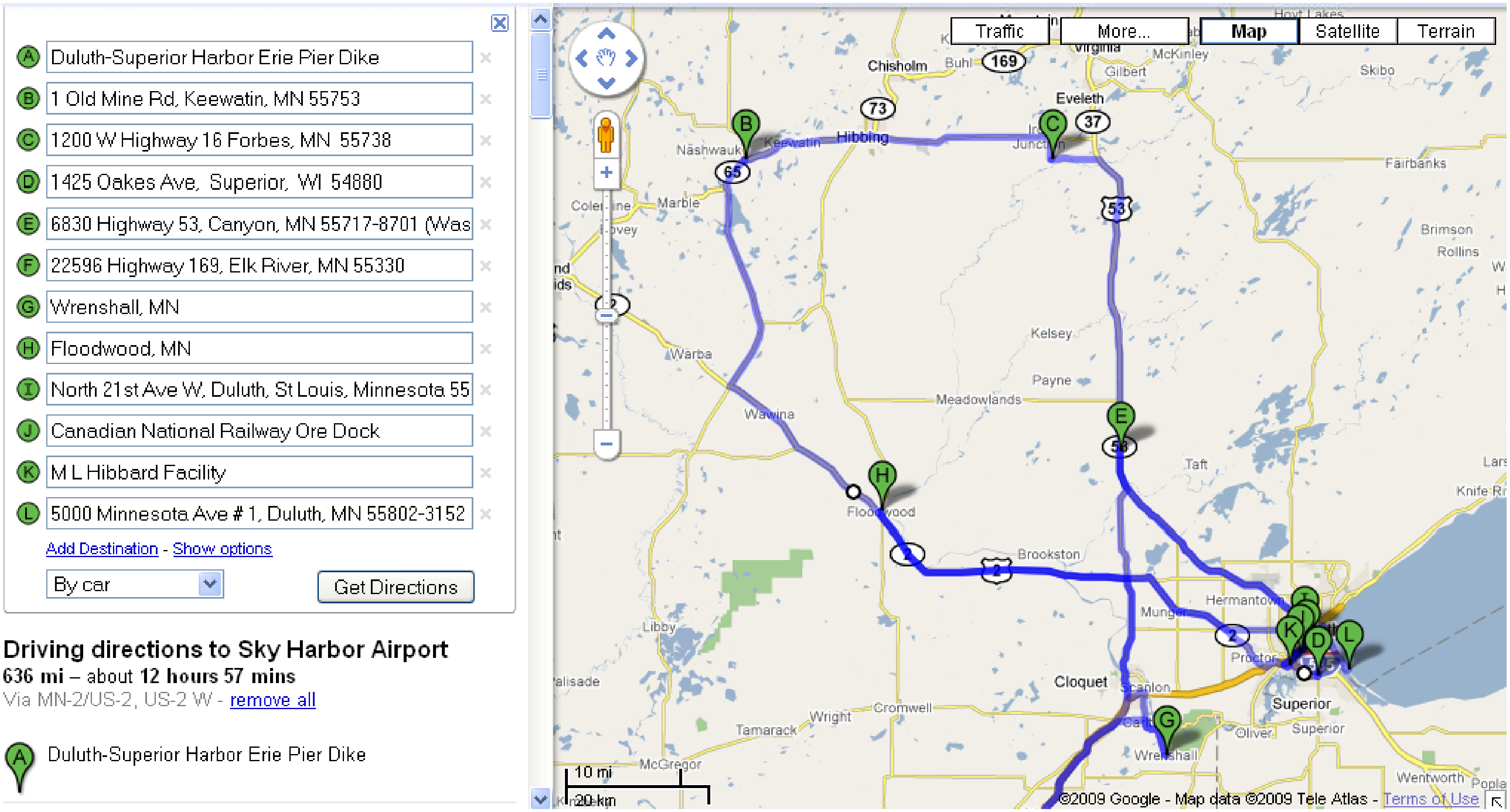
- Short-Term Customer Options

Industry Sector	Customer	Miles from Erie Pier	Annual Demand (cubic yard)
Mine Reclamation	Keewatin Taconite	81.6	8,873
Mine Reclamation	United Taconite	60.0	8,873
Land Fill	Wisconsin Waste Management (Superior)	4.6	21,207
Land Fill	Waste Management (Canyon, MN)	29.8	21,207
Land Fill	Waste Management (Elk River, MN)	163.0	21,207
Soil Enrichment	Wrenshall Farming	22.8	64,560
Soil Enrichment	Floodwood Farming	44.4	64,560

Analysis (Cont.)

- Long-Term Customer Options

Industry Sector	Customer	Miles from Erie Pier	Annual Demand (cubic yard)
Soil Enrichment	Duluth Wetlands Habitat 21st Ave. W Project	1.2	950,000
Construction Fill	CN Railroad Ore Docks	2.2	900,000
Construction Fill	Hibbard Power Plant	2.8	1,000,000
Construction Fill	Sky Harbor Airport	7.4	250,000


A Duluth-Superior Harbor Erie Pier Dike
B 1 Old Mine Rd, Keewatin, MN 55753
C 1200 W Highway 16 Forbes, MN 55738
D 1425 Oakes Ave, Superior, WI 54880
E 6830 Highway 53, Canyon, MN 55717-8701 (Was
F 22596 Highway 169, Elk River, MN 55330
G Wrenshall, MN
H Floodwood, MN
I North 21st Ave W, Duluth, St Louis, Minnesota 55
J Canadian National Railway Ore Dock
K M L Hibbard Facility
L 5000 Minnesota Ave # 1, Duluth, MN 55802-3152
Add Destination - Show options
By car
Get Directions
Driving directions to Sky Harbor Airport
636 mi – about 12 hours 57 mins
Via MN-2/US-2, US-2 W - remove all
A Duluth-Superior Harbor Erie Pier Dike
Traffic
More...
Map
Satellite
Terrain
Chisholm
Hibbing
Keewatin
Nashwauk
Eveleth
Gilbert
McKinley
Skibo
Fairbanks
Brimson
Rollins
Marble
Warba
Wawina
Kelsey
Payne
Meadowlands
Floodwood
Brookston
Taft
Hermantown
Proctor
Cloquet
Scanlon
Superior
Oliver
Wrenshall
Cromwell
Wright
Tamarack
McGregor
Libby
Wentworth
10 mi
20 km
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Analysis – Assumptions

Material	Recurring Yearly Total	Total Accumulation to Date
Coarse Material	48,000 cubic yards	
Fines Material	50,000 cubic yards	
Removable Fines		1,250,000 cubic yards
Allowable Removal of Materials per year: 100,000 cubic yards		
Minimum Amount of Materials to be Removed: 90% of total fine material**		
Density of Fines: 1.29 tons / cubic yard (16.5%-17.5% moisture level)		
One transportation option per project		

RailMate™ Option	
Within 30 Miles to Rail track	**$17/ton**
Beyond 30 Miles to Rail track	No Data

**Modifications were made with these assumptions to test how the solutions would change.*
***Total fine material includes accumulated material (1,250,000 cubic yards) plus the annual recurring fine material.*

ANALYSIS – ASSUMPTIONS (CONT.)

Lakehead Trucking Option	
Transportation Costs per cubic yard mile	$2.25
Dry Material Cubic Yards per Load*	18
Damp Material Cubic Yards per Load	15
Wet Packed Material Cubic Yards per Load	14
Loading and Unloading Time of Truck (Hours)	0.5
Transit Costs (at $100/hour)	$50
Miles from Erie Pier	17.7

Udeen Trucking Options (Quad and End Dump)	
Quad Truck	
Costs Per Hour	$90
Cubic Yards per Load (Minnesota)	14
Cubic Yards Per Load (Wisconsin)	17
Loading and Unloading Time of Truck (Hours)	0.5
Transit Costs (at $90/hour)	$45
End Dump Truck	
Costs Per Hour	$100
Cubic Yards per Load	20
Loading and Unloading Time of Truck (Hours)	0.5
Transit Costs (at $100/hour)	$50
Miles from Erie Pier	9.3

ANALYSIS – ASSUMPTIONS (CONT.)

- Available working hours
  - Work Hours per Day – 10
  - Work Days per Year – 304
  - All-year-round access to Erie Pier
- Bulldozers
  - Existing number – 3
  - Cost for New Bulldozers: $2,689,096.78
- Loaders
  - Existing number – 3
  - Costs for New Loaders: $2,689,096.78
- Useful Life Remaining for Existing Equipment – 6250 hours (1/2 Life)
- Additional Costs
  - 4% inflation + interest rate
  - Wisconsin Waste Management in Superior —$100 tipping fee per truck load
  - Framings—application fee, tillage cost.

MODEL FORMULATION I – OPTIMAL PLAN

- Decision Variables
  - Project Options
  - Transportation options for each project
- Constraints
  - Total fine materials for selected projects ≥ 90% of currently accumulated and recurring fine materials.
  - One transportation option per project.
    - Each selected project needs some form of transportation (trucking or RailMate).
- Objective Function
  - Minimize total costs of selected short and long-term projects.

Model Formulation II (Year-By-Year Plan)

- Decision Variables
  - Recurring Projects: Which years to recur?
  - Total Cubic Yards to remove each year for each project with the selected transportation option.
- Constraints
  - Total Cubic Yards for a given year cannot exceed the maximum allowable (set at 100,000 cubic yards).
  - Year-by-year cumulative total of cubic yards for a project must equal the customer demand.
  - Total number of recurring years = Pre-determined number
- Objective Function
  - Minimize total costs of selected short and long-term projects taking into consideration the future value of project costs (inflation, interest).

SCENARIO 1: OPTIMAL CASE

Project Selected	Total Fines Removed (Cubic Yards)	Transportation Option	Transportation Costs
Waste Management (Canyon, MN)	106,035 (recur 5 years)	RailMate	$176,452
UTAC	44,365 (recur 5 years)	RailMate	$73,827
CN Railroad Ore Dock	950,000	RailMate	$1,497,690
Hibbard Power Plant	1,000,000	RailMate	$1,664,100
Total Materials Used: 2,050,400 cubic yards			
Total Transportation Costs: $3,412,069			
Total Loading and Equipment Costs: $15,987,616			
Total Project Costs: $19,399,685			

SCENARIO 1: OPTIMAL CASE YEAR-BY-YEAR PLAN

Project Selected	Years Selected	Cubic Yards Per Year
Waste Management (Canyon, MN)	1 – 4, 21	21,207
UTAC	1 – 5	8,873
CN Railroad Ore Dock	12 - 21	Year 12: 70,807 Years 13-20: 100,000 Year 21: 29,193
Hibbard Power Plant	1 – 12	Years 1 – 4: 69,920 Year 5: 91,127 Years 6 – 11: 100,000 Year 12: 29,293
Total Transportation Costs (including 4% inflation & interest): $5,344,706.59		
Total Project Costs: $21,332,323.55		

Scenario 2: Truck Only Optimal Case

Project Selected	Total Fines Removed (Cubic Yards)	Transportation Option	Transportation Costs
Wisconsin Waste Management	106,035 (Recur 5 years)	Udeen (End-Dump)	$528,230
21st Ave. W. Project	950,000	Udeen (End-Dump)	$4,039,020
Hibbard Power Plant	1,000,000	Udeen (End-Dump)	$4,617,400
Total Materials Used: 2,056,035 cubic yards			
Total Loading and Equipment Costs: $16,032,654.13			
Total Additional Costs (for Wisconsin Waste Management): $530,500.00			
Total Project Costs: $25,747,804.13			

SCENARIO 2: TRUCK ONLY OPTIMAL CASE YEAR-BY-YEAR PLAN

Project Selected	**Years Selected**	**Cubic Yards Per Year**
Wisconsin Waste Management	1 – 5	21,207
21st Ave. W. Project	12 – 21	Year 12: 93,965 Years 13 – 20: 100,000 Year 21: 56,035
Hibbard Power Plant	1 – 12	Years 1 – 5: 78,793 Years 6 – 11: 100,000 Year 12: 6,035
Total Transportation Costs (including 4% inflation & interest): $14,269,867.88		
Total Project Costs: $30,833,022.22		

RECOMMENDATIONS

	Optimal Case (RailMate™ for all Projects)	**Truck Scenario**
Long-Term Project(s)	CN Railroad Ore Docks, Hibbard Power Plant	21st Ave. West Hibbard Power Plant
Short-Term Project(s)	Waste Management (Canyon), UTAC (Recur 5 Years)	Wisconsin Waste Management (Recur 5 Years)
Total Transportation Costs*	$3,412,069.00 ($5,344,706.59)	$9,184,650.00 ($14,269,867.88)
Total Loading & Equipment Costs	$15,787,616	$16,032,654.13
Additional Costs**	$0	$530,500.00
Total Project Costs*	**$19,399,685 ($21,332,323.55)**	**$25,547,804.13 ($30,833,022.02)**

** The value in parentheses is the total transportation costs after inflation and interest.*
*** Additional costs applied to Wisconsin Waste Management in Superior, Wrenshall and Floodwood Farming projects.*

ISSUES FOR FURTHER INVESTIGATION

- Purple loosestrife
  - Impact on the potential customers list?
  - Additional cost?
- Transfer Station
  - Loading Equipment
  - Conveyor?
- More insights/requirement from stakeholders
  - More scenarios

ACKNOWLEDGEMENT

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- *Jim Sharrow* and the Duluth Seaway Port Authority Staff
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- *Elizabeth J. Juntune*, Executive Vice President, Rail-Mate, Minneapolis, MN
- *All those who also helped with phase I of this project.*

QUESTIONS?


Traffic
More...
Map
Satellite
Terrain
Show labels
Carlton St
23
254
Helm St
Courtland St
35
W Michigan St
W Superior St
Access Rd
253B
Oneida St
S 37th Ave W
500 ft
200 m
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BACK UP SLIDES

MODEL FORMULATION I (CONT.)

Decision Variables:

$X_{ij} = 1$ if Project option i with Truck option j is selected $(i = 1 - 14,\ j = 1 - 5)$

$X_{ij} = 0$ if Project option i with Truck option j is not selected $(i = 1 - 14,\ j = 1 - 5)$

$Y_i = 1$ if Project option i is selected $(i = 1 - 14)$

$Y_i = 0$ if Project option i is not selected $(i = 1 - 14)$

$i = 1 - 14$

1 = Wisconsin Waste Management	2 = Mn/DOT Scenario 1
3 = Wrenshall Farmers	4 = Mn/DOT Scenario 2
5 = Waste Management (Canyon, MN)	6 = Keewatin Taconite (Keetac)
7 = Waste Management (Elk River, MN)	8 = United Taconite (UTAC)
9 = Mn/DOT Scenario 3	10 = Floodwood Farmers
11 = 21st Ave. W Project	12 = CN Railroad Ore Docks
13 = Hibbard Power Plant	14 = Sky Harbor Airport

$j = 1 - 5$

1 = Lakehead Trucking   2 = Udeen (Quad) Trucking   3 = Udeen (End – Dump) Trucking

4 = Elk River Trucking (applicable only for $i = 7$)   5 = RailMate System (applicable only for $i = 6,7$)

Additional Variables:

C_{ij} = Total Transportation Costs for Project Option i with Option j $(i = 1 - 14,\ j = 1 - 5)$

N_i = Minimum Number of Years to Complete Project Option i $(i = 1 - 14)$

CY_i = Total Cubic Yards of Material for Project Option i $(i = 1 - 14)$

TL_{ij} = Number of Truckloads required for Project Option i $(i = 1)$ with Truck Option j $(j = 1 - 3)$

R_i = Number of Recurring Years for Project Option i $(i = 1, 3, 5 - 8, 10)$

TY = Total Number of Years to Complete Selected Projects

MODEL FORMULATION I (CONT.)

Objective Function:

$$\text{MIN: } \left(\sum C_{ij} \times X_{ij}\right) + \left((110 \times 10 \times 304) \times \sum N_i \times Y_i\right)$$

$$+ \left(3 \times 200{,}000 \times \frac{((\sum N_i \times Y_i) \times 10 \times 304) - 6{,}250}{12{,}500}\right)$$

$$+ \left(3 \times 200{,}000 \times \frac{((\sum N_i \times Y_i) \times 10 \times 304) - 6{,}250}{12{,}500}\right) + (100 \times (TL_{11} + TL_{12} + TL_{13}) \times Y_1)$$

$$+ (1.10 \times CY_3 \times Y_3) + (100 \times (N_{10} \times 304) \times Y_{10}) + \left(1.73 \times \sum CY_i \times Y_i\right)$$

Subject to: ***Constraints***

$$\sum CY_i \times Y_i \geq 0.90 \times (1{,}250{,}000 + (50{,}000 \times TY))$$

$$\sum CY_i \times Y_i \leq (1{,}250{,}000 + (50{,}000 \times TY))$$

$$Y_{11} + Y_{12} + Y_{13} + Y_{14} \geq 1$$

$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6 + Y_7 + Y_8 + Y_9 + Y_{10} \geq 0$$

$$X_{1,1} + X_{1,2} + X_{1,3} \leq 1$$

$$X_{2,1} + X_{2,2} + X_{2,3} \leq 1$$

$$X_{3,1} + X_{3,2} + X_{3,3} \leq 1$$

$$X_{4,1} + X_{4,2} + X_{4,3} \leq 1$$

$$X_{5,1} + X_{5,2} + X_{5,3} \leq 1$$

$$X_{6,1} + X_{6,2} + X_{6,3} + X_{6,5} \leq 1$$

$$X_{7,4} + X_{7,5} \leq 1$$

$$X_{8,1} + X_{8,2} + X_{8,3} \leq 1$$

$$X_{9,1} + X_{9,2} + X_{9,3} \leq 1$$

$$X_{10,1} + X_{10,2} + X_{10,3} \leq 1$$

$$X_{11,1} + X_{11,2} + X_{11,3} \leq 1$$

$$X_{12,1} + X_{12,2} + X_{12,3} \leq 1$$

$$X_{13,1} + X_{13,2} + X_{13,3} \leq 1$$

$$X_{14,1} + X_{14,2} + X_{14,3} \leq 1$$

$0 \le Y_1 - X_{1,1} \le 1$ $0 \le Y_1 - X_{1,2} \le 1$ $0 \le Y_1 - X_{1,3} \le 1$

$0 \le Y_2 - X_{2,1} \le 1$ $0 \le Y_2 - X_{2,2} \le 1$ $0 \le Y_2 - X_{2,3} \le 1$

$0 \le Y_3 - X_{3,1} \le 1$ $0 \le Y_3 - X_{3,2} \le 1$ $0 \le Y_3 - X_{3,3} \le 1$

$0 \le Y_4 - X_{4,1} \le 1$ $0 \le Y_4 - X_{4,2} \le 1$ $0 \le Y_4 - X_{4,3} \le 1$

$0 \le Y_5 - X_{5,1} \le 1$ $0 \le Y_5 - X_{5,2} \le 1$ $0 \le Y_5 - X_{5,3} \le 1$

$0 \le Y_6 - X_{6,1} \le 1$ $0 \le Y_6 - X_{6,2} \le 1$ $0 \le Y_6 - X_{6,3} \le 1$ $0 \le Y_6 - X_{6,5} \le 1$

$0 \le Y_7 - X_{7,4} \le 1$ $0 \le Y_7 - X_{7,5} \le 1$

$0 \le Y_8 - X_{8,1} \le 1$ $0 \le Y_8 - X_{8,2} \le 1$ $0 \le Y_8 - X_{8,3} \le 1$

$0 \le Y_9 - X_{9,1} \le 1$ $0 \le Y_9 - X_{9,2} \le 1$ $0 \le Y_9 - X_{9,3} \le 1$

$0 \le Y_{10} - X_{10,1} \le 1$ $0 \le Y_{10} - X_{10,2} \le 1$ $0 \le Y_{10} - X_{10,3} \le 1$

$0 \le Y_{11} - X_{11,1} \le 1$ $0 \le Y_{11} - X_{11,2} \le 1$ $0 \le Y_{11} - X_{11,3} \le 1$

$0 \le Y_{12} - X_{12,1} \le 1$ $0 \le Y_{12} - X_{12,2} \le 1$ $0 \le Y_{12} - X_{12,3} \le 1$

$0 \le Y_{13} - X_{13,1} \le 1$ $0 \le Y_{13} - X_{13,2} \le 1$ $0 \le Y_{13} - X_{13,3} \le 1$

$0 \le Y_{14} - X_{14,1} \le 1$ $0 \le Y_{14} - X_{14,2} \le 1$ $0 \le Y_{14} - X_{14,3} \le 1$

$(X_{1,1} + X_{1,2} + X_{1,3}) - Y_1 = 0$

$(X_{2,1} + X_{2,2} + X_{2,3}) - Y_2 = 0$

$(X_{3,1} + X_{3,2} + X_{3,3}) - Y_3 = 0$

$(X_{4,1} + X_{4,2} + X_{4,3}) - Y_4 = 0$

$(X_{5,1} + X_{5,2} + X_{5,3}) - Y_5 = 0$

$(X_{6,1} + X_{6,2} + X_{6,3} + X_{6,5}) - Y_6 = 0$

$(X_{7,4} + X_{7,5}) - Y_7 = 0$

X_{ij} Binary

$(X_{8,1} + X_{8,2} + X_{8,3}) - Y_8 = 0$

$(X_{9,1} + X_{9,2} + X_{9,3}) - Y_9 = 0$

$(X_{10,1} + X_{10,2} + X_{10,3}) - Y_{10} = 0$

$(X_{11,1} + X_{11,2} + X_{11,3}) - Y_{11} = 0$

$(X_{12,1} + X_{12,2} + X_{12,3}) - Y_{12} = 0$

$(X_{13,1} + X_{13,2} + X_{13,3}) - Y_{13} = 0$

$(X_{14,1} + X_{14,2} + X_{14,3}) - Y_{14} = 0$

Y_i Binary

MODEL FORMULATION II (CONT.)

***Decision Variables*:**

CY_{ijk} = Total Cubic Yards of Material for Project Option i (i = 2, 4, 9, 11 − 14) with Option j (1 − 5) during year k (TY from previous model)

Z_{ijk} = 1 if Project Option i with Option j during year k is selected (i = 1, 3, 5 − 8, 10)(j = 1 − 5)

Z_{ijk} = 0 if Project Option i with Option j during year k is not selected (i = 1, 3, 5 − 8, 10) (j = 1 − 5)

i = 1 − 14

1 = Wisconsin Waste Management	2 = Mn/DOT Scenario 1
3 = Wrenshall Farmers	4 = Mn/DOT Scenario 2
5 = Waste Management (Canyon, MN)	6 = Keewatin Taconite (Keetac)
7 = Waste Management (Elk River, MN)	8 = United Taconite (UTAC)
9 = Mn/DOT Scenario 3	10 = Floodwood Farmers
11 = 21st Ave. W Project	12 = CN Railroad Ore Docks
13 = Hibbard Power Plant	14 = Sky Harbor Airport

j = 1 − 5

1 = Lakehead Trucking 2 = Udeen (Quad)Trucking 3 = Udeen (End − Dump)Trucking

4 = Elk River Trucking (applicable only for i = 7) 5 = RailMate System (applicable only for i = 6,7)

MODEL FORMULATION II (CONT.)

Additional Variables:

C_{ij} = Cost per Cubic Yard for Project Option i with Option j (i = 1 − 14, j = 1 − 5)

MCY_k = Maximum Number of Cubic Yards in year k (Set at 100,000 cubic yards)

i' = Real interest rate (inflation + interest) − assumed to be 4.0%

CY_i = Total Cubic Yards of Material for Project Option i (i = 1, 3, 5 − 8, 10)

N_i = Minimum Number of Years to Complete Project Option i (i = 1, 3, 5 − 8, 10)

R_i = Number of Recurring Years for Project Option i (i = 1, 3, 5 − 8, 10)

E = Total Equipment Costs from Previous Model

$$E = \left((110 \times 10 \times 304) \times \sum N_i \times Y_i \right) + \left(3 \times 200{,}000 \times \frac{((\sum N_i \times Y_i) \times 10 \times 304) - 6{,}250}{12{,}500} \right)$$
$$+ \left(3 \times 200{,}000 \times \frac{((\sum N_i \times Y_i) \times 10 \times 304) - 6{,}250}{12{,}500} \right)$$

A = Total Additional Costs from Previous Model

$$A = (100 \times (TL_{11} + TL_{12} + TL_{13}) \times Y_1) + (1.10 \times CY_3 \times Y_3) + (100 \times (N_{10} \times 304) \times Y_{10})$$

L – Total Loading Costs from Previous Model

$$L = \left(1.73 \times \sum CY_i \times Y_i\right)$$

Objective Function:

$$\text{MIN: } \left(\sum (CY_{ijk} \times C_{ij}) \times (1 + i')^k\right) + \left(\sum (Z_{ijk} \times C_{ij} \times CY_i) \times (1 + i')^k\right) + E + A + L$$

MODEL FORMULATION II (CONT.)

Subject to: ***Constraints***

$$\sum CY_{ijk} + \sum (Z_{ijk} \times CY_i) \leq MCY_k$$

$$\sum N_i \times Z_{ijk} \leq 1$$

$$\sum Z_{ijk} = R_i$$

$$\sum CY_{ijk} = CY_i$$

$$\sum (Z_{ijk} \times CY_i) = R_i \times CY_i$$

$$CY_{ijk} \geq 0$$

Z_{ijk} binary

Analysis and Discussion of Results:
Identifying Optimal Number of Recurring Years

- Optimal Case

# of Recurring Years

Wisconsin	Canyon	Elk River	Wrenshall	Keetac	UTAC	Floodwood	Total Cost	# of Long-Term Projects	# of Short-term (Recurring)	# of Years
1	1	1	1	1	1	1	$15,832	2	2	20.57
2	2	2	2	2	2	2	$15,798	2	1	20.53
3	3	3	3	3	3	3	$15,815	2	2	21
4	4	4	4	4	4	4	$15,825	2	2	20.7
5	***5***	***5***	***5***	***5***	***5***	***5***	***$15,787***	***2***	***1***	***20.56***
6	6	6	6	6	6	6	$15,836	2	0	20.77
7	**7**	**7**	**7**	**7**	**7**	**7**	**$15,772**	**2**	**1**	**20.48**
8	8	8	8	8	8	8	$15,941	2	1	21
9	9	9	9	9	9	9	$15,862	2	0	21
10	10	10	10	10	10	10	$15,880	2	1	20.62
11	11	11	11	11	11	11				21
12	12	12	12	12	12	12	$15,836	2	0	21

* *"Total Cost" values in table are represented in millions*

TRUCK ONLY WITH ONE LONG-TERM PROJECT

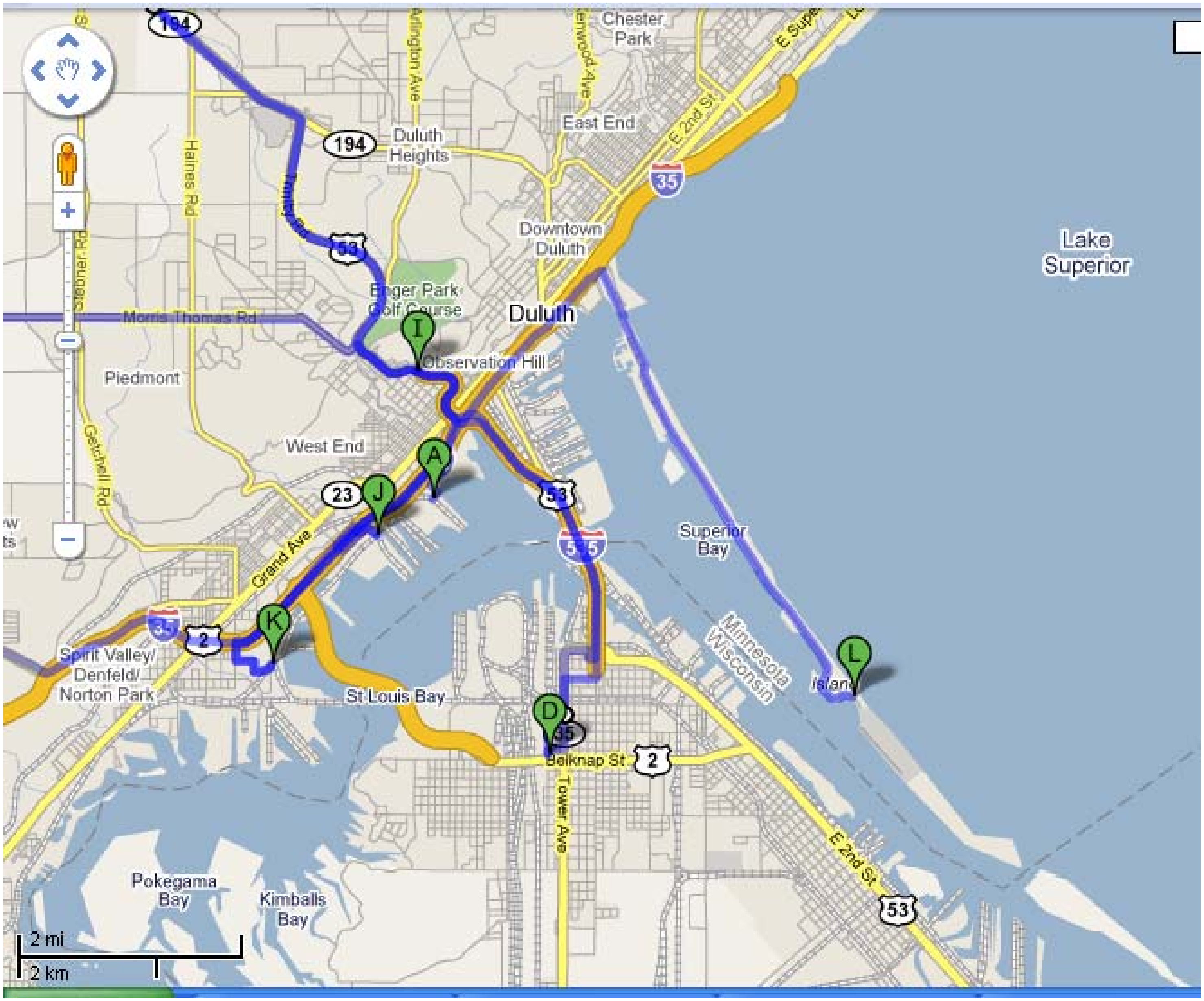
- CN Railroad Ore Docks Project
- Farming Projects recur for 9 years

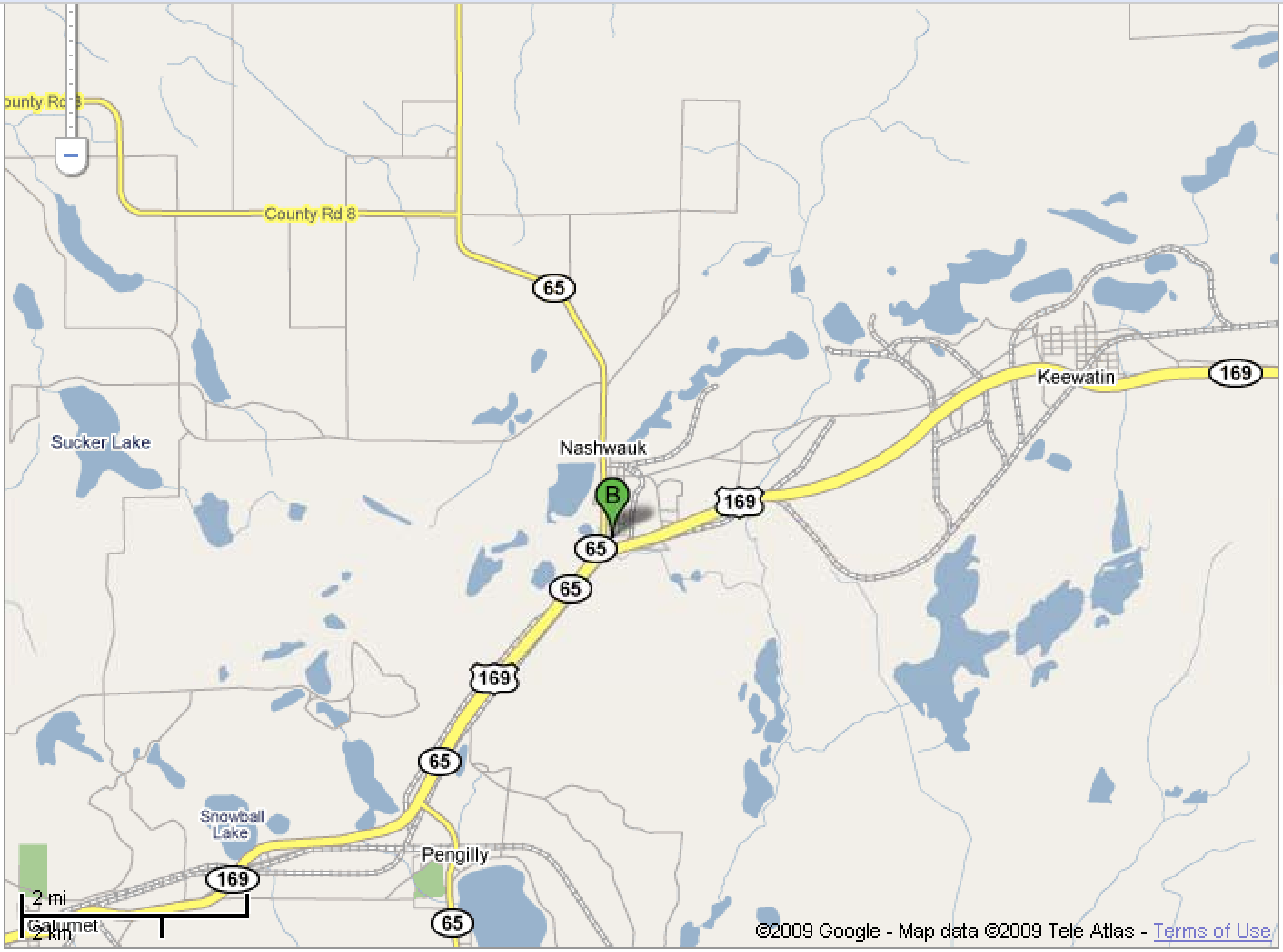
Project Selected	**Total Cubic Yards**	**Transportation Option**	**Total Transportation Costs**
Wrenshall Farming	581,040 (Fine)	Udeen (End-Dump)	$6,787,399.50
Floodwood Farming	581,040 (Fine)	Lakehead	$13,007,784.60
CN Railroad Ore Docks	900,000 (Fine)	Udeen (End-Dump)	$4,089,600.00
Total Materials Used: 2,062,080 cubic yards			
Total Equipment Costs: $15,880,968.19			
Total Additional Costs (for Wisconsin Waste Management and Farming): $815,780.16			
Total Project Costs: $40,581,532.45 *(Increase from Optimal of 37.0%)*			

TRUCK ONLY WITH ONE LONG-TERM PROJECT YEAR-BY-YEAR PLAN

Project Selected	Years Selected	Cubic Yards Per Year
Wrenshall Farming	7 – 12, 14, 17 – 18	64,560
Floodwood Farming	1 – 6, 13, 15 – 16	64,560
CN Railroad Ore Docks	1 – 21	Years 1 – 18: 35,440 Years 19 – 20: 100,000 Year 21: 62,080
Total Transportation Costs (including inflation/interest): $35,463,044.43		
Total Project Costs: **$52,159,792.78** ***(Increase from Optimal of 41.3%)***		

Erie Pier Re-Use Facility Phase II: An Optimized Cost-Effective Strategy for Increased Transport and Handling of Dredged Materials




County Rd 8
County Rd 8
65
Sucker Lake
Nashwauk
B
169
Keewatin
169
65
65
169
65
Snowball Lake
Pengilly
169
65
2 mi
2 km
Calumet
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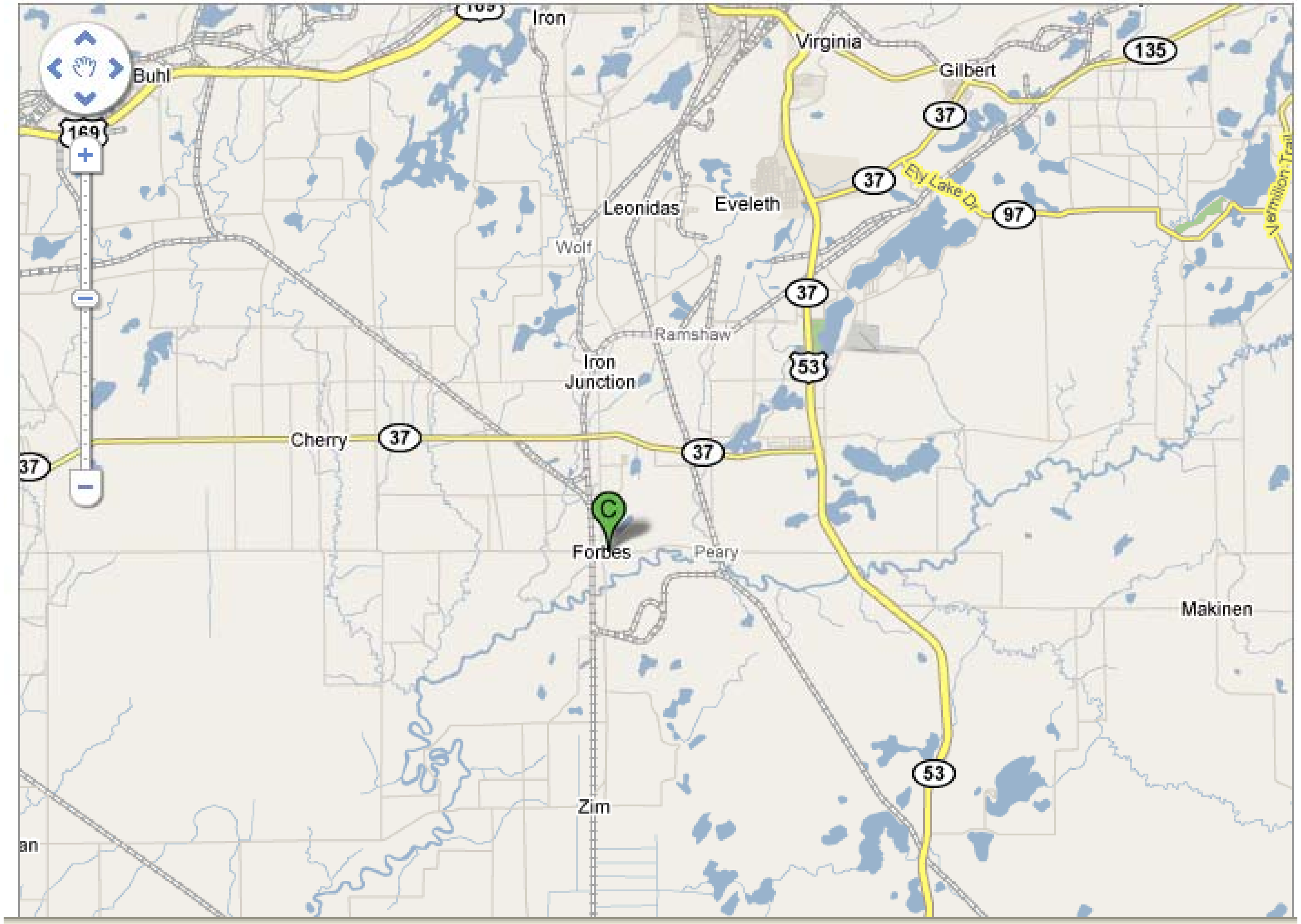
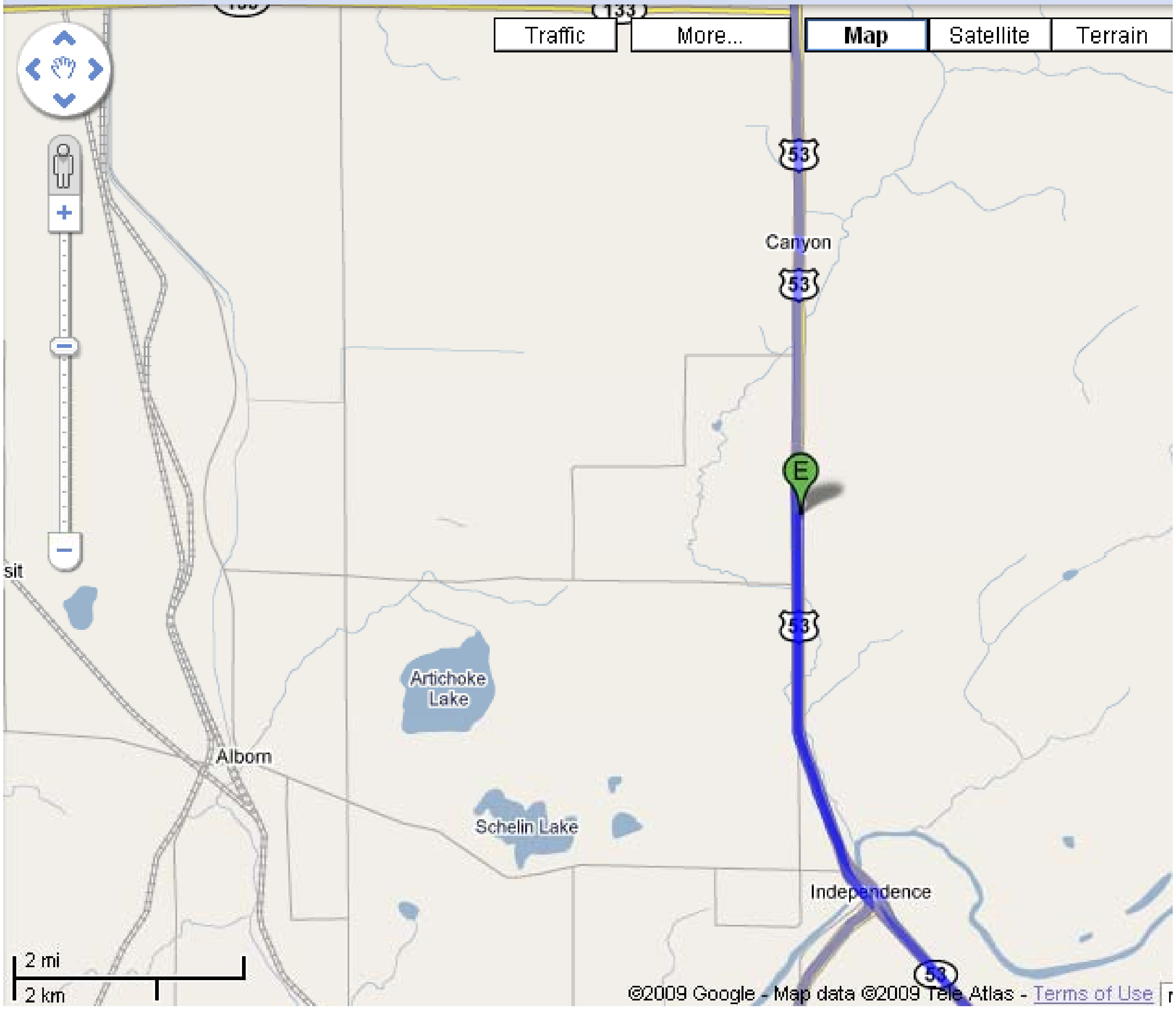
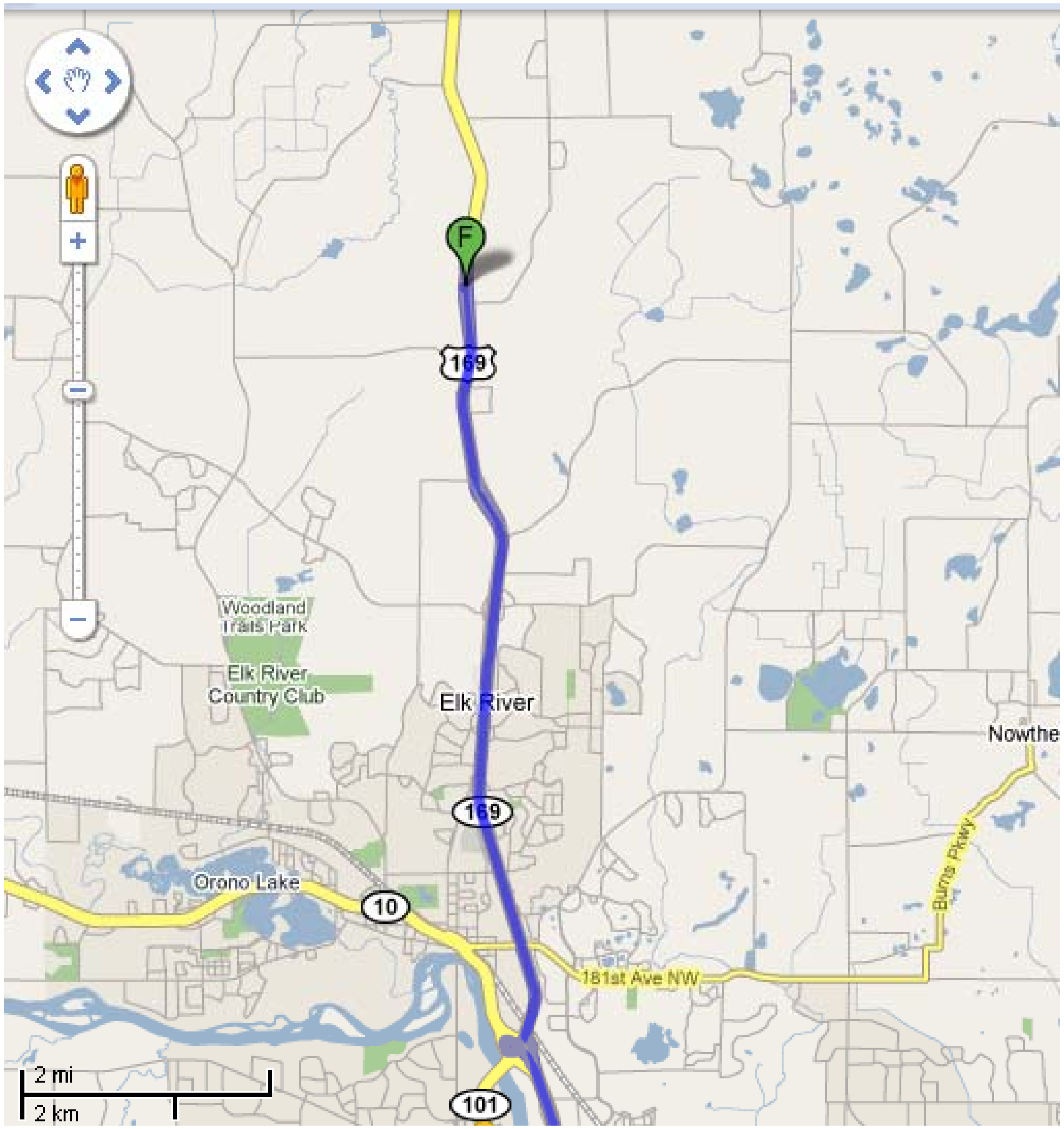
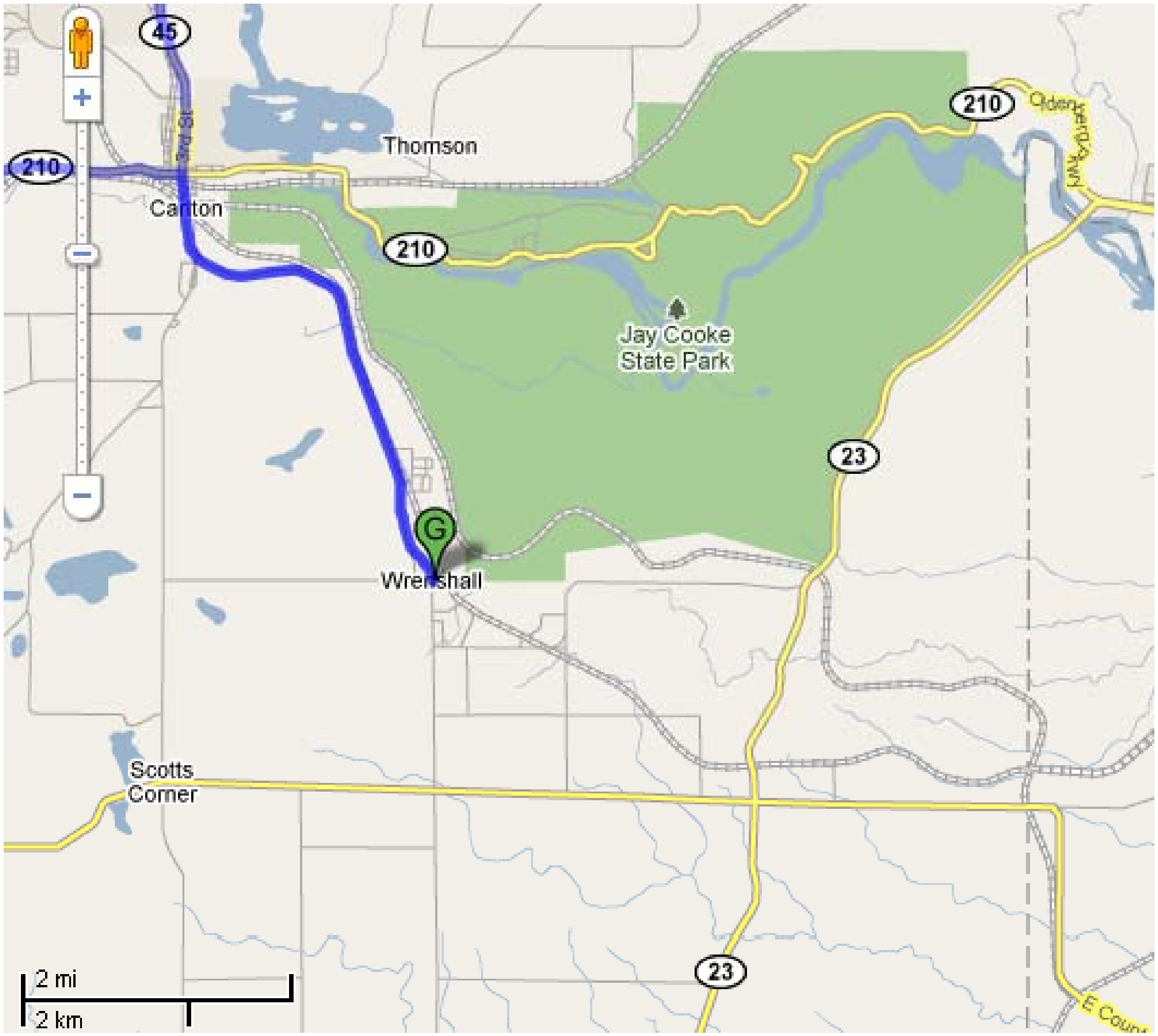
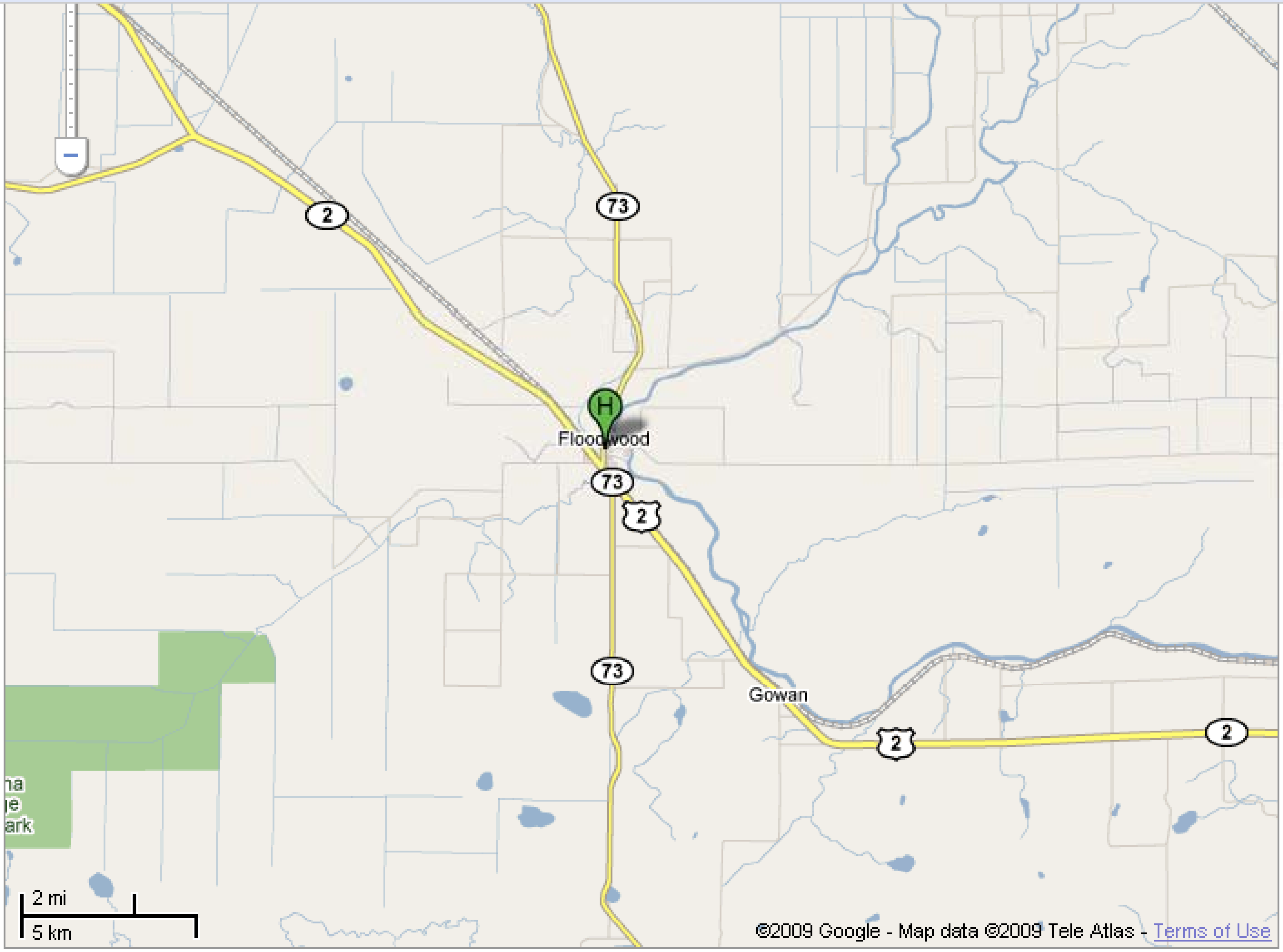

Iron
Virginia
Gilbert
135
Buhl
169
37
Ely Lake Dr
97
Vermilion Trail
Leonidas
Eveleth
Wolf
Ramshaw
53
Iron
Junction
Cherry
C
Forbes
Peary
Makinen
Zim
an


Traffic
More...
Map
Satellite
Terrain
133
53
Canyon
E
Artichoke Lake
Albom
Schelin Lake
Independence
2 mi
2 km
©2009 Google - Map data ©2009 Tele Atlas - Terms of Use


F
169
Woodland Trails Park
Elk River Country Club
Elk River
Nowthe
169
Orono Lake
10
181st Ave NW
Burns Pkwy
101
2 mi
2 km


45
210
Thomson
Carlton
210
210
Jay Cooke
State Park
23
G
Wrenshall
Scotts
Corner
23
2 mi
2 km


2
73
Floodwood
73
2
73
Gowan
2
2
2 mi
5 km
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