
EWITS Research Report Number 18

by

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EWITS Research Reports: 
Background and Purpose

This is the eighteenth in a series of reports prepared from the Eastern Washington Intermodal Transportation Study (EWITS). The reports prepared as part of this study provide information to help shape the multimodal network necessary for the efficient movement of both freight and people into the next century.

EWITS is a six-year study funded jointly by the Federal government and the Washington State Department of Transportation as a part of the Intermodal Surface Transportation Efficiency Act of 1991. Dr. Ken Casavant of Washington State University is Director of the study. A state-level Steering Committee provides overall direction pertaining to the design and implementation of the project. The Steering Committee includes Jerry Lenzi, Regional Administrator (WSDOT, Eastern Region); Richard Larson (WSDOT, South Central Region); Don Senn (WSDOT, North Central Region); Charles Howard (WSDOT, Planning Manager), and Jay Weber (Douglas County Commissioner). Pat Patterson represents the Washington State Transportation Commission on the Steering Committee. An Advisory Committee with representation from a broad range of transportation interest groups also provides guidance to the study. The following are key goals and objectives for the Eastern Washington Intermodal Transportation Study:

- Facilitate existing regional and state-wide transportation planning efforts.
- Forecast future freight and passenger transportation service needs for eastern Washington.
- Identify gaps in eastern Washington’s current transportation infrastructure.
- Pinpoint transportation system improvement options critical to economic competitiveness and mobility within eastern Washington.

For additional information about the Eastern Washington Intermodal Transportation Study or this research report, please contact Ken Casavant at the following address:

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# Table of Contents

Introduction ........................................................................................................................................... 1

Objective and Approach ......................................................................................................................... 2

Information Sources ............................................................................................................................... 3

Optimization/Modeling Procedure ......................................................................................................... 5

Results .................................................................................................................................................. 12

Disaggregated Wheat Highway Flows ..................................................................................................... 15

Conclusions ........................................................................................................................................... 16

References .............................................................................................................................................. 29

Appendix A: Arc Macro Language (AML) Program Description ......................................................... 30

Appendix B: GAMS Model Description ................................................................................................. 42
| Figure 1 | Eastern Washington Study Area .......................................................... 3 |
| Figure 2 | Data and Information Sources ............................................................... 4 |
| Figure 3 | Columbia/Snake River, Elevators, Feedlots, River Ports and Active Rail Lines in Eastern Washington ................................................. 6 |
| Figure 4 | Eastern Washington Roads, Highways and Interstates ........................ 7 |
| Figure 5 | Eastern Washington Wheat Production Per Acre, by Township/Range ...... 8 |
| Figure 6 | Eastern Washington Barley Production Per Acre, by Township/Range ...... 9 |
| Figure 7 | Optimization Methodology Using GIS and External Optimization Program, GAMS ................................................................. 10 |
| Figure 8 | Optimized Wheat Flows on Eastern Washington Highways (Base Scenario) .............................................................................. 17 |
| Figure 9 | Optimized Wheat Flows on Eastern Washington Highways (No-Barge Scenario) ................................................................. 18 |
| Figure 10 | Optimized Barley Flows on Eastern Washington Highways (Base Scenario) ........................................................................... 19 |
| Figure 11 | Optimized Barley Flows on Eastern Washington Highways (No-Barge Scenario) ..................................................................... 20 |
| Figure 12 | Optimized Wheat Highway Flows (Farm to Elevators Without Rail, Base Scenario) ................................................................. 21 |
| Figure 13 | Optimized Wheat Highway Flows (Farm to Elevators Without Rail, No Barge Scenario) ................................................................. 22 |
| Figure 14 | Optimized Wheat Highway Flows (Farm to Elevators With Rail, Base Scenario) ................................................................. 23 |
| Figure 15 | Optimized Wheat Highway Flows (Farm to Elevators With Rail, No-Barge Scenario) ................................................................. 24 |
| Figure 16 | Optimized Wheat Highway Flows (Farm to River Ports, Base Scenario) ... 25 |
| Figure 17 | Optimized Wheat Highway Flows (Farm to River Ports, No-Barge Scenario) .............................................................................. 26 |
| Figure 18 | Optimized Wheat Highway Flows (Elevator to Elevator and Elevator to River Ports, Base Scenario) ..................................................... 27 |
| Figure 19 | Optimized Wheat Highway Flows (Elevator to Elevator and Elevator to River Ports, No-Barge Scenario) ..................................................... 28 |
List of Tables

Table 1  Wheat Flow Modal Distribution (bushels)................................................... 12
Table 2  Wheat Transportation Costs ................................................................. 12
Table 3  Wheat Transportation Costs by Origin-Destination Shipment Type .......... 13
Table 4  Barley Flow Modal Distribution............................................................... 14
Table 5  Barley Transportation Costs .................................................................. 14
Table 6  Barley Transportation Costs by Origin-Destination Shipment Type ........... 14
Table A1 Node Type Descriptions......................................................................... 30
Table A2 Origin and Destination File Descriptions ............................................ 30
Table A3 Number of Closest Node Pairs Selected for Each O-D Type ................. 31
Table B1 Description of Input Sets Used in the GAMS Model............................... 42
Table B2 Parameter Description for GAMS Model.............................................. 43
Introduction

A myriad of policy debates involving transportation infrastructure, production agriculture, environmentalism, business and trade, and economic welfare are currently underway in the Pacific Northwest. Among these debates are several of specific interests to residents of Eastern Washington where intense wheat and barley production comprise the predominant land use. In addition to heavy concentration of land allocated to production activities, significant economic activity and transportation demands are generated from the production, harvesting and marketing of tremendous grain volumes. These immediate and far reaching ties to residents of Eastern Washington, therefore, create sizeable impacts when external or political stimuli alter the manner of grain production, harvesting, and especially, marketing.

Recent national rail mergers and consolidations have targeted several low density rail lines in Eastern Washington for abandonment or sale to shortline operators, creating shipping concerns for producers who rely upon rail transport, highway degradation fears for state transportation officials and highway users, air and noise pollution worries for environmentalists, and traffic safety issues for commuters and passenger vehicle operators.

Perhaps less problematic, but significant nonetheless, is the seasonal occurrence of grain rail car shortages. The problem arises from the seasonality associated with grain production, harvest and transport. Favorable marketing conditions from September through February encourage producers to ship the majority of grain during these time periods, with considerably less grain movement the remaining six months. Consequently, the quantity of rail cars demanded is considerably larger during this time period.

Rail companies, however, invest in equipment (grain cars) with the anticipation of receiving a favorable return on investment, which is difficult if the rail car is not used throughout the year. Thus, to maintain a consistent return on investment, railroad companies attempt to purchase and allocate grain cars on a monthly basis, supplying a base number of rail cars throughout the year rather than supplying cars to meet peak demand. Unfortunately, the demand for grain cars is not evenly distributed throughout the year and a sub-optimal transportation system results as grain is diverted to other, often more costly, modes.

Environmental choices also impact grain flows, illustrated by recent attempts to save certain species of salmon from extinction. Regional residents involved with, and affected by, salmon recovery efforts in the Northwest realize the complexities involved with debating the competing interests between fish and man. History has favored man, especially in the Pacific Northwest, where the lock and dam system on the Columbia and Snake rivers has generated an abundance of cheap electricity for businesses and consumers, plentiful water for irrigation in the agricultural sector and cheap, easy access to ocean ports via river barge navigation from Lewiston, Idaho to the ocean.
Certain salmon stocks have continued to decrease, to the point where four Snake River Chinook and sockeye species are listed for protection under the federal Endangered Species Act. Since 1980, the Pacific Northwest has spent more than $3 billion trying to save the native fish from extinction, resulting in a multitude of strategies designed to improve salmon survival.

One strategy, known as a "river drawdown," involves lowering the water level, thereby increasing river flow and riverine habitat and hopefully, the salmon's odds of survival. Unfortunately, barge traffic would probably cease during drawdown periods, causing potentially adverse impacts on grain farmers, who rely heavily on barge transportation, and on state and local highways as previously river bound commodities take to the highways.

Paramount with each of these policy debates is weighing the positive and negative impacts for different constituents and having access to accurate, relevant information. This endeavor works toward that end by constructing a tool that provides information regarding grain producer and transportation infrastructure impacts, for these and other policy discussions. The tool is a transportation optimization model for commodity flows and blends a Geographic Information System (GIS) with a Generalized Algebraic Modeling System (GAMS) optimization package. After describing the model specification and optimization procedure, the model is applied to the river drawdown debate mentioned above.

**Objective and Approach**

This study's purpose is to empirically investigate shipper and transportation infrastructure usage for current Eastern Washington grain flows, and then in the presence of a Snake River drawdown. Changes in transportation flows and shipping cost in the 20 county grain production region of Eastern Washington (see Figure 1) are determined and graphically illustrated. A transportation optimization model, implemented through a Geographical Information System (GIS) incorporating grain movements originating from 695 township centers and passing through over 400 grain elevators en route to final destinations, is descriptively and analytically developed. Impacts on producer's (private) cost of transportation are estimated and transportation flow changes on roads and highways are also presented. Shifts in modal reliance are also provided. Descriptions of the data acquisition and modification procedures are first presented, followed by the transportation optimization model description. The appendices contain detailed technical information about the Arc Macro Language (AML) and GAMS optimization programs, in addition to the program code.
Information Sources

The transportation and marketing system being modeled involves grain movements from production areas in eastern Washington to feedlots and ocean ports for processing, consumption and export. Intermediate destinations, such as elevators and river ports, serve as short (and long) term storage facilities, transfer stations and points of consolidation. Hence, information each component of the system was needed on a common platform to facilitate investigation and analysis. The one common element for each component of the system being modeled is geography. The production areas, elevators, river ports, ocean ports and transportation infrastructure (roads, highways, rail lines, barges) are all connected through geography, creating an ideal environment for a Geographical Information Systems approach.

Figure 1: Eastern Washington Study Area

The GIS coverage’s were constructed primarily from four sources, as illustrated in Figure 2. The Washington State Department of Transportation (WSDOT) provided GIS coverage’s for most county, state, U.S., and Interstate highways, in addition to active rail lines and navigable waterways (see Figure 3). However, these files weren’t entirely complete; missing road names and lower density county roads were added from. U.S. Bureau of Census Topologically Integrated Geographic Encoding and Referencing (TIGER) files. WSDOT and TIGER file coverage’s were merged and edited to remove any coinciding arcs or needless road coverage’s, resulting in a complete and non-duplicative coverage of the road and highway transportation network (Figure 4). The WSDOT no longer differentiates between U.S. and state highways, since both are maintained by the state. However, they are presented separately here, corresponding to the TIGER file classifications.
Additional information relating to the grain production areas and intermediate destinations (elevators and river ports) was obtained from the Agricultural Soil and Conservation Service (ASCS) and from an elevator survey sent to each of the 400 plus grain elevators in the study area. Detailed data concerning on-farm storage locations and capacities, in addition to acreage and production estimates within each township, were obtained from the ASCS, county assessors, and on site visual inspection (see Figures 5 and 6). Elevator locations, capacities, handling and storage rates, and modal usage were acquired from the survey sent to all elevators in the study area. Over 90% of the surveyed elevators (96% of volume) returned completed questionnaires, providing valuable information on grain movements from production locations to final destinations and the modes utilized in the process. Transport rates for truck shipments were also obtained from the elevator survey. Rail rates were collected from Burlington Northern and Union Pacific, the two class I railroad companies operating in the region, and barge rates were obtained from barge companies operating on the river.

Figure 2: Data and Information Sources
Optimization/Modeling Procedure

Several GIS software packages designed for transportation modeling and analysis do provide some limited internal optimization features. However, the approach implemented in this analysis utilizes, for flexibility and robustness, an optimization package, which is external to the GIS software. The process being modeled consists of two products (wheat and barley), utilizing multiple modal options and passing through multiple intermediate destinations along several route options, to different final destinations. The complexity associated with this transportation system necessitates a modeling procedure with tremendous flexibility at each phase of the transport process. Therefore, the optimization software used to allocate grain shipments on various modes and routes is called GAMS, an acronym for Generalized Algebraic Modeling System, and is external to the GIS software, ArcInfo.

The method used to combine the GIS with the minimum cost transportation model is presented in Figure 7. Arc Info is used to generate a collection of minimum distance node combination tables from township centers to elevators, township centers to ports, elevators to elevators, and elevators to river ports (see AML description in Appendix A). These distance tables are then exported to an intermediate program, such as Quattro Pro and Fox Pro, to generate cost coefficients, which are used as an input file in the GAMS optimization model. At each phase of the transportation process, multiple shipment alternatives are incorporated into the optimization model to provide maximum flexibility. Hence, should an optimization run, examining an alternative policy, preclude use of one route, the model still has several routing alternatives from which to choose. Once the set of minimum distance routes are compiled in ArcInfo, and associated cost components incorporated in Quattro Pro, the GAMS optimization software is used to determine the least cost set of shipping routes (see GAMS description in Appendix B).

Truck transportation cost coefficients were calculated by estimating a regression equation from elevator survey responses concerning truck transport cost per bushel/mile. A separate equation for wheat (Equation 1) and barley (Equation 2) was estimated. Both equations have the same form where cost per bushel/mile decreases as distance increased initially, but then reaches a point where costs bottom out and then increases with subsequent increases in distance. This reflects the fixed cost of owning a truck and how that amount decreases per bushel/mile as it's spread across more miles. But as distance increases, truck operating expenses increases, causing truck transportation costs per bushel/mile to increase as well.

\[
\text{Wheat Truck Cost Per Bushel Mile} = .036018 + (.001911 \times \text{miles}) + (.1518661 \times \text{miles}) \quad \text{Equation (1)}
\]

\[
\text{Barley Truck Cost Per Bushel Mile} = .026728 + (.001853 \times \text{miles}) + (.1190261 \times \text{miles}) \quad \text{Equation (2)}
\]
Figure 3: Columbia/Snake River, Elevators, Feedlots, River Ports and Active Rail Lines in Eastern Washington
Figure 4: Eastern Washington Roads, Highways and Interstates
Figure 6: Eastern Washington Barley Production Per Acre, by Township/Range
The GAMS model is a linear programming model where the objective is to ship known quantities of grain from production points (township centers) to predefined destinations, while minimizing total transportation cost. The volume of grain supply (and demand) at each township (and final destination) is known. However, the volume of shipments on given routes and modes to reach the final destination is not known. The complexity increases with the introduction of intermediate destinations (elevators and river ports). The movement from production areas is predominately confined to truck shipments, which generally haul directly to river ports for barge transport or to elevators. Once the grain reaches the elevator, several possibilities exist for where and how it may move. If the elevator has rail access, the grain may be loaded onto rail for shipment to final destinations. If the elevator doesn’t have rail access, then grain may be transhipped to another elevator with rail access or trucked to a river port for barge transport. The GAMS optimization model incorporates each of these modal shipment and route options at each stage of the grain marketing process, with the decision criteria at each juncture being cost minimization.

The optimization model also includes a variety of constraints, which are constructed to maintain realism in the modeling process. A theoretical optimization system would identify the origin points and the quantities to be shipped, the collection of possible routes on various modes, the cost associated with each route option, and the final destinations, and then allow the linear program to solve for the least cost optimal solution. However, there are capacity constraints at the intermediate destinations which fin-tit the amount of grain, which can be handled at each location. There are also capacity constraints associated with usage of certain modes of transport, particularly for rail shipments. Therefore, to insure that these capacities and others relating to the origins and destinations are not exceeded, the following constraints are included in the optimization model.
Supply Balance Equation

\[ \sum_{i=1}^{n} S_{ij} \leq S_j \quad \forall \ j \]  

Equation (3)

Where \( S \) is the \( i \)th grain shipment from townships and \( S \) is the available grain supply produced in townships. Thus, the supply balance equation prevents the total amount of shipments from any township from exceeding the available supply produced within that township.

Node Balance Equation

\[ \sum_{i=1}^{n} x_{ij} = \sum_{i=1}^{n} y_{ij} \quad \forall \ j \]  

Equation (4)

Here \( x_{ij} \) is the \( i \)th grain shipment into the \( j \)th intermediate location (river ports and elevators) and \( y_{ij} \) is the \( i \)th shipment leaving the \( j \)th intermediate location. Therefore, the total volume of grain flowing into intermediate locations must equal the amount flowing out of each location. This constraint abstracts from reality somewhat by preventing any grain storage. However, the analysis utilizes grain production and consumption volumes for the year and the majority of grain produced in a given year is usually marketed before the next harvest period.

Destination Balance Equation

\[ \sum_{i=1}^{n} d_{ij} \geq \sum_{i=1}^{n} D_j \quad \forall \ j \]  

Equation (5)

This constraint verifies that the sum of all shipments (\( d_{ij} \)) to the \( j \)th final destination is greater than or equal to the grain demanded at each final destination.

Elevator Capacity Equation

\[ \sum_{i=1}^{n} x_{ij} \leq C_j \quad \forall \ j \]  

Equation (6)

This constraint assures that elevator capacity is not exceeded at any individual elevator. Here \( x_{ij} \) is the \( i \)th shipment into the \( j \)th elevator and \( C \) is the grain capacity at elevators. Therefore, the sum of all shipments into a given elevator cannot exceed the capacity of the elevator.

Once the optimal shipping routes have been determined for the entire transport of grain from production locations to final destinations, truck shipments are assigned to individual highways for each segment throughout the transport chain. Traffic volumes
are then summed for each individual highway arc, since truck shipments starting at different origin points and traveling to different destinations may at times utilize common roads and highways. The truck traffic volumes on roads and highways can then be displayed geographically using either Arclnfo or Arcview. Identification of highway segments with heavy concentrations of truck traffic are then easily identified, in addition to illustrating changes in highway truck traffic flows from different policy scenarios.

Results

This portion of the research report presents results from the transportation optimization model concerning modal usage, highway grain flows, and transportation costs for wheat and barley shipments. Two different scenarios are provided including (1) a base scenario depicting current grain flows and (2) a no-barge scenario where barge traffic is eliminated above the Tri-Cities. The total volume of one years grain production (1 994) in this case study is modeled, assuming no extended grain storage.

The total volume of wheat shipped via different modes for the base and no-barge Scenarios is 132,836,124 bushels, as depicted in Table 1. Approximately 60 percent of this volume is shipped from production areas to elevators and the remaining 40 percent shipped directly to river ports via truck. This proportion is practically the same for both scenarios, indicating that sizeable amounts of grain would still be trucked directly from production locations to river ports at/or below the Tri-Cities in the absence of river navigation above the Tri-Cities. The largest change in modal usage for wheat shipment in the presence of a river drawdown would be the elevator to river port shipments, which would switch to rail. Elevator to river port shipments decrease 21 percent while elevator to Portland via rail shipments increase by roughly the same percentage. In terms of absolute change, 28.3 million bushels of wheat, would switch from barge to rail.

Total transportation costs for all wheat shipments are $65,901,176 and $67,205,885 for the Base and No-Barge Scenarios, respectively, as illustrated in Table 2. The $1.3 million increase in shipper transportation costs amounts to slightly less than 1 cent/bushel, illustrating very little change in region wide shipping charges. However, this represents somewhat of an "averaged" cost per bushel shipping charge indicating that certain shippers would be more adversely impacted than others.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Township to Elevator</th>
<th>Township to River Port</th>
<th>Elevator to Elevator</th>
<th>Elevator to River Port</th>
<th>Elevator to Portland</th>
<th>Barge to River Port</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>78,098,753</td>
<td>54,737,371</td>
<td>40,276</td>
<td>51,102,369</td>
<td>26,996,384</td>
<td>105,839,740</td>
<td>132,836,124</td>
</tr>
<tr>
<td>(Percent of Total)*</td>
<td>59%</td>
<td>41%</td>
<td>.03%</td>
<td>38%</td>
<td>20%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>No-Barge</td>
<td>78,288,953</td>
<td>54,547,171</td>
<td>595,817</td>
<td>22,921,729</td>
<td>55,367,224</td>
<td>77,468,900</td>
<td>132,836,124</td>
</tr>
<tr>
<td>(Percent of Total)</td>
<td>59%</td>
<td>41%</td>
<td>.4%</td>
<td>17%</td>
<td>42%</td>
<td>58%</td>
<td></td>
</tr>
<tr>
<td>Absolute Change</td>
<td>+190,200</td>
<td>-190,200</td>
<td>+555,541</td>
<td>-28,180,640</td>
<td>+28,370,840</td>
<td>-28,370,840</td>
<td></td>
</tr>
</tbody>
</table>

*Does not sum to 100% due to double counting

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total Transportation Cost ($)</th>
<th>Total Transportation Cost/bu. (cents/bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>65,901,176</td>
<td>49.61</td>
</tr>
<tr>
<td>No-Barge</td>
<td>67,205,885</td>
<td>50.59</td>
</tr>
</tbody>
</table>
Separating the total wheat transportation cost into the different origin-destination type components helps illuminate which shippers are most dramatically impacted without Snake River access, as illustrated in Table 3. Per bushel shipping cost increase slightly for farm to elevator shipments, illustrating the slightly longer distance shippers must travel to reach elevators with rail access. Farmers whose least cost-shipping alternative continues to be directly from farm to river ports experience the largest increase in transportation cost with more than a 6 cent increase. Elevator to elevator transportation costs increase 2 cents per bushel, as transhipments are forced to travel further to reach elevators with rail access. However, transportation costs for elevator to river port shipments decreases 2.7 cents per bushel, since those elevators which continue to ship to river ports (below the Tri-Cities) are the ones, which are relatively close to the Tri-Cities. Transportation costs for rail shipments from elevators to Portland also decrease slightly. This is likely due to a larger proportion of wheat being shipped to elevators with larger rail loading capacity, and therefore lowers rail rates. The 1.4-cent per bushel decrease in transportation cost for river port to Portland barge shipments are due to the shorter distances barges travel when the ports above the Tri-Cities are accessed.

<table>
<thead>
<tr>
<th>O-D Shipment Type</th>
<th>Base Transportation Cost (cents/bushel)</th>
<th>No-Barge Transportation Cost (cents/bushel)</th>
<th>Change (cents/bushel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm to Elevator</td>
<td>22.8</td>
<td>23.1</td>
<td>0.3 increase</td>
</tr>
<tr>
<td>Farm to River Port</td>
<td>14.1</td>
<td>20.3</td>
<td>6.2 increase</td>
</tr>
<tr>
<td>Elevator to Elevator</td>
<td>15.2</td>
<td>17.2</td>
<td>2.0 increase</td>
</tr>
<tr>
<td>Elevator to River Port</td>
<td>20.7</td>
<td>18.0</td>
<td>2.7 decrease</td>
</tr>
<tr>
<td>Elevator to Portland</td>
<td>33.7</td>
<td>33.3</td>
<td>0.4 decrease</td>
</tr>
<tr>
<td>River Port to Portland</td>
<td>19.5</td>
<td>18.1</td>
<td>1.4 decrease</td>
</tr>
</tbody>
</table>

Barley shipments are mostly divided between township to river port (62 percent) and township to feedlot (38 percent) shipments, as illustrated in Table 4. Of the 16,718,505 bushels produced, only 21,342 bushels are shipped to elevators under the base scenario. This amount increases slightly without barge access but truck-barge transport maintains the largest modal share. The volume of barley utilizing barge transport to Portland changes from 10,410,272 bushels to 10,404,866 bushels after a river drawdown. Transportation costs for barley shipments increases $1.14 million dollars, which translates to 6.8 cents per bushel (Table 5.).

Transportation costs for farm to elevator shipments also increases slightly for barley, once again highlighting the further distance trucks must traverse to reach elevators with rail access, as illustrated in Table 6. Farmers shipping directly to river ports experience the most dramatic increase in transportation cost with a 12.9-cent per bushel increase. The longer distance to the available river ports (Tri-Cities) is responsible for this increase in transportation cost. Transportation cost for farm to feedlots also increases (0.9 cents) as more grain is shipped directly from farms to feedlots, many of which are now longer distance from the feedlots than before Snake River access was diminished. Transportation cost for elevator rail shipments increase 8.1 cents per bushel, indicating that the least cost alternative for many barley shippers without access to Snake River ports is considerably higher rail transport.
Table 4--Barley Flow Modal Distribution (bushels)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Township to Elevator</th>
<th>Township to River Port</th>
<th>Elevator to Elevator</th>
<th>Elevator to River Port</th>
<th>Rail Elevator to Portland</th>
<th>Barge River Port to Portland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>21,342</td>
<td>10,410,272</td>
<td>6,286,891</td>
<td>17,165</td>
<td>4,177</td>
<td>10,410,272</td>
<td>16,718,505</td>
</tr>
<tr>
<td>(Percent of Total)*</td>
<td>.1%</td>
<td>62%</td>
<td>38%</td>
<td>.1%</td>
<td>.02%</td>
<td>62%</td>
<td>62%</td>
</tr>
<tr>
<td>No-Barge</td>
<td>22,109</td>
<td>10,404,866</td>
<td>6,291,530</td>
<td>12,526</td>
<td>9,583</td>
<td>10,404,866</td>
<td>16,718,505</td>
</tr>
<tr>
<td>(Percent of Total)</td>
<td>.0%</td>
<td>62%</td>
<td>38%</td>
<td>.07%</td>
<td>.05%</td>
<td>62%</td>
<td>62%</td>
</tr>
<tr>
<td>Absolute Change</td>
<td>+767</td>
<td>-5,406</td>
<td>+4,639</td>
<td>-4,639</td>
<td>+5,406</td>
<td>-5,406</td>
<td></td>
</tr>
</tbody>
</table>

*Does not sum to 100% due to double counting

Table 5--Barley Transportation Costs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total Transportation Cost ($)</th>
<th>Total Transportation Cost/bu. (cents/bu.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>4,733,499</td>
<td>28.31</td>
</tr>
<tr>
<td>No-Barge</td>
<td>5,874,353</td>
<td>35.13</td>
</tr>
</tbody>
</table>

Table 6--Barley Transportation Costs by Origin-Destination Shipment Type

<table>
<thead>
<tr>
<th>O-D Shipment Type</th>
<th>Base Transportation Cost (cents/bushel)</th>
<th>No-Barge Transportation Cost (cents/bushel)</th>
<th>Change (cents/bushel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm to Elevator</td>
<td>35.0</td>
<td>35.8</td>
<td>0.8 increase</td>
</tr>
<tr>
<td>Farm to River Port</td>
<td>13.8</td>
<td>26.7</td>
<td>12.9 increase</td>
</tr>
<tr>
<td>Farm to Feedlot</td>
<td>26.6</td>
<td>27.5</td>
<td>0.9 increase</td>
</tr>
<tr>
<td>Elevator to Feedlot</td>
<td>40.2</td>
<td>40.2</td>
<td>No change</td>
</tr>
<tr>
<td>Elevator to Portland</td>
<td>24.2</td>
<td>32.3</td>
<td>8.1 decrease</td>
</tr>
<tr>
<td>River Port to Portland</td>
<td>15.5</td>
<td>13.0</td>
<td>2.5 decrease</td>
</tr>
</tbody>
</table>

Base scenario flows for wheat shipments are concentrated on key roads and highways heading to river ports along the Snake/Columbia river (Figure 8). Wheat highway flows are substantially altered with a river drawdown as more truck shipments head for the Tri-Cities, as illustrated in Figure 9. These collector routes are easily identified with yellow and red flows. Without barge access above the Tri-Cities, wheat flows funnel into state route 395, the primary corridor into the Tri-Cities and the accessible river ports.

Barley highway flows under the Base scenario rely heavily on certain strategic routes to river ports, since 62 percent of the barley crop heads to Portland (Figure 10). Considerably fewer volumes are shipped to feedlots (mostly under 1,000,000 bushels). The 395 corridor to the Tri-Cities receives the primary increase in truck traffic for barley flows when barge access is not available (Figure 11).
Disaggregated Wheat Highway Flows

Wheat highway flows are further disaggregated for different phases of the wheat marketing process in the remaining Figures (Figures 12-19). Before (base) and after (no-barge) pictures are provided for 1) farm to elevators with rail, 2) farm to elevators without rail, 3) farm to river ports, and 4) elevator to elevator and elevator to river port shipments. Detailed identification of grain flow changes at the disaggregated level reveals patterns not evident for total highway flow changes. Comparing farm to elevators without rail shipments for the base (Figure 12) and no-barge (Figure 13) highlights a noticeable decline in grain flows (in terms of number of farms shipping to an elevator without rail). This seems like a reasonable expectation since elevators without rail loading facilities likely ship to river ports and without river port access, elevators with rail access would be the least cost alternative. Comparison of Figure 14 (farm to elevator with rail, base scenario) and Figure 15 (farm to elevator with rail, no-barge scenario) supports this claim. Several key elevators with rail loading facilities (those with large rail grain loading capacity) become collector points for rail shipments when barge transport ceases above Pasco.

Farm to river port grain highway flows also change substantially with fewer local and rural roads east of Pasco receiving much truck traffic, comparing the no-barge scenario (Figure 16) with the base (Figure 17). Without barge access, a few critical highways (US395, SR26, and SR17) become collector roads for grain truck traffic to Pasco. Elevator to river port grain movements follow this same pattern with considerably less truck traffic being concentrated on roads leading to river ports above Pasco (Figures 18 and 19).
Conclusions

The primary focus of this research study has been the development of a tool for evaluating impacts to different constituents regarding transportation infrastructure, production agricultural, economic and environmental policy issues currently confronting Eastern Washington residents. The transportation optimization model (tool) uniquely blends a Geographical Information System with an external GAMS optimization capability, resulting in a modeling approach that offers improved flexibility and robustness to commodity flow and transportation infrastructure analysis. Visual identification of traffic flow changes in addition to enhanced data detail capabilities through the use of a GIS provides an appealing argument for this type of modeling approach.

Applying this model to the Snake River drawdown issue provides timely information regarding impacts to producers (in terms of changes in transportation cost) and transportation planners (in terms of altered truck traffic flows). Total transportation cost for transporting wheat from production locations to final market increases $1.3 million without barge access above Pasco. However, when spread across the 132 million bushels produced in Eastern Washington, this amounts to about 1 cent/bushel. However, those farmers which ship directly from farm to river ports will experience a 6.2 cent/bushel increase in transportation cost. The transportation cost increase for barley is slightly less at $1.1 million without barge access above the Tri-Cities, but when calculated on a bushel basis amounts to a 6-cent/bushel increase. This is because there is considerably less barley produced in Eastern Washington when compared to wheat. Barley shippers, which continue to ship from farm to river ports, will experience a 12.9 cent/bushel increase in transportation cost. Truck traffic flows for both commodities no longer concentrate on several corridors to river ports as they do with the base scenario, but instead become concentrated on a few routes to Pasco, Washington.

Other policy issues can readily be addressed with this tool, including rail car shortages for grain shipments, road closures during selective time periods, rail line abandonment, and changes in truck (vehicle) size and weight configurations for commodity shipments.
Figure 8: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 9: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 10: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 11: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 12: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 13: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 14: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 15: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 16: Optimized Wheat Flows on Eastern Washington Highways
(Base Scenario)
Figure 17: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 18: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
Figure 19: Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)
References


The route generation process begins with a parent coverage (in this AML the parent coverage is bigcov) where the collection of all arcs and nodes are contained. An arc is a series of points that start and end with a node. A node is an intersection point where two or more arcs meet. Nodes are also classified into numeric categories based on common features or characteristics. This model is concerned with generating grain-shipping routes on highways between certain nodes of interest, which are provided in Table A1.

### Table A1--Node Type Descriptions

<table>
<thead>
<tr>
<th>Node Type</th>
<th>Geographic Description</th>
<th>Origin/Destination Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>On-farm grain storage location</td>
<td>Origin Point</td>
</tr>
<tr>
<td>3</td>
<td>Elevator without rail loading facilities</td>
<td>Intermediate Destination</td>
</tr>
<tr>
<td>4</td>
<td>Elevator with rail loading facilities</td>
<td>Intermediate Destination</td>
</tr>
<tr>
<td>5</td>
<td>River Port</td>
<td>Intermediate Destination</td>
</tr>
<tr>
<td>6</td>
<td>Feedlot</td>
<td>Final Destination</td>
</tr>
<tr>
<td>8</td>
<td>Township Center</td>
<td>Origin Point</td>
</tr>
</tbody>
</table>

Node types 2 and 8 are considered origin nodes in Table A1 but in the current model specification only node types 8 are used as origin shipping points. Future analysis may require using node type 2 instead of node type 8 (or some combination of the two) as origin points in the model. Also notice that the final destination "Portland" is not listed in the table. This is because Portland is accessed via river barge or rail and not truck shipment.

The model begins by first checking to see if important files, which are generated in the model, already exist and then deletes them. This is to prevent problems overwriting files should the program abort before completion. Then beginning on page 35, three origin files (stop1.stp, stop2.stp, and stop3.stp) and three destination files (cen1.cen, cen2.cen, and cen3.cen) are generated from the parent coverage (bigcov) node attribute table. These origin and destination files separate node attribute information to allow pairing of different origin and destination node combinations of interest. The node types contained in each .stp and .cen file are provided in Table A2.

### Table A2--Origin and Destination File Description

<table>
<thead>
<tr>
<th>Origin File</th>
<th>Node Type</th>
<th>Destination File</th>
<th>Node Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>stop1.stp</td>
<td>8</td>
<td>cen1.cen</td>
<td>3 and 4</td>
</tr>
<tr>
<td>stop2.stp</td>
<td>3</td>
<td>cen2.cen</td>
<td>4</td>
</tr>
<tr>
<td>stop3.stp</td>
<td>3, 4 and 8</td>
<td>cen3.cen</td>
<td>5 and 6</td>
</tr>
</tbody>
</table>

After these stop and cen files are created the netcover is specified for the parent coverage bigcov as maint. The netcover command simply specifies the line coverage containing the network and the output route system to which paths, tours and allocations are written. The impedance variable is time, which is used to identify which origin, and destination node pairs are selected. The stop and cen files in Table A2 are
then used to generate a distance file named disn.dat which contains all origin and destination node pair combinations generated by traveling from nodes in stopl.stp to those in cen1.cen, and likewise between stop2.stp and cen2.cen, and stop3.stp and cen3.cen. The nodedistance command first chooses each node in the stop files and then selects all nodes in the respective cen file which may be reached within a specified travel time (for 83 and 84 node pair combinations the specified travel time is 5 hours, 3 hours for 34 node pair combinations and 6 hours for 35, 36, 45, 46, 85, 86 node pair combinations). The networks of roads and highways have been assigned average travel speeds prior to execution of this command. Thus, the nodedistance command identifies (for example) for each node type 3, all node types 4 which may be reached within three hours of travel and writes these records to the disn.dat file.

Once the disn.dat file is created at the top of page 37, several items are added to the file and the file is sorted so that the shortest time origin-destination (O-D) node pairs appear first for each O-D type. Indices are then created for certain item in the disn.dat file and the cursor, "cur2", is defined so that the reselect command may be performed more quickly.

The disn.dat file contains many O-D node pairs, which are not needed. Therefore a new file (close.dist) is created, containing a subset of all records in disn.dat. Using the previously defined cursor, the closest O-D node pairs are selected for each O-D node pair type beginning on page 38 and continuing to page 40 of the AML. The number of node pairs selected for each O-D type (provided in Table A3.) was chosen to provide maximum route option flexibility in the subsequent transportation optimization model. As an example, O-D type 83 denotes township to elevator (without rail) shipments and for every township only the closest seven elevators are selected and the records (with travel time) written to the file close.dist.

<table>
<thead>
<tr>
<th>Origin – Destination Node Type Pair</th>
<th>Number of Closest Node Pairs Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>7</td>
</tr>
<tr>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>85</td>
<td>10</td>
</tr>
<tr>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>86</td>
<td>12</td>
</tr>
<tr>
<td>36</td>
<td>12</td>
</tr>
<tr>
<td>46</td>
<td>12</td>
</tr>
</tbody>
</table>

The close.dist file contains only the origin node type, the destination node type, and the travel time between the two nodes, assuming the shortest path is taken to reach the destination node. However, the actual route connecting the O-D nodes hasn't been specifically defined and the connecting arcs written to a file. Therefore, beginning at the top of page 40 of the AML the "PATH" command is used to determine the route between each O-D node pair and the collection of arcs traversed in the process. The records are then written to the route attribute table in the parent coverage (bigcov.ratmainrt) including the arc length (in miles). The final file, mainrt.dat, is created.
from the bigcov.ratmainrt file but first two additional files (orig.dat and dest.dat) must be created so that the items contained in each file may be joined with mainrt.dat.

The orig.dat and dest.dat files are created by first selecting certain items from the bigcov.nat file and writing the records to each respective file. Orig.dat contains node information about all origin nodes and dest.dat contains information about all destination nodes. The item names in both files are changed to names that are more descriptive and consistent across files and then these two files, in addition to close. dist, are joined with mainrt.dat with the use of the "JOINITEM" command.

As previously mentioned, the file mainrt.dat is created from the route attribute table bigcov.ratmainrt, with some added items and new names. Both files are a record of all routes and the length (in miles) of all combined arcs that comprise a given route. Mainrt.dat is then used to create the input sets in the GAMS transportation optimization model. Routes are divided into separate O-D node type pairings (83, 84, 85, 86, 34, 35, 36, 45, 46) and the distances are multiplied by per bushel/mile cost coefficients to determine the cost associated with traversing each route. Routes that end at an elevator or river port have storage and handling charges added to the cost of each route. These routes (and their associated cost) are the set of all potential routes from which the transportation model has to choose in determining the least cost optimal solution, given certain constraints on grain supply availability, elevator capacity, and quantity demanded at each final destination.

Once the transportation optimization model has allocated grain volumes to specific routes, some additional steps are necessary to link the grain flows to individual highway arcs. Grain volumes from the GAMS model output corresponds to routes that are referenced using unique origin and destination site names which are separated by a period (for example, TR653138.EL46E representing a township to elevator (83) route). However, instead of having a name to represent routes, numbers are assigned to specific routes in ArcInfo indicating that the GAMS output must be linked (via the O-D name) with the mainrt.dat file to query those routes from mainrt.dat with positive grain flows. This newly created file (named new.dat for illustration) contains all the information of mainrt.dat, in addition to grain flows for each route. This file is then joined with the section table bigcov.secmaintrt to add the grain flows for each route to the individual highway arcs comprising a route.

After the grain volumes are added to individual highway arcs, the "FREQUENCY" command is used to sum over all routes the grain volume utilizing each highway arc. In many situations, a given highway arc will be common to several routes. Hence, all grain shipments, which utilize an arc, must be summed to represent the total volume passing over that particular arc. The file that is generated (specified when executing the "FREQUENCY" command) with this procedure contains the aggregated grain flows on each arc. Joining this table with the arc attribute table bigcov.aat allows display of the, grain flows throughout the entire highway network.
This AML finds the closest nodes of types 3, 4, and 8 in the NAT to nodes of types 3 thru 6 in the network. An INFO file CLOSF,.DIST is generated with the node numbers and -IDs (A and B) along with the NETWORK DISTANCE between the two nodes. A final table mainrt.dat with the shortest routes (7, 6, 10, and 12 closest O-D pairs depending on the destination type). Route numbers, as well as origin and destination node information is also generated. Shortest paths are based on minimum time to traverse the arcs.

NOTE that the program assumes that the parent coverage is bigcov and that the item co# (a redefined version of the destination site-name has been defined in the NAT table.

It is also assumed that two relates to the NAT are established.

These are stored in INFO file noderel

if [exists bigcov.ratmainrt -info] &then
if [exists bigcov.secmainrt -info] &then
if [exists close.cen -info] &then
if [exists close.dist -info] &then
if [exists destname.dat -info] &then
if [exists cen1.cen -info] &then
if [exists cen2.cen -info] &then
if [exists cen3.cen -info] &then
if [exists cen4.cen -info] &then
if [exists stopl.stp -info] &then
if [exists stop2.stp -info] &then
if [exists stop3.stp -info] &then
&if [exists stop4.stp'-infol &then
&s del29 = [delete stop4.stp –info

&messages &off
tables
sel bigcov.nat
calc bigcov-id = bigcov#
qu stop
/* Create the base file from the NAT for use with the nodedistance command in ap
pullitems bigcov.nat cen1.cen
bigcov-id
ntype
end
/* Create stops and centers files for 3 options
/* Stops files are used for origins and centers files for the destinations
/*

/* stops file  ntypes  centers file  ntype  time limit */
/*
/* stopl.stp  8  cen1.cen  3,4  3 hrs
/* stop2.stp  3  cen2.cen  4  3 hrs
/* stop3.stp  3,4,8  cen3.cen  5,6  4 hrs
/*
/*
/* Assumes ntype entity
  2  on farm storage location
  3  elev
  4  elev with rail
  5  port
  6  feedlot
  8  township center

/*
tables
copy cen1cen stopl.stp
copy cen1cen stop2.stp
copy cen1cen stop3.stp
copy cen1cen cen2.cen
copy cen1cen cen3.cen
sel cen1cen
resel ntype = 3 or ntype  4
nsel
purge
y
sel cen2.cen
resel ntype = 4
nsel
purge
y
sel cen3.cen
resel ntype = 5 or ntype = 6
nsel
purge
y
sel stop1.stp
resel ntype = 8
nsel
purge
y
sel stop2.stp
resel ntype = 3
nsel
purge
y
sel stop3.stp
resel ntype = 3 or ntype = 4 or ntype = 8
nsel
purge
y
q stop
display 9999
ap
mape bigcov
clearselect
/* specify netcover for generation of node distance table netcover bigcov mainrt
impedance time

/* Selecting the origin nodes
reselect bigcov node ntype = 8 or ntype = 3 or ntype = 4
/* Save the selected node numbers
writeselect firstclass.sel
clearsel
/*
/**delete existing distance info files if they already exist..
&if [exists disn.dat -info] &then
&s dell [delete disn.dat -info]
/* calculate dist. table for option I
centers cen1.cen
stops stop1.stp
nodedistance stops centers disn.dat 5 network ids
/* calculate dist. table for option 2
centers cen2.cen
stops stop2.stp
nodedistance stops centers disn2.dat 3 network ids
/* calculate dist. table for option 3
centers cen3.cen
stops stop3.stp
nodedistance stops centers disn3.dat 6 network ids
&messages &on
/* join 4 distance tables together using arcedit
&data arc arcedit
edit disn.dat info
get disn2.dat
get disn3.dat
save disn.dat
y
y
y
q
&end
&messages &off
&data arc tables
/* Add items for origin ntype, dest. ntype, and combination
additem disn.dat ot 4 5 b
additem disn.dat dt 4 5 b
additem disn.dat odt 4 5 b
additem disn.dat oco# 2 2 c
additem disn.dat dco# 2 2 c
relate restore noderel
sel disn.dat
calc ot = orel//ntype
calc dt = drel//ntype
calc odt = 10 * ot + dt
move orel//co# to oco#
move drel//co# to dco#
/* Put table in correct order so that least time elev are in the table
/* first.
sort odt bigcov#a network
q stop
&end
/* Create indices on selected items so that reselect perform more quickly &data arc
/* open the nodes in the first class */
readselect firstclass.sel
&$ cnt [extract I [show select bigcov node]]
cursor cur2 declare disn.dat info
&$ t2 = [show &pt time]
&format 3
relate restore noderel
&do $ i = 1 &%cnt%
/*set the record numbers for the class1 nodes*/
&$ mnhl [show select bigcov node %i% item bigcov#]
 &$ ontype [show select bigcov node %i% item ntype]
 &$ oname = [show select bigcov node %i% item co#]
 &lv oname
clearsel bigcov node
/*find those node pair distances of interest*/
/* for dest type 3 */
/* If the od pair is type 33 (elev to elev) writes only for those*/
/* pairs within the same firm. Does not limit the write to only the /*3 closest for od pairs of this type. Other od pair types (i.e., 83) /* are written for the 3 closest pairs to a given origin node.*/
aselect disn.dat info
reselect disn.dat info bigcov#a = %mnhl%
reselect disn.dat info dt = 3
&if [value ontype] <> 3 &then
 &do
 /*find the 7 closest nodes and write to INFO file appended*/
 &$ num1 = [extract I [show select disn.dat info]]
 &$ num2 = [min 7 %num1 %]
cursor cur2 open
 &do k = 1 &to %num2%
 inf6file disn.dat info close.dist # append
cur cur2 next
 &end
 cursor cur2 close
 &end
/* For od type 33 pairs, write out all entries within a given firm &else &do*/
reset disn.dat info dco# co [quote %oname%]
&s num1 = [extract 1 [show select disn.dat info]]
&if %num1% ge 1 &then
infofile disn.dat info close.dist # append
&end

clearsel
/*find those node pair distances of interest
/* for dest type 4
aselect disn.dat info
reselect disn.dat info bigcov#a = %mnhl%
reselect disn.dat info dt = 4
/*find the 6 closest nodes and write to INFO file appended
&s num1 = [extract I [show select disn.dat info]]
&s num2 = [min 6 %num l%]
cursor cur2 open
&do k = I &to O/num2%
infofile disn.dat info close.dist # append
cur cur2 next
&end

cursor cur2 close

clearsel
/*find those node pair distances of interest
/* for dest type 5
aselect disn.dat info
reselect disn.dat info bigcov#a = %mnhl%
reselect disn.dat info dt = 5
/*find the 10 closest nodes and write to INFO file appended
&s num1 = [extract I [show select disn.dat info]]
&s num2 = [min 10 %num l%]
cursor cur2 open
&do k = I &to %num2%
infofile disn.dat info close.dist # append
cur cur2 next
&end

cursor cur2 close

clearsel
/*find those node pair distances of interest
/* for dest type 6
aselect disn.dat info
reselect disn.dat info bigcov#a = %mnhl%
reselect disn.dat info dt = 6
/*find the 12 closest nodes and write to INFO file appended
&s num1 = [extract I [show select disn.dat info]]
&s num2 = [min 12 %num l%]
cursor cur2 open
&do k = 1 &to %num2%
infofile disn.dat info close.dist # append
cur cur2 next
&end
cursor cur2 close
clearsel
readselect firstclass.sel
&end
/* end of big loop to create file close.dist
/* Time to generate the route system for those records in close.dist
&s t3 = [show &pt time]
clearsel
relate restore noderel
cursor curl declare close.dist ro
cursor curl open
&do &while %:cur1.AML$NEXT%
&s x = [VALUE :cur1.bigcov-ida]
&s y = [VALUE :cur1.bigcov-idb]
&s w = [VALUE :cur1.orel//ntype * 10 + [VALUE :cur1.drel//ntype] path %x% %y% end
%w%
cursor curl next
&end
cursor curl close
/* draw the resulting route system
/* routelines bigcov mainrt 6
/* &sv done [QUERY 'Hit return to continue' .FALSE.]
/* quit ap
q
/* Tack the arclength onto the RAT file
routestats bigcov mainrt
arclength
end
end
/* delete old files if they exist
&if [exists orig.dat -info] &then
&s del5 = [delete orig.dat -info]
&if [exists dest.dat -info] &then
&s del6 = [delete dest.dat -info]
&if [exists mainrt.dat -info] &then
&s del7 = [delete mainrt.dat -info]
/* Pull selected items from the NAT to create an orig and dest file to
/* tack onto the RAT file and create the file mainrt.dat

pullitems bigcov.nat orig.dat
bigcov#
nctype
site-name
county
crt
end
/* additem %rt%# to close.dist so can join to RAT

tables

copy orig.dat dest.dat
additem close.dist mainrt# 4 5 b
dropitem close.dist bigcov-ida bigcov-idb
sel close.dist
calc mainrt# = $recno
/* 143 reduce the orig.dat to only origin nodes and alter item names

sel orig.dat
resel nctype = 3 or nctype 4 or nctype 8
nsel
purge
y
alter bigcov#
bigcov#a,,,,
alter nctype
ontype,,,,
alter site_name
osn,,,,
alter county
ocounty,,,,
alter ctr
octr,,,,
/* reduce the dest.dat to only destination nodes and alter item names

sel dest.dat
resel nctype ge 3 and nctype le 6
nsel
purge
y
alter bigcov#
bigcov#b,,,,
alter nctype
dntype,,,,
alter site_name
dsn,,,,
alter county

dcounty, 
alter ctre

copy bigcov.ratmainrt mainrt-dat
q stop
/* 177 join close.dist to the copied RAT and then join
/* the origin and destination node information
joinitem mainrt.dat close.dist mainrt.dat mainrt# arclength joinitem mainrt.dat orig.dat
mainrt.dat bigcov#a network joinitem mainrt.dat dest.dat mainrt.dat bigcov#b octr
dropitem mainrt.dat mainrt.dat ot
dropitem mainrt.dat mainrt.dat dt
dropitem mainrt.dat mainrt.dat odt
tables
sel mainrt.dat
list
&m sessages &on
N
q stop
&s t4 = [show &pt time]
&lv t1 t2 t3 t4
Appendix B

GAMS Model Description

The transportation optimization model, which allocates grain shipments throughout the transportation network, utilizes the Generalized Algebraic Modeling System (GAMS). A condensed version of the actual program used to model the base scenario follows this brief description.

GAMS models have a very unique structure and format. Large, complex models can be represented in a very compact, understandable language and changes easily made. Initially, however, they can be confusing without some basic explanation. The transportation optimization model begins by defining all input SETS to be used in the model. In this model there are 36 input sets, which are described in Table B 1. These input sets provide the basic building blocks for the remainder of the GAMS program since any algebraic manipulations will generally involve these input sets.

<table>
<thead>
<tr>
<th>Table B1--Description of Input Sets Used in the GAMS Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set Name</strong></td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>R(M)</td>
</tr>
<tr>
<td>WS1(N)</td>
</tr>
<tr>
<td>WS2(N)</td>
</tr>
<tr>
<td>WINT(N)</td>
</tr>
<tr>
<td>ELEV(N)</td>
</tr>
<tr>
<td>RELEV(N)</td>
</tr>
<tr>
<td>WD(N)</td>
</tr>
<tr>
<td>WD2(N)</td>
</tr>
<tr>
<td>IPORT(N)</td>
</tr>
<tr>
<td>BS1(N)</td>
</tr>
<tr>
<td>BS2(N)</td>
</tr>
<tr>
<td>BINT(N)</td>
</tr>
<tr>
<td>BFD(N)</td>
</tr>
<tr>
<td>BINT2(N)</td>
</tr>
<tr>
<td>BD(N)</td>
</tr>
<tr>
<td>BD2(N)</td>
</tr>
<tr>
<td>CAPSET(N)</td>
</tr>
<tr>
<td>C01(N)</td>
</tr>
<tr>
<td>C05(N)</td>
</tr>
<tr>
<td>C07(N)</td>
</tr>
<tr>
<td>C13(N)</td>
</tr>
<tr>
<td>C17(N)</td>
</tr>
<tr>
<td>C21(N)</td>
</tr>
</tbody>
</table>
Every township/range in Garfield and Asotin counties with positive wheat production.

Every township/range in Grant county with positive wheat production.

Every township/range in Kittitas county with positive wheat production.

Every township/range in Klickitat county with positive wheat production.

Every township/range in Lincoln county with positive wheat production.

Every township/range in Okanogan county with positive wheat production.

Every township/range in Spokane and Ferry counties with positive wheat production.

Every township/range in Stevens county with positive wheat production.

Every township/range in Walla Walla county with positive wheat production.

Every township/range in Whitman county with positive wheat production.

After all input sets have been defined, the data is then declared by using the 'TABLES' command. Two large tables are declared: WARCS and BARCS for wheat and barley arcs, respectively. Within each table is a listing of all origin-destination node pairs and the cost coefficient to travel between the two nodes. Each table has truck, 3-car rail, 26-car rail, and barge shipment options. All route combinations generated in the previous AML program are included in the tables, WARCS and BARCS.

The next segment of the model involves defining the parameters and assigning the values for each set of parameters. The 'PARAMETER' command is used here to define the nine parameters described in Table B2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>WSUP(N)</td>
<td>Wheat supply (in bushels) produced in each township/range.</td>
</tr>
<tr>
<td>BSUP(N)</td>
<td>Barley supply (in bushels) produced in each township/range.</td>
</tr>
<tr>
<td>RAILCAPW(N)</td>
<td>Historical volume of wheat shipped on rail from elevators.</td>
</tr>
<tr>
<td>RAILCAPB(N)</td>
<td>Historical volume of barley shipped on rail from elevators.</td>
</tr>
<tr>
<td>RAILCAPW2(N)</td>
<td>Variable used to scale RAILCAPW(N).</td>
</tr>
<tr>
<td>RAILCAPB2(N)</td>
<td>Variable used to scale RAILCAPB(N).</td>
</tr>
<tr>
<td>CAPRHS(N)</td>
<td>Elevator grain capacity, in bushels.</td>
</tr>
<tr>
<td>CAPRHS2(N)</td>
<td>Variable used to scale elevator grain capacity.</td>
</tr>
<tr>
<td>BDEM(N)</td>
<td>Volume of barley demand at each feedlot and Portland.</td>
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</tbody>
</table>

All variables and equations in the model are then defined. The variables are all unknowns to be determined in the optimization process such as grain flows on individual arcs and total cost. The variables in combination with the input sets and parameters defined earlier are the ingredients used to construct the equations. The variables and equations are described in the GAMS program.

The final step is to specify how the model is to be solved which simply involves submitting the 'SOLVE' statement, instructing the model to minimize total transport cost using a linear program. Following this statement are several loops where the display of grain flows are separated into several origin-destination pairs for analysis.
GAMS Model
(Condensed Version of Base Scenario)

SETS
  N NODES FOR WHOLE NETWORK
  / ER00A
  ER00B
  EL00C
  EL00D
  ER00E
  FD1
  FD2
  FD3
  PORTLAND
  PALMOTA
  PCFRP
  TR011535
  TR011536
  TR011537
  TR771220
  TR771221
  TR771222
  TR771223
  TR771318
  TR771416
  TR771418/
  M MODES /TRUCK,RAIL3,RAIL26,BARGE/
  R(M) RAIL MODES /RAIL3,RAIL26/
  * WHEAT RELATED NODES****************************************
  WS1(N) WHEAT FIRST NODES
  TR011530
  TR011531
  TR011532
  TR771223
  TR771318
  TR771416
  TR771418/
  WS2(N) WHEAT 2NDARY SOURCES
  TR011530
  TR011531
  TR011532
  TR771222
  TR771223
  TR771318
  TR771416
  TR771418
  ER00A
RELEV(N) WHEAT ELEVATORS WITH RAIL
/ ER00A
ER00B
ER00E
ER00F
ER00G
ER71A
ER71D
ER71F
ER71I
ER71J
ER71M/
WD(N) WHEAT DEST NODE /PORTLAND/
WD2(N) WHEAT 2NDARY DESTINATIONS
/ ER00A
EL00C
EL00D
ER00E
ER00F
ER00G
EL00H
ER00K
EL01B
ER01C
ER71M
EL710
Palmota
PCFRP
PCFPGG
PLYONSF
PWINDUST
PCLARK
Pumatill
PROOSVLT
PBIGGS
PDALLES
PORTLAND/
IPORT(N) INTERMEDIATE PORTS
/ PALMOTA
PCFRP
PCFPAGG
PLYONSF
PWINDUST
PCLARK
PWILMA
PSHEFLR
PPPASCO
PKENN
PBURBANK
PWALLULA
PPTKELLY
PUMATILL
PROOSVLT
PBIGGS
PDALLES/

* BARLEY RELATED NODES***************
BS1(N) BARLEY FIRST SOURCES
/ TR011531
TR011535
TR011536
TR011628
TR011736
TR011738
TR771220
TR771416
TR771418/

BS2(N) 2NDARY BARLEY SOURCES
/ TR011531
TR011535
TR011536
TR011628
TR011629
TR011631
ER00A
ER00B
EL00C
EL00D
ER00E
ER00G
EL00H
EL01B
ER01C
EL02A
ER02B
ER02F
ER06A
EL11A
EL710
PALMOTA
PCFRP
PCFPGG
PPPASCO
PKENN
PBURBANK
PWALLULA
PPTKELLY
PUMATILL
PROOSVLT
PBIGGS
PDALLES/

BINT(N)  BARLEY INTERMEDIATE NODES
/       ER00A
       ER00B
       EL00C
       ER711
       ER71J
       ER71M
       EL71O
       PALMOTA
       PCFRP
       PCFPGG
       PLYONSF
       PWINDUST
       PCLARK
       PWILMA
       PSHEFLR
       PPPASCO
       PKENN
       PBURBANK
       PWALLULA
       PPTKELLY
       PUMATILL
       PROOSVLT
       PBIGGS
       PDALLES/

BFD(N)  FEEDLOTS
/       FD1
       FD2
       FD3
       FD4
BINT2(N) ADD BARLEY INTERMEDIATE NODES
BD(N) BARLEY FINAL DESTINATIONS
/    FD1
    FD2
    FD3
    FD4
    FD5
    FD6
    FD7
    FD8
    FD9
    FD10
    FD11
    FD12
PORTLAND/
BD2(N)  2NDARY BARLEY FINAL DESTINATIONS
    ER00A
    ER00B
    EL00C
    EL00D
    EL71G
    ER711
    ER71J
    ER71M
    EL71O
    PALMOTA
    PCFRP
    PCFPGG
    PLYONSF
    PWINDUST
    PCLARK
    PWILMA
    PSHEFLR
    PPPASCO
    PKENN
    PBURBANK
    PWALLULA
    PPTKELLY
PUMATILL
PROOSVLT
PBIGGS
PDALLES
FD1
FD2
FD3
FD4
FD5
FD6
FD7
FD8
FD9
FD10
FD11
FD12
PORTLAND/
CAPSET (N) ELEV WITH MAX CAPACITIES
/  ER00A
   ER00B
   EL00C
   EL00D
   ER00E
   ER00F
   ER00G
   EL00H
   ER00K
   EL01B
   ER01C
   EL02A
   EL71G
   ER711
   ER71J
   ER71M
   EL71O/
C01(N)  ADAMS COUNTY WHEAT TRS
/       TRO11530
       TR011531
       TR011532
       TR011533
       TR01203 5
       TR012036
       TR012037
       TR012038/
C05(N)  BENTON COUNTY WHEAT TRS
/       TR050524
C07(N) CHELAN COUNTY WHEAT TRS
/ TR072121
   TR072122
   TR072220
   TR072319
   TR072320
   TR072721
   TR072722/

C13(N) COLUMBIA COUNTY WHEAT TRS
/ TR130839
   TR130938
   TR130939
   TR131237
   TR131238
   TR131239
   TR131338
   TR131339/

C17(N) DOUGLAS COUNTY WHEAT TRS
/ TR172122
   TR172221
   TR172222
   TR172521
   TR172522
   TR172523
   TR172524
   TR173028
   TR173029
   TR173030/

C21 (N) FRANKLIN COUNTY WHEAT TRS
/ TR211133
   TR211428
   TR211431
   TR211433
   TR211434
   TR211435/

C23(N) GARFIELD AND ASOTIN COUNTY WHEAT TRS
/ TR030745
   TR030746
   TR030844
   TR030845
   TR030846
C47(N)  OKANOGAN COUNTY WHEAT TRS
/   TR472925
    TR472931
    TR473025
    TR473026
    TR473027
    TR473327
    TR473625
    TR473626
    TR473628
    TR473727
    TR473728
    TR473827
    TR473929/

C63(N)  SPOKANE AND FERRY COUNTY WHEAT TRS
/   TR632140
    TR632141
    TR632142
    TR632844
    TR632942
    TR632943
    TRI92935
    TRI93236
    TRI93237
    TRI93537
    TRI93836
    TRI94032
    TRI94034/

C65(N)  STEVENS COUNTY WHEAT TRS
/   TR652741
    TR652839
    TR652840
    TR652841
    TR653341
    TR653437
    TR653739
    TR653837/

C71(N)  WALLA WALLA COUNTY WHEAT TRS
/   TR710631
    TR710632
    TR710633
    TR711036
    TR711133
    TR711134
C75(N)  WHITMAN COUNTY WHEAT TRS
 /  TR751145
    TR751146
    TR751245
    TR751246
    TR751337
    TR752044
    TR752045
    TR752046/
C77(N)  YAKIMA COUNTY WHEAT TRS
 /  TR770720
    TR770721
    TR770722
    TR770723
    TR770821
    TR770822
    TR771222
    TR771223
    TR771318
    TR771416
    TR771418/

ALIAS (N,NP);
BINT12(N) = BINT(M) + BFD(N);
TABLE WARCS (N,NP,M) TRANSPORT AND HANDLING COSTS BY MODE

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PARAMETER WSUP(N) AVAILABLE WHEAT BU
/ TR011530  238605.0
TR011531  426408.0
TR011532  312468.0
TR011533  319029.0
TR011534  304851.0
TR011535  396002.0
TR011536  195014.0
TR011537  300501.0
TR011538  44093.0
TR011628  12390.0
TR011539  100501.0
TR011630  664014.0
TR771416  15140.0
TR771418  1090.0  /;

PARAMETER BSUP(N) AVAILABLE BARLEY BU
/ TR011531  74981.0
TR011535  1066.0
TR011536  3305.0

61
PARAMETER RAILCAPW(N) RAIL CAPACITY FOR WHEAT ELEV W RAIL
/  
ER00A 256000
ER00K 119700
ER02B 48000
ER09A 600000
ER09B 100000
ER09G 400000
ER091 100000
ER09Q 20672
ER67C 5476
ER67R 789232
ER71A 446500
ER71D 339150
ER71F 188100
ER711 716300
ER71J 157700
ER71M 324900
/

PARAMETER RAILCAPB(N) RAIL CAPACITY FOR BARLEY
/  
ER02B 16000
ER02F 6400
ER16A 150000
ER16D 200000
ER18A 184933
ER18B 90048
ER20A 400
ER33B 51512
ER35A 71966
ER67M 6924
ER67P 96000
ER67R 322585
ER71A 336600
ER71D 256700
ER71F 142800
ER711 541450
ER71J 119850
ER71M 461550
/

PARAMETER CAPRHS(N) ELEV CAPACITIES
/  
ER00A 2197000
ER00B 62000
EL00C 575000
EL00D 670000
ER68E 567000
ER71A 901000
ER71D 687000
/
PARAMETER BDEM(N) BARLEY DEMAND AT DEST SITES
  / PORTLAND 10414449 /
FD1 379473
FD2 43663
FD3 6238
FD4 0
FD5 4990095
FD6 1965
FD7 9356
FD8 124752
FD9 218317
FD10 18713
FD11 24950
FD12 486534;
PARAMETER CAPRHS2(N) UPDATED ELEV. CAPACITIES;
  CAPRHS2(N) = 1*CAPRHS(N);
PARAMETER RAILCAPW2(N) UPDATED WHT RAIL MAX VALUES;
PARAMETER RAILCAPB2(N) UPDATED BARLEY RAIL MAX VALUES;
  RAILCAPW2(N) = 1*RAILCAPW(N);
  RAILCAPB2(N) = 1*RAILCAPB(N);
VARIABLES W(NNP,M) WHEAT FLOW ON ARCS N TO NP VIA MODE M
  B(N,NP,M) BARLEY FLOW ON ARCS N TO NP VIA MODE M
TC TOTAL COST
WTC TOTAL COST WHEAT
BTC TOTAL COST BARLEY
TRW TOTAL WHEAT RAIL
TRB TOTAL BARLEY RAIL
POSITIVE VARIABLES W, B;

EQUATIONS WNB(N) NODE BALANCE WHEAT
  WDB(N) DESTINATION BALANCE WHEAT
  WSB(N) SUPPLY BALANCE WHEAT
  BNB(N) NODE BALANCE BARLEY
  BDB(N) DESTINATION BALANCE BARLEY
  BSB(N) SUPPLY BALANCE BARLEY

CAP(N) CAPACITIES ON ELEVATORS
RAILW(N) RAIL CAPACITY FOR WHEAT
RAILB(N) RAIL CAPACITY FOR BARLEY
T01 LIMIT ON ADAMS COUNTY TR TO PORT
T05 LIMIT ON BENTON COUNTY TR TO PORT
T07 LIMIT ON CHELAN COUNTY TR TO PORT
T13 LIMIT ON COLUMBIA COUNTY TR TO PORT
T17 LIMIT ON DOUGLAS COUNTY TR TO PORT
T21 LIMIT ON FRANKLIN COUNTY TR TO PORT
T23 LIMIT ON GARFIELD COUNTY TR TO PORT
T25 LIMIT ON GRANT COUNTY TR TO PORT
T37 LIMIT ON KIMTAS COUNTY TR TO PORT
T39 LIMIT ON KLICKITAT COUNTY TR TO PORT
T43 LIMIT ON LINCOLN COUNTY TR TO PORT
T47 LIMIT ON OKANOGAN COUNTY TR TO PORT
T63 LIMIT ON SPOKANE COUNTY TR TO PORT
T65 LIMIT ON STEVENS COUNTY TR TO PORT
T71 LIMIT ON WALLA WALLA COUNTY TR TO PORT
T75 LIMIT ON WHITMAN COUNTY TR TO PORT
T77 LIMIT ON YAKIMA COUNTY TR TO PORT
WCOST ACCTING: TOTAL COST WHEAT
BCOST ACCTING. TOTAL COST BARLEY
TCOST ACCTTNG: TOTAL COST;

WDB(WD).. SUM((WINT,M)$WARCS(WINT,WD,M),W(WINT,WD,M))=G=132836124;

WSB(WS 1).. SUM((WINT,M)$WARCS(WS1,WINT,M),W(WS1,WINT,M)) =L= WSUP(WS 1);

WNB(WINT)SSLJM((N,M),WARCS(WINT,N,M))..
SUM((WS2,M)$WARCS(WS2,WINT,M), W(WS2,WINT,M)) =E= SUM((WD2,M)$WARCS(WINT,WD2,M), W(WINT,WD2,M))

T01.. SUM((C01,IPORT,M)SWARCS(C01,IPORT,M),W(C01,IPORT,M)) =L=4469867;

T05.. SUM((C05,IPORT,M)SWARCS(C05,IPORT,M),W(C05,IPORT,M)) =L=5089365;

T07.. SUM((C07,IPORT,M)SWARCS(C07,IPORT,M),W(C07,IPORT,M)) =L=14300;

T13.. SUM((C13,IPORT,M)SWARCS(C13,IPORT,M),W(C13,IPORT,M)) =L=867058;

T17.. SUM((C17,IPORT,M)SWARCS(C17,IPORT,M),W(C17,IPORT,M)) =L=5881930;

T21.. SUM((C21,IPORT,M)SWARCS(C21,IPORT,M),W(C21,IPORT,M)) =L=4703398;

T23.. SUM((C23,IPORT,M)SWARCS(C23,IPORT,M),W(C23,IPORT,M)) =L=3800669;
T25.. SUM((C25,IPORT,M)$WARCS(C25,IPORT,M),W(C25,IPORT,M)) =L=4642981;

T37.. SUM((C37,IPORT,M)$WARCS(C37,IPORT,M),W(C37,IPORT,M)) =L=141519;

T39.. SUM((C39,IPORT,M)$WARCS(C39,IPORT,M),W(C39,IPORT,M)) =L=2242982;

T43.. SUM((C43,IPORT,M)$WARCS(C43,IPORT,M),W(C43,IPORT,M)) =L=7680181;

T47.. SUM((C47,IPORT,M)$WARCS(C47,IPORT,M),W(C47,IPORT,M)) =L=121171;

T63.. SUM((C63,IPORT,M)$WARCS(C63,IPORT,M),W(C63,IPORT,M)) =L=577097;

T65.. SUM((C65,IPORT,M)$WARCS(C65,IPORT,M),W(C65,IPORT,M)) =L=289432;

T71.. SUM((C71,IPORT,M)$WARCS(C71,IPORT,M),W(C71,IPORT,M)) =L=1795242;

T75.. SUM((C75,IPORT,M)$WARCS(C75,IPORT,M),W(C75,IPORT,M)) =L=11530216;

T77.. SUM((C77,IPORT,M)$WARCS(C77,IPORT,M),W(C77,IPORT,M)) =L=995879;

BDB(BD).. SUM((BS2,M)$BARCS(BS2,BD,M),B(BS2,BD,M))=G=BDEM(BD);

BSB(BS1).. SUM((BINT2,M)$BARCS(BS1,BINT2,M),B(BS1,BINT2,M)) =L= BSUP(BS1);

BNB(BINT)$SUM((N,M),BARCS(BINT,N,M)).. SUM((BS2,M)$BARCS(BS2,BINT,M), B(BS2,BINT,M)) =E= SUM((BD2,M)$BARCS(BINT,BD2,M), B(BINT,BD2,M));

CAP(CAPSET).. SUM((WS2,M)$WARCS(WS2,CAPSET,M), W(WS2,CAPSET,M)) + SUM((BS2,M)$BARCS(BS2,CAPSET,M), B(BS2,CAPSET,M)) =L= CAPRHS2(CAPSET);
RAILW(WINT) = \sum((WD,R) \in WARCS(WINT,WD,R), W(WINT,WD,R)) \\
= \text{RAILCAPW(WINT)};

RAILB(BINT) = \sum((BD,R) \in BARCS(BINT,BD,R), B(BINT,BD,R)) \\
= \text{RAILCAPB(BINT)};

TCOST = TC = \sum((N,NP,M) \in WARCS(N,NP,M), WARCS(N,NP,M) \times W(N,NP,M)) + \\
\sum((N,NP,M) \in BARCS(N,NP,M), BARCS(N,NP,M) \times B(N,NP,M));

WCOST = WTC = \sum((N,NP,M) \in WARCS(N,NP,M), WARCS(NNP,M) \times W(N,NP,M));

BCOST = BTC = \sum((N,NP,M) \in BARCS(NNP,M), BARCS(N,NP,M) \times B(N,NP,M));

MODEL TEST /ALL/;
OPTION LIMROW = 5;
OPTION LIMCOL = 5;
OPTION RESSLIM = 5000;
OPTION ITERLIM = 100000;
SOLVE TEST MINIMIZING TC USING LP;
DISPLAY W.L, B.L;

FILE RES /'EJ.DAT'/;
PUT RES;
PUT "TOTAL COST = /;
PUT TC.L /;
PUT /;
PUT "TOTAL COST WHEAT = /;
PUT WTC.L /;
PUT /;
PUT 'TOTAL COST BARLEY =" /;
PUT BTC.L /;
PUT /;

***PUT "WHEAT ARCS" /;
***LOOP ((N,NP,M),
***IF (W(N,NP,M) GT 0,
***PUT N.TL, NP.TL, M.TL, W.L(N,NP,M) /));

PUT "WHEAT ARCS FOR TRS TO ELEVATORS" /;
LOOP ((WS1,CAPSET,M),
IF (W(WS1,CAPSET,M) GT 0,
PUT WS1.TL, CAPSET.TL, M.TL, W.L(WS1,CAPSET,M) /));

PUT "WHEAT ARCS FOR TRS TO RIVER PORTS" /;
LOOP ((WS1,IPORT,M),
IF (W(WS1,IPORT,M) GT 0
PUT WS1.TL, IPORT.TL, M.TL, W.L(WS1,IPORT,M) /));
PUT “WHEAT ARCS FOR ELEVATORS TO ELEVATORS WITH RAIL” /;
LOOP ((ELEV,RELEV,M),
  IF (W(ELEV,RELEV,M) GT 0,
    PUT ELEV.TL, RELEV.TL, M.TL, W.L(ELEV,RELEV,M) /));

PUT “WHEAT ARCS FOR ELEVATORS TO RIVER PORTS” /;
LOOP ((CAPSET,IPORT,M),
  IF (W(CAPSET,IPORT,M) GT 0,
    PUT CAPSET.TL, IPORT.TL, M.TL, W.L(CAPSET,IPORT,M) /));

PUT “WHEAT ARCS FOR RIVER PORTS TO PORTLAND” /;
LOOP ((IPORT,WD,M),
  IF (W(IPORT,WD,M) GT 0,
    PUT IPORT.TL, WD.TL, M.TL, W.L(IPORT,WD,M) /));

PUT “WHEAT ARCS FOR ELEVATORS WITH RAIL TO PORTLAND” /;
LOOP (RELEV,WD,M),
  IF (W(RELEV,WD,M) GT 0,
    PUT RELEV.TL, WD.TL, M.TL, W.L(RELEV,WD,M) /));

***PUT “BARLEY ARCS” /;
***LOOP ((N,NP,M),
***  IF (B(N,NP,M) GT 0,
***    PUT N.TL, NP.TL, M.TL, B.L(N,NP,M) /));

PUT “BARLEY ARCS FOR TRS TO ELEVATORS” /;
LOOP ((BS1,CAPSET,M),
  IF (B(BS1,CAPSET,M) GT 0
    PUT BS1.TL, CAPTSET.TL, M.TL, B.L(BS1,CAPSET,M) /));

PUT “BARLEY ARCS FOR TRS TO RIVER PORTS” /;
LOOP ((BS1,IPORT,M),
  IF (B(BS1,IPORT,M) GT 0,
    PUT BS1.TL, IPORT.TL, M.TL, B.L(BS1,IPORT,M) /));

PUT “BARLEY ARCS FOR ELEVATORS TO ELEVATORS WITH RAIL” /;
LOOP ((ELEV,RELEV,M),
  IF (B(ELEV,RELEV,M) GT 0,
    PUT ELEV.TL, RELEV.TL, M.TL, B.L(ELEV,RELEV,M) /));

PUT “BARLEY ARCS FOR ELEVATORS TO RIVER PORTS” /;
LOOP ((CAPSET,IPORT,M),
  IF (B(CAPSET,IPORT,M) GT 0,
    PUT CAPSET.TL, IPORT.TL, M.TL, B.L(CAPSET,IPORT,M) /));
PUT "BARLEY ARCS FOR RIVER PORTS TO PORTLAND" /;
LOOP ((IPORT,BD,M),
IF (B(IPORT,BD,M) GT 0,
PUT IPORT.TL, BD.TL, M.TL, B.L(IPORT,BD,M) /));

PUT "BARLEY ARCS FOR ELEVATORS WITH RAIL TO PORTLAND" /;
LOOP ((RELEV,BD,M),
IF (B(RELEV,BD,M) GT 0,
PUT RELEV.TL, BD.TL, M.TL, B.L(RELEV,BD,M) /));

PUT "BARLEY ARCS FOR TRS TO FEEDLOTS" /;
LOOP ((BS1,BFD,M),
IF (B(BS1,BFD,M) GT 0,
PUT BS1.TL, BFD.TL, M.TL, B.L(BS1,BFD,M) /));

PUT "BARLEY ARCS FOR ELEVATORS TO FEEDLOTS" /;
LOOP ((CAPSET,BFD,M),
IF (B(CAPSET,BFD,M) GT 0,
PUT CAPSET.TL, BFD.TL, M.TL, B.L(CAPSET,BFD,M) /));

***PUT "DUAL PRICES FOR ELEVATOR CAPACITY " /;
***LOOP ((CAPSET),
***PUT CAPSET.TL, CAP.M(CAPSET) /);
***PUT "DUAL PRICES FOR WHEAT RAIL " /;
***LOOP ((WINT),
***PUT WINT.TL, RAILW.M(WINT) /);
***PUT "DUAL PRICES FOR BARLEY RAIL" /;
***LOOP ((BINT),
***PUT BINT.TL, RAILB.M(BINT) /);