Center of Energy Excellence Feedstock Supply Chain Models

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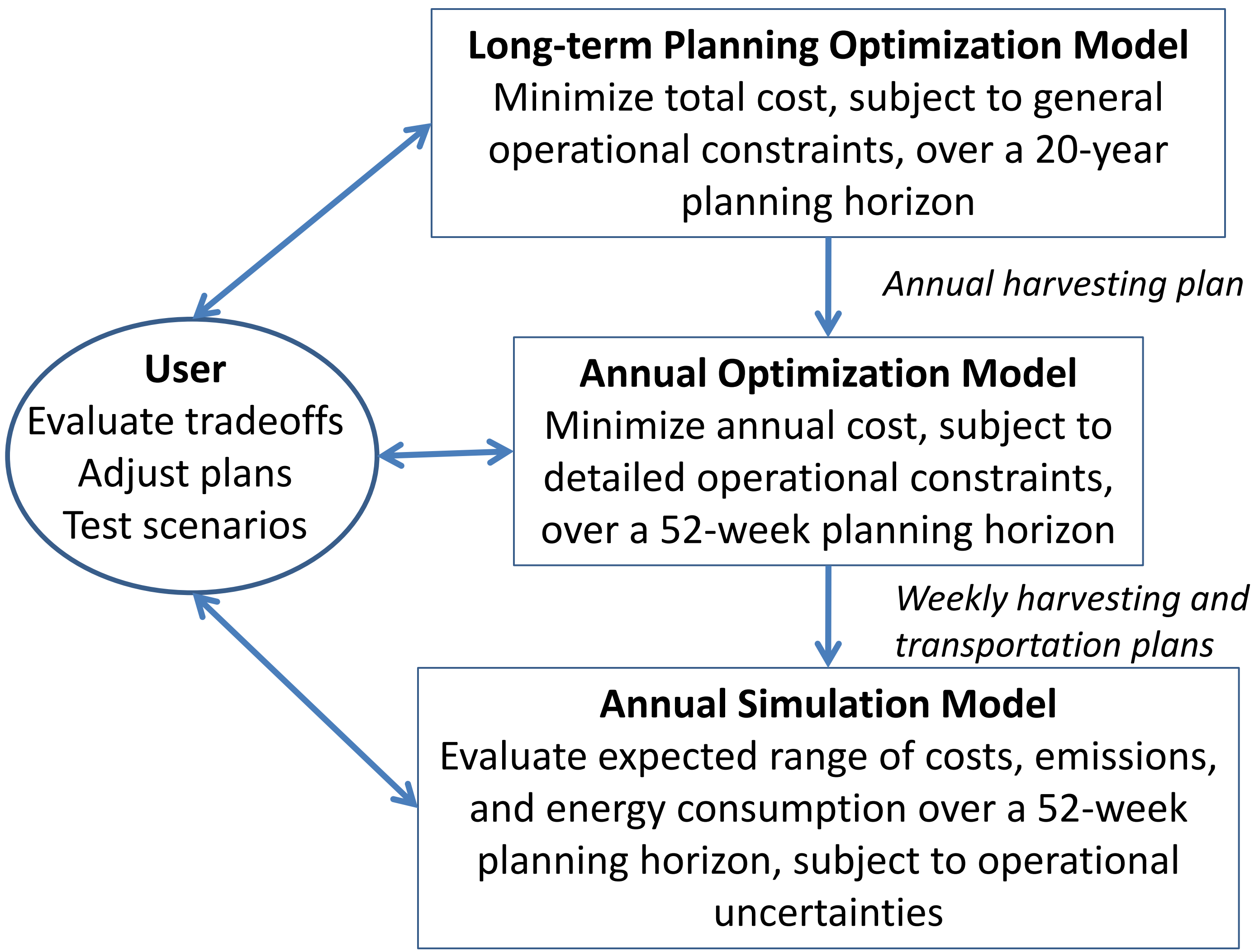
Role of Modeling

- To support development of an efficient supply chain for the Kinross Frontier facility
- Efficiency in this context is:
  - Supply sufficient fiber
    - Maintain reliable supply through spring “break-up”
  - Minimize cost of harvesting and delivering the fiber
    - Minimize/limit energy consumption and CO_2 emissions
  - Maintain supply chain reliability under a range of “likely” management scenarios
    - Recognize different behaviors by different land owners
    - Recognize different harvest costs for different levels of harvest intensity and site difficulty

Decision Support Modeling Framework



Data Sources for the Optimization Model

- Timber availability data from the MSU Project 2/Tessa Systems report
- Land base split into 4 ownerships
  - Federal (mostly Forest Service)
  - State (mostly DNR)
  - Private corporate/REIT/TIMO
  - Private small non-industrial
- Land base subdivided into 4 harvest cost categories
  - Clearcut - least expensive (aspen)
  - Shelterwood - second least expensive (oak)
  - Northern hardwoods – more expensive (normal & difficult sites)
- Harvest costs from MSU Project 3
- Transportation costs from MTU Project 3

Available Fiber Calculations

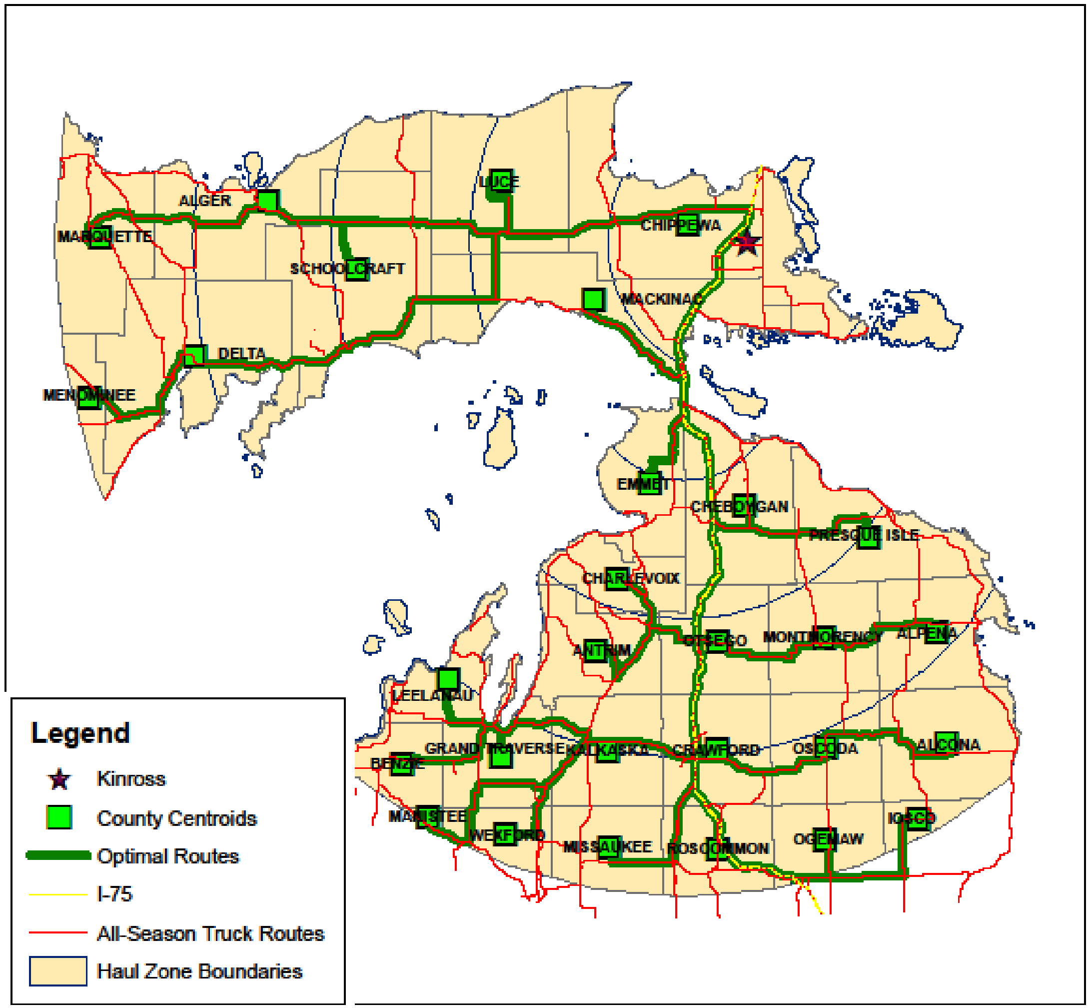
- Forest Inventory and Analysis data provided by MSU Project 2
    - Growth summarized for each
        - County
        - Haul zone
        - Ownership
        - Harvest cost category
        - Each of these combinations enters the model as a constraint

Transportation Distance Calculations

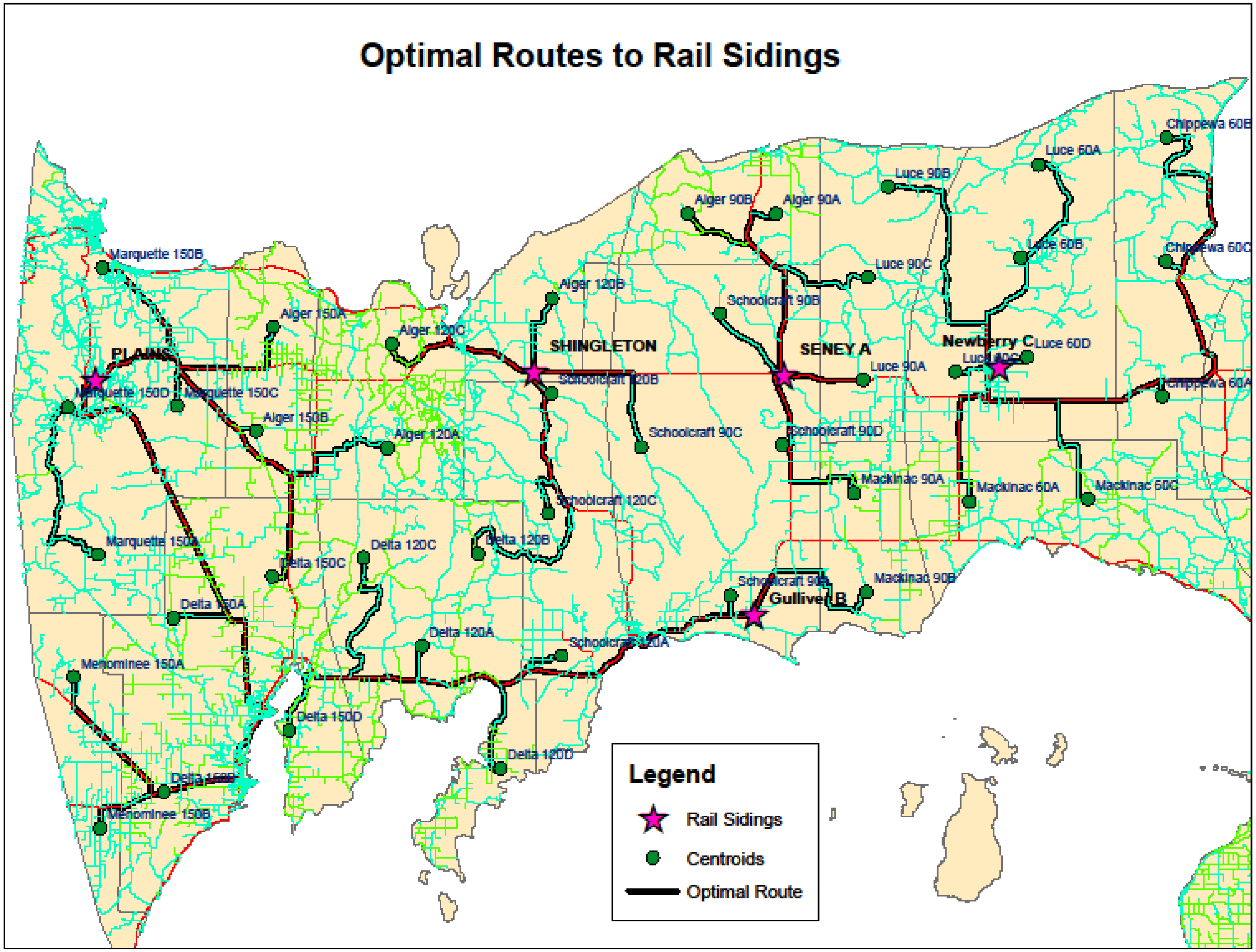
- Distance to facility was calculated from generated points
- Mileages were calculated for Class A highways, other public roads, and woods roads
  - Data layer of public roads provided by MTU Project 3
  - Woods roads were determined by inspection of air photos and USGS quad maps
    - A likely road path was selected from the closest woods road

Transportation Routes and Distances

Optimal Haul Routes from County Centroids



Transportation Routes and Distances



The Optimization User Interface

- Uses an Excel spreadsheet
- Allows fundamental data to be altered easily as new information becomes available
  - e. g., harvest cost data
- Allows scenario analysis by user
  - Impact of different harvest decisions by owners
  - Availability of wood delivered by rail from greater than 150 miles

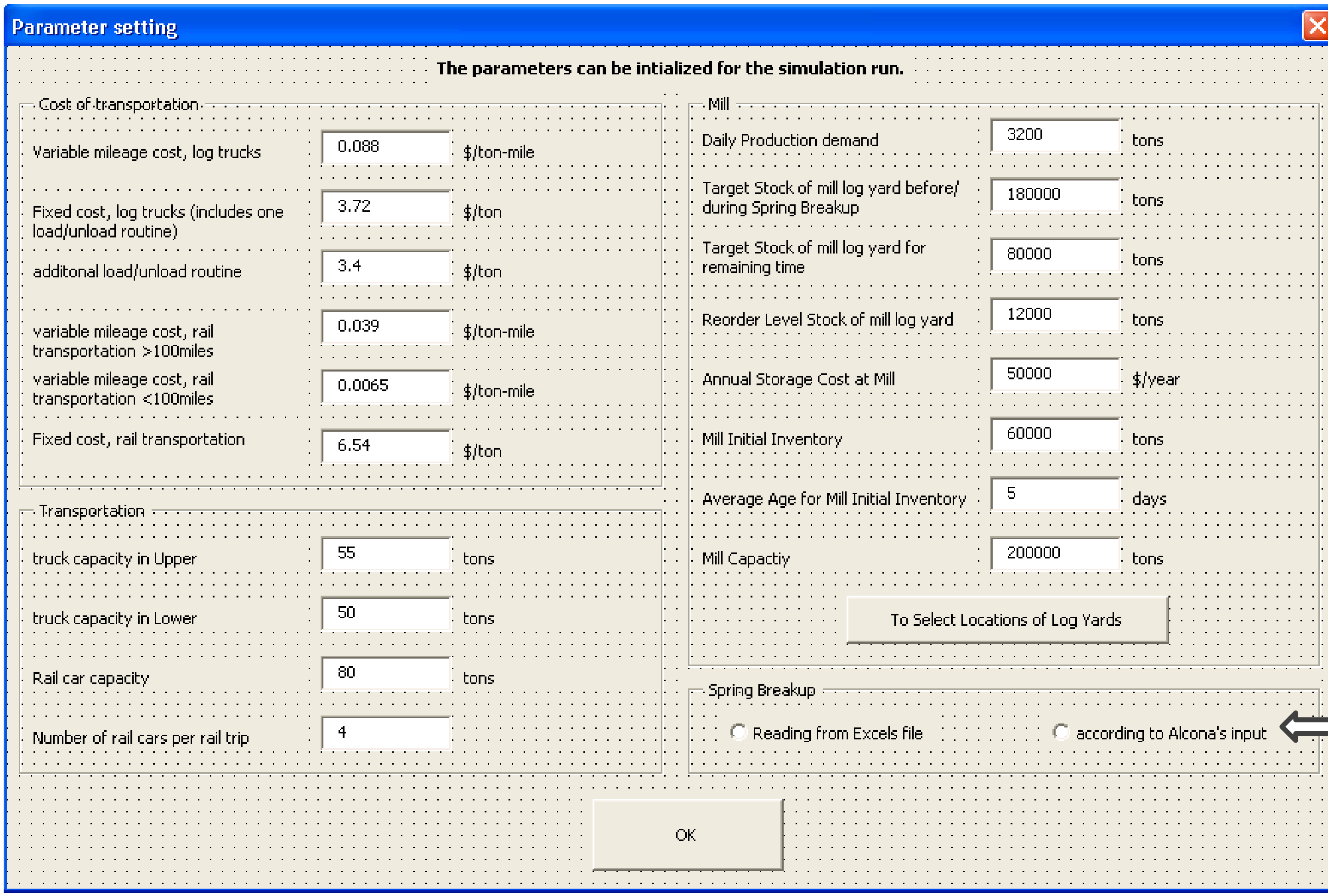
Overview of the Simulation Model

- 43 harvest areas based on the intersection of 29 counties and 30-mile-radius haul zones and 3 harvest areas farther than 150 miles;
  - Simulates daily supply chain operations for a 1-year duration;
- Simulation is driven by the daily demand of the facility (“pull”) and a specified harvest plan (“push”).
  - The facility requests logs from log yards or roadside storage;
  - All harvested logs assumed to “pass through” roadside storage;
- Transporters (trucks/railcars) are dispatched according to daily feedstock demand;
  - Three types of transporters: rail, truck in U.P., and truck in L.P.;

Inputs to the Simulation Model

- Model inputs include:
  - Transportation and harvesting plans
  - Transportation and storage costs
  - Mill/log yards capacity data
  - Emissions and energy consumption rates
  - Spring breakup start day and end day
    - Either read in from Excel file or simulated by the model based on the user-specified distributions of start day and end day;
- Input data are either in an Excel file or in a data entry window that appears before the model runs.

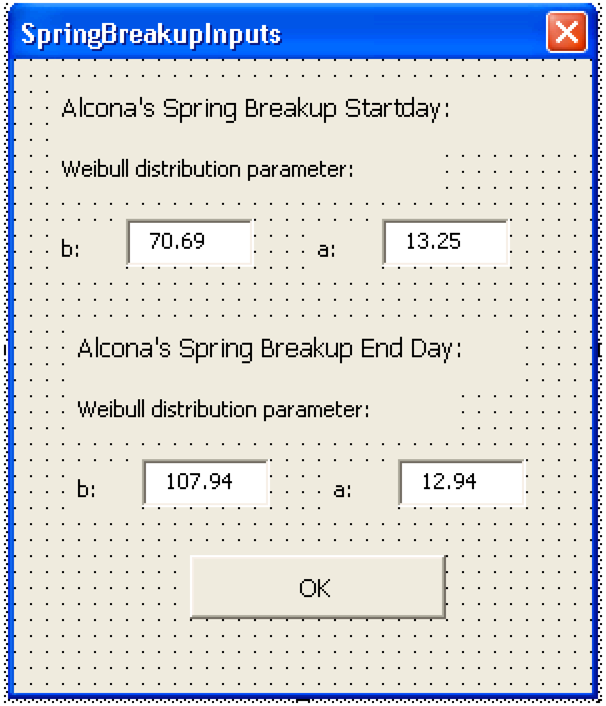
Input: Data Entry Window



Two ways to input spring breakup data

Input: Data Entry Window

If the second option is chosen, another box opens:



If no option is chosen, a warning shows up. The default option is reading data from the Excel file:

Input: Excel Spreadsheet

Harvesting Plan

From optimization model

Logs production (50 tons /week)	Harvest Area #1 Alcona 150	#2 Alger 120	#3 Alger 150	#4 Alger 90	#5 Alpena 120	#6 Alpena 150	#7 Antrim 120	#8 Benzie 150	#9 Charlevoix 90	#10 Cheboygan 90	#11 Chippewa 30	#12 Chippewa 60	#13 Crawford 120	#14 Crawford 150	#15 Delta 120
Week 1	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3
Week 2	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3
Week 3	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3
Week 4	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3
Week 5	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3
Week 6	26.4	31.1	11.3	10.5	8.0	4.1	20.7	9.8	17.6	23.8	30.4	18.3	5.4	6.4	21.3

Transportation Plan

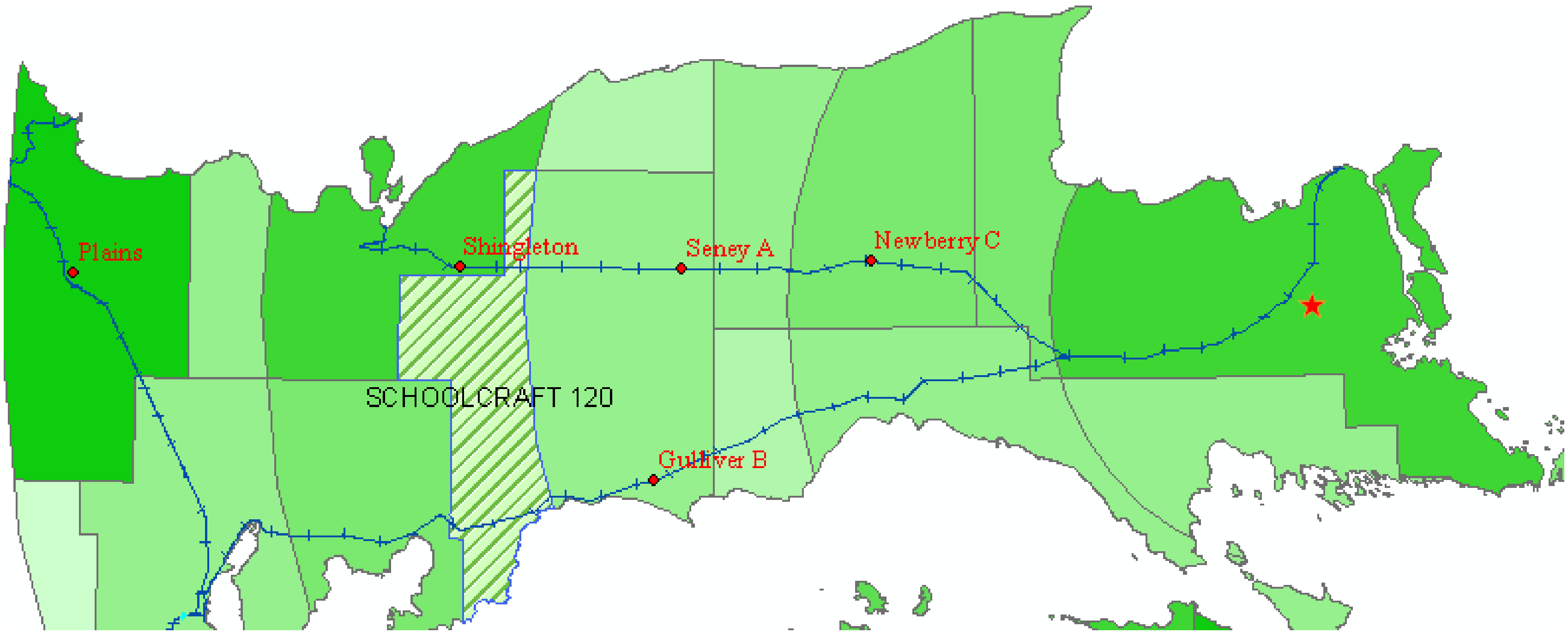
Regular transportation plan	LP #1	UP #2	UP #3	UP #4	LP #5	LP #6	LP #7	LP #8
Week 1	3	4	3	4	2	2	3	3
Week 2	3	4	3	4	2	2	3	3
Week 3	3	4	3	4	2	2	3	3
Week 4	3	4	3	4	2	2	3	3
Week 5	3	4	3	4	2	2	3	3
Week 6	3	4	3	4	2	2	3	3
Week 7	3	4	3	4	2	2	3	3
Week 8	3	4	3	4	2	2	3	3
Week 9	3	4	3	4	2	2	3	3

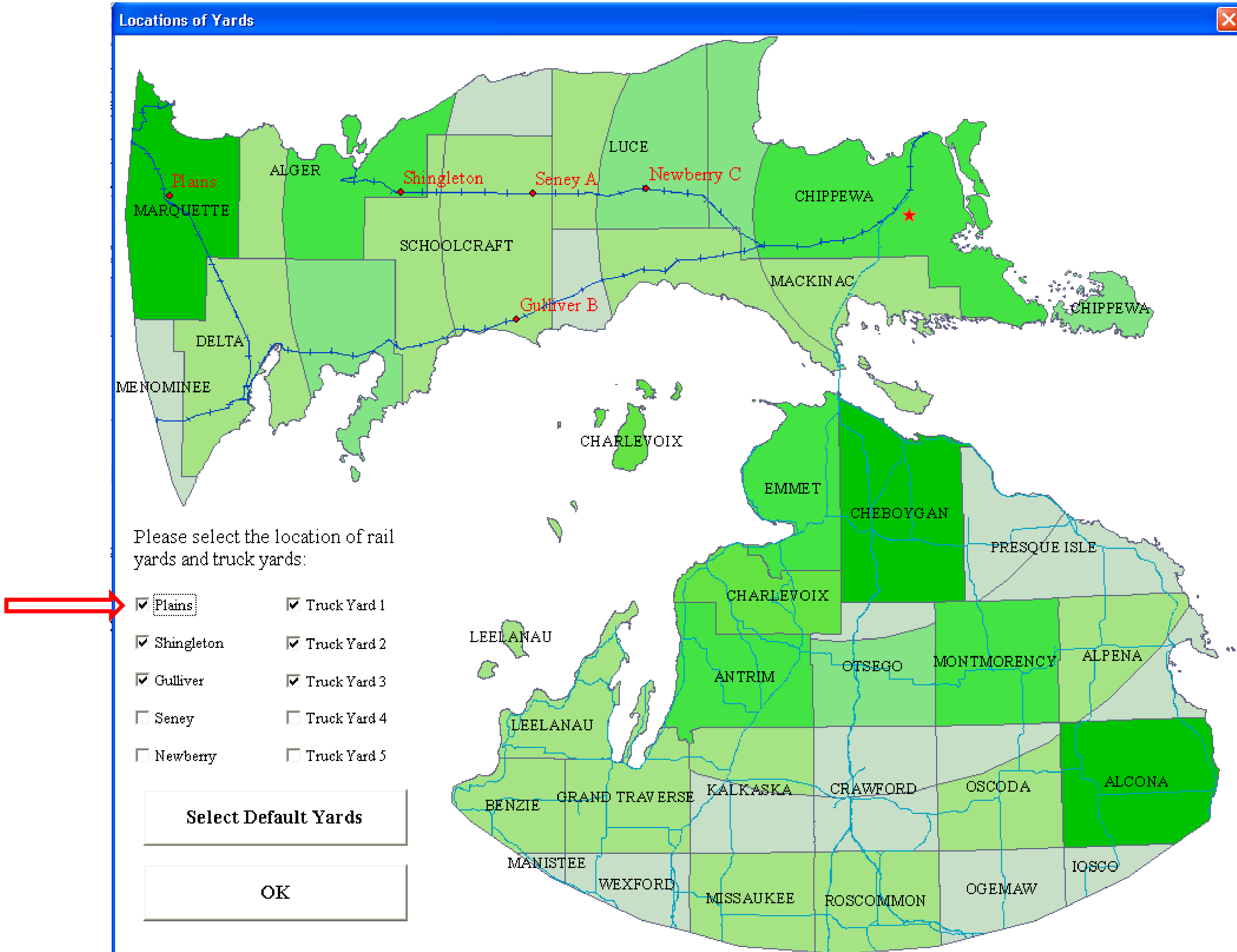
Spring Breakup

	Harvesting Area	Daily Logs Production in Spring Break-up (50 tons/week)	1 Historic Start Date
1	**Alcona 150**	2.1	68
2	**Alger 120**	2.5	76
3	**Alger 150**	0.9	76
4	**Alger 90**	0.8	76
5	**Alpena 120**	0.6	68
6	**Alpena 150**	0.3	68
7	**Antrim 120**	1.7	68

Harvesting, transportation, and storage costs
Transportation (network) distances
Roadside, log yards, and mill yard storage capacities
Initial, target, and reorder inventory levels
Energy use and emissions data

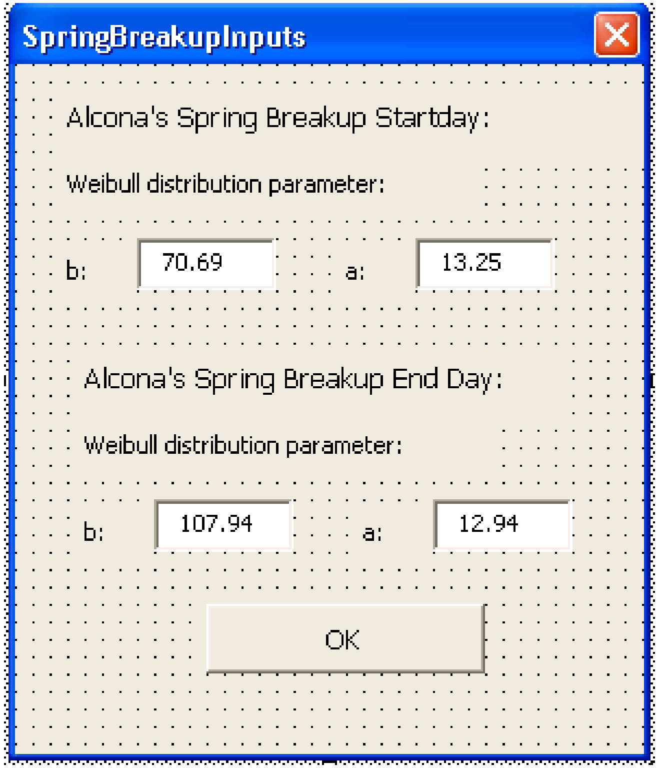
User Input: Select Log Yards




Locations of Yards
Plains
Shingleton
Seney A
Newberry C
Gulliver B
MARQUETTE
ALGER
SCHOOLCRAFT
LUCE
CHIPPEWA
MACKINAC
CHIPPEWA
DELTA
MENOMINEE
CHARLEVOIX
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
LEELANAU
ANTRIM
OTSEGO
MONTMORENCY
ALPENA
LEELANAU
BENZIE
GRAND TRAVERSE
KALKASKA
CRAWFORD
OSCODA
ALCONA
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
Please select the location of rail yards and truck yards:
Plains
Shingleton
Gulliver
Seney
Newberry
Truck Yard 1
Truck Yard 2
Truck Yard 3
Truck Yard 4
Truck Yard 5
Select Default Yards
OK

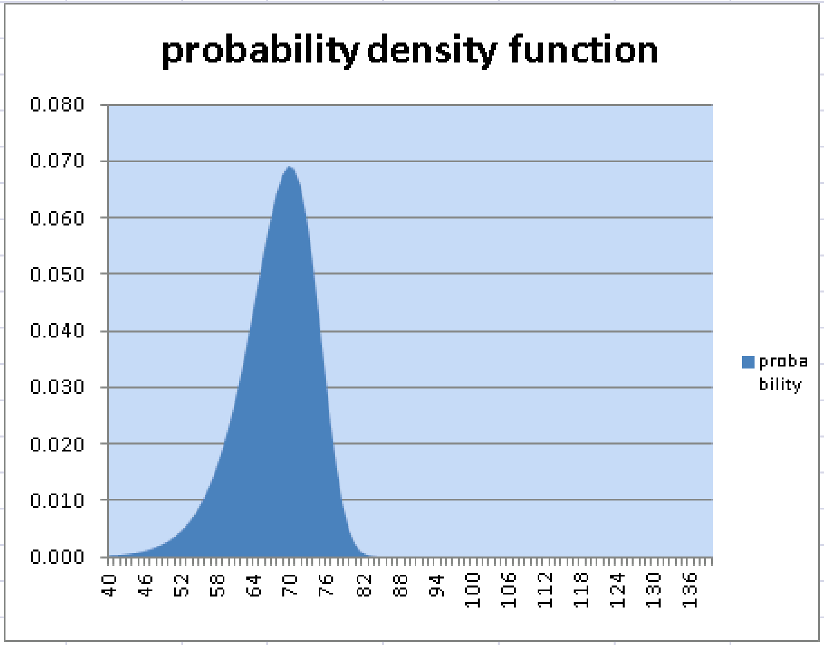
User Input: Spring Break-up Parameters

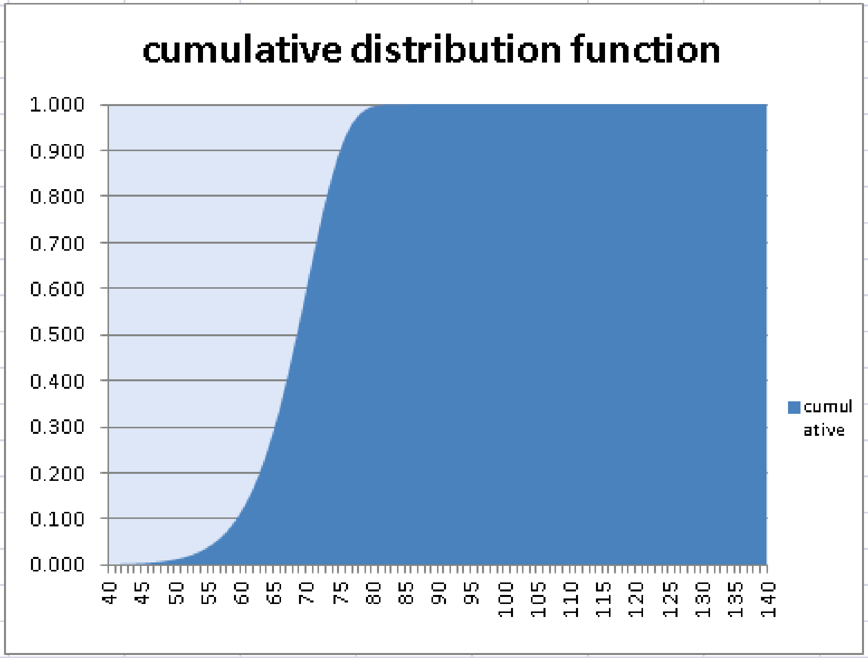
- The distribution for start day and end day of spring breakup in Alcona County;



Weibull Distribution

Probability Density Function and Cumulative Distribution Function





13.256	a	shape parameter
70.69	b	scale parameter

County	Year	End day	Start Day
Alcona	2010	98	62
	2009	118	68
	2008	120	77
	2007	116	71
	2006	108	68
	2005	110	73
	2004	111	61
	2003	119	74
	2002	115	52
	2001	114	67

The parameters a=13.256, b=70.6925 for start day and a=12.94, b=107.94 for end day in Alcona are developed based on historical data by Matlab.

Simulation Model Outputs

- Model outputs include, but are not limited to:

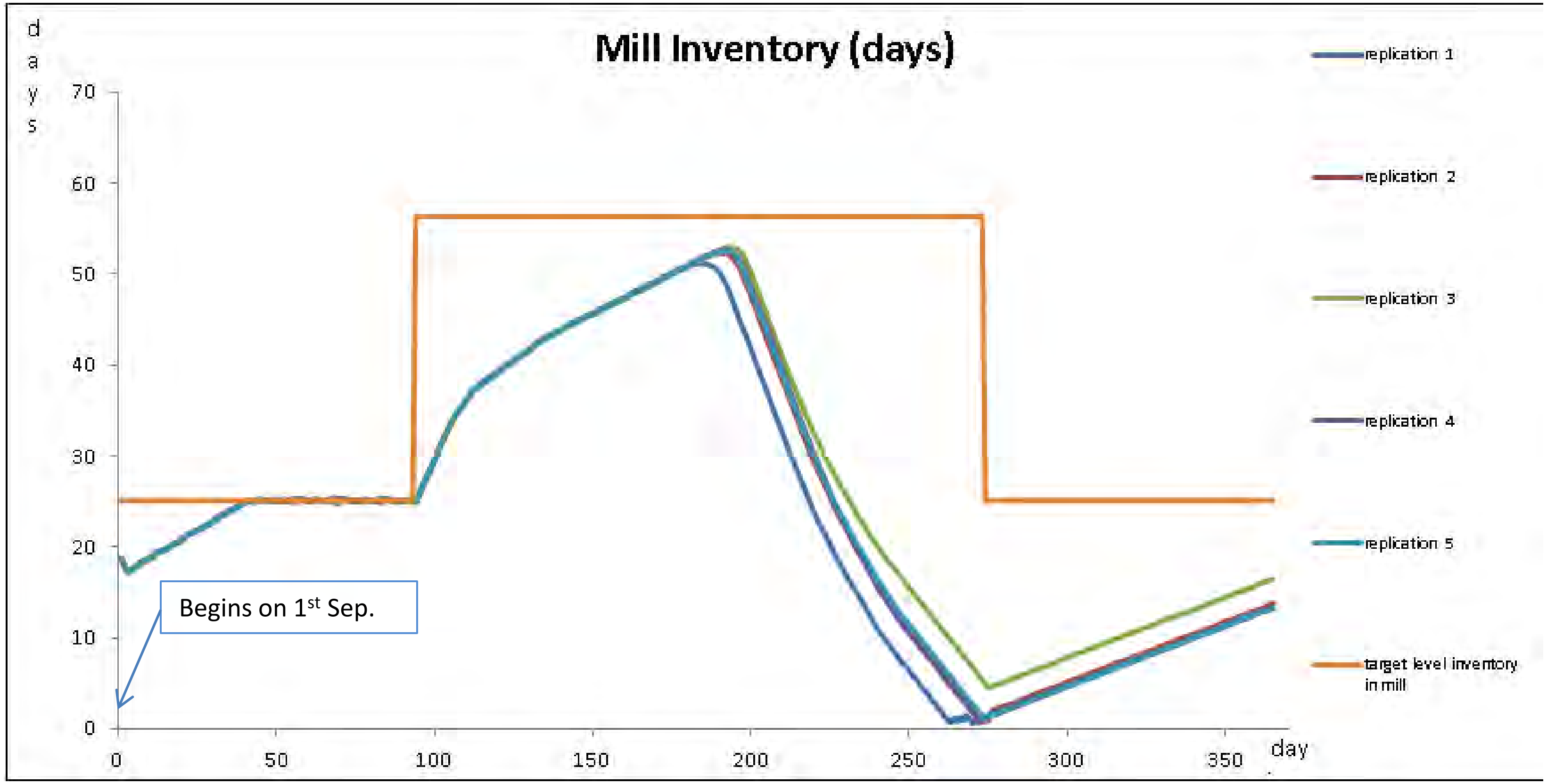
  - Daily inventory of the facility yard, roadside storage areas, and log yards.

  - Time series and total annual system cost, fuel usage, and emissions.

  - Transportation statistics.

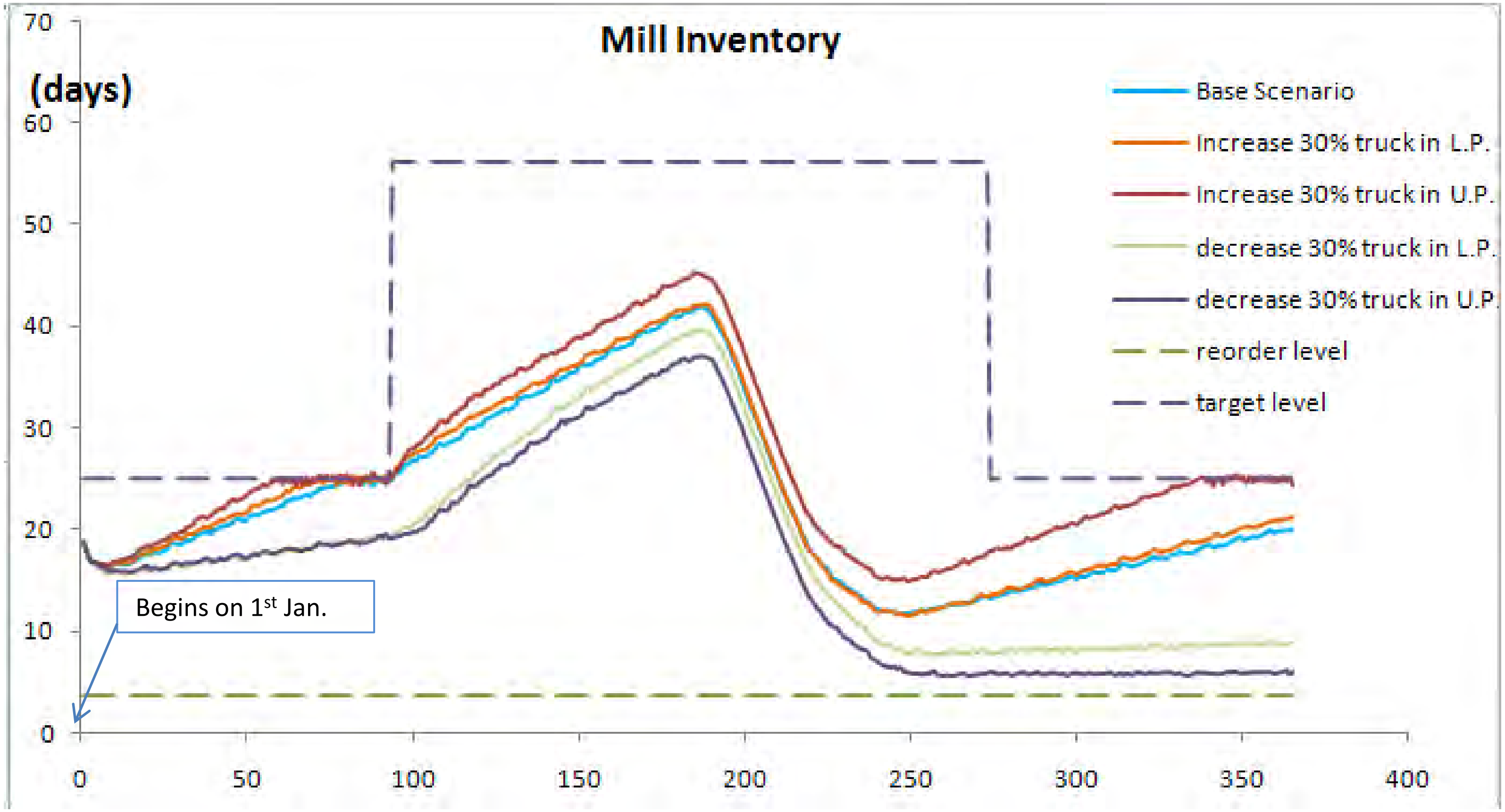
  - Record of average and maximum log ages processed at the facility.

Example Output Time Series



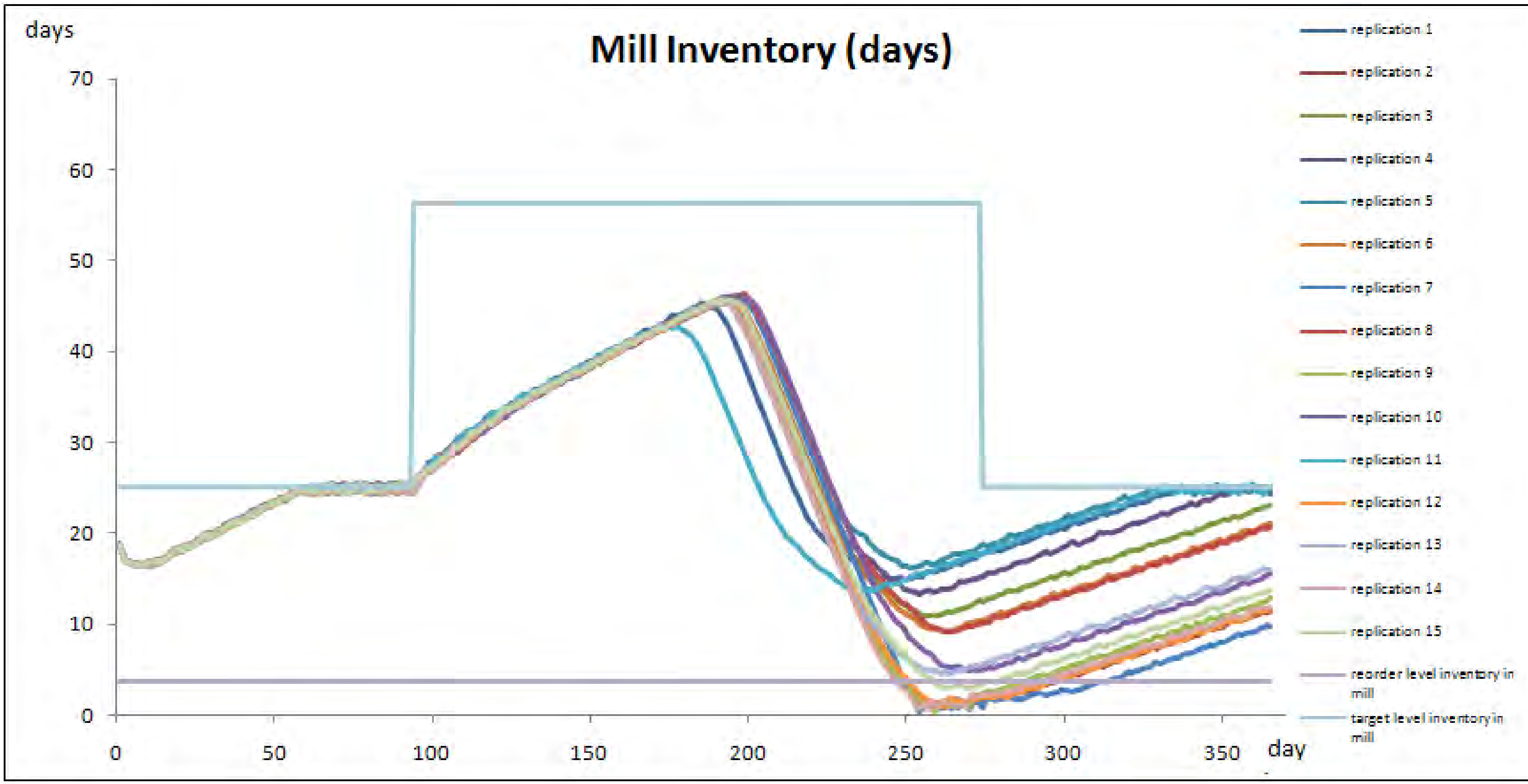
Inventory at the facility/mill (in days of supply) vs. Julian day for the baseline transportation plan under five scenarios of weather/spring break-up.

Scenario Analysis: Truck Availability



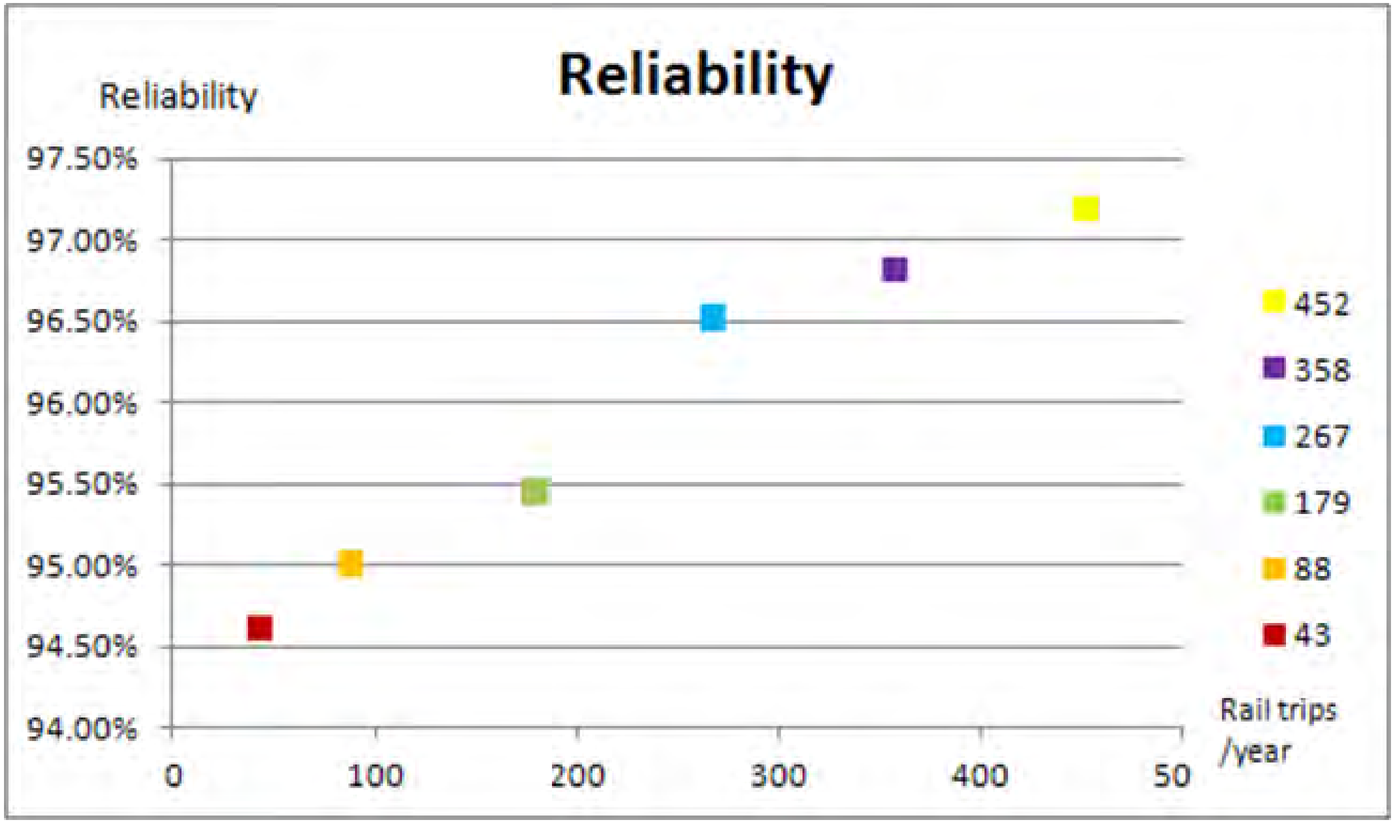
Inventory at the facility/mill (in days of supply) vs. Julian day for the baseline transportation plan under scenarios of truck availability.

Scenario Analysis: Spring Break-up Timing



Inventory at the facility/mill (in days) vs. Julian day for the baseline transportation plan under 15 spring break-up scenarios.

Trade-off Analysis: Reliability and Rail Use



Rail use vs. reliability of supply at the facility/mill. Assumes each rail trip has 4 railcars with 80 tons capacity per car,