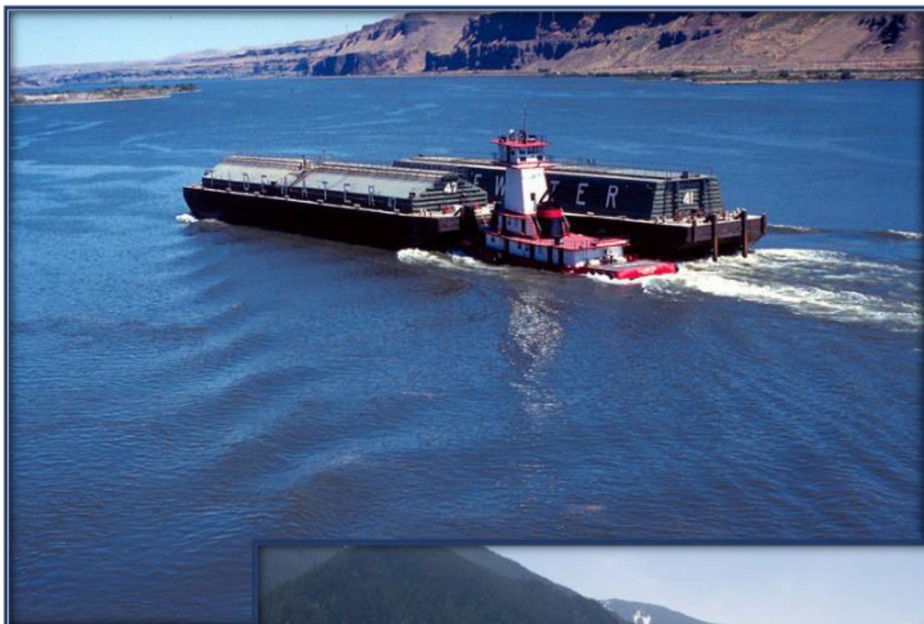
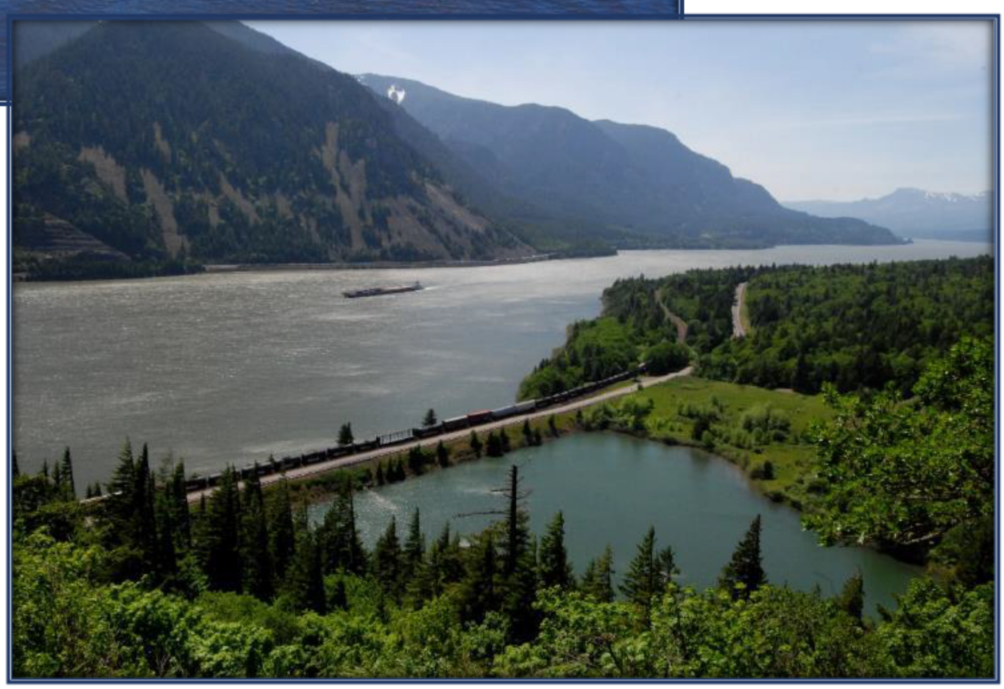
# THE IMPORTANCE OF COLUMBIA-SNAKE RIVER NAVIGATION TO U.S. AGRICULTURE

United States Department of Agriculture

Transportation Services Division/Agricultural Marketing Service





Photos by U.S. Army Corps of Engineers (https://www.nwcouncil.org/sites/default/files/navigation.jpg) and Dan Van Horn (https://commons.wikimedia.org/wiki/File:Barge_in_the_Columbia_River_Gorge.jpg).

**Eric Jessup (Principal Investigator)**
Research Professor
School of Economic Sciences
Washington State University
301 Hulbert Hall
Pullman, WA 99164-6420
Ph: 509-335-4987
eric_jessup@wsu.edu

**Jake Wagner**
Assistant Research Professor
School of Economic Sciences
Washington State University

**Riley Higby**
Director of Revenue
Higby Barrett LLC

**Alan Barrett**
Director of Research & Consulting
Higby Barrett LLC

**Libby Ogard**
President
Prime Focus LLC

**Kevin Morris**
Research Assistant
Washington State University

**Timur Dincer**
Research Assistant
Washington State University

# CONTENTS

## Background

The 465-mile Columbia-Snake River Inland Waterway System is essential for the movement of bulk raw materials which supports the regional economies it connects in Idaho, Washington and Oregon. This freight network includes trucks, which support the first and last mile movement of goods, typically less than 30 miles to a long-haul freight mode, such as a barge or a railroad. Barge and rail systems have historically competed over the last 100 years and cargo owners have often used both services to develop a resilient competitive transportation system to connect to global markets.

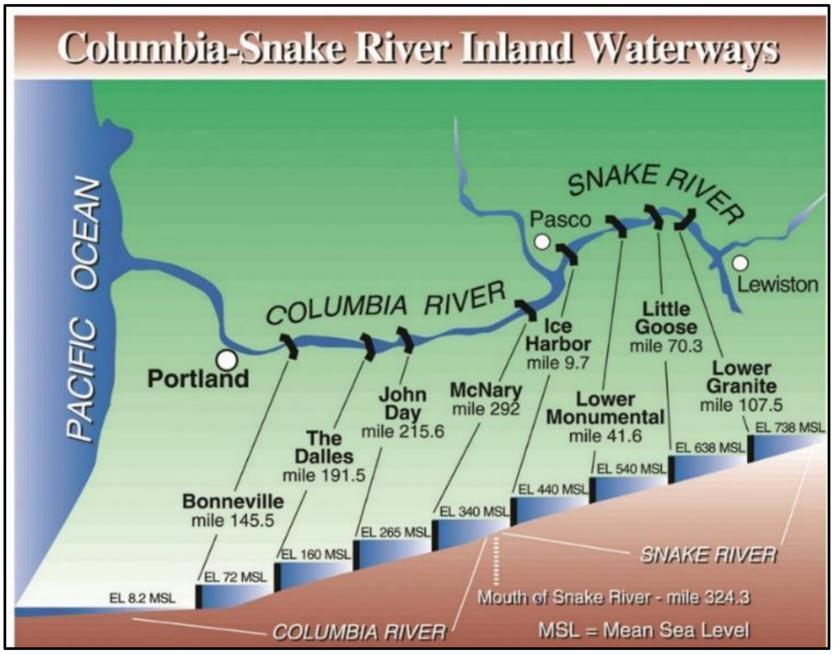



*Figure 1: Columbia -Snake River Inland Waterway (USACE)*

The objective of this research is to complement previous research—the Importance of Inland Waterways to U.S. Agriculture (Agribusiness Consulting for USDA, 2019)—with a focus on the Columbia-Snake River Inland Waterway. Total transportation costs and total economic impacts are evaluated under a baseline scenario as well as across three alternative operating scenarios using historical river volumes and transportation optimization models of primary commodities.

Five commodity supply chains were included in the analysis: grain, fertilizer, petroleum products, forest products and sand & gravel aggregates. These products represent 83% of the cargo on the Columbia River and 88% of the cargo on the Snake River (USACE Waterborne Commerce and Statistics). The total transportation costs and economic impacts of river navigation are evaluated for each economy across a baseline scenario, where river operating conditions/efficiency remain at their current levels, and three alternative operating scenarios: (1) an improved scenario in which all planned, outstanding, and proposed maintenance projects are completed, improving river transportation efficiency; (2) an unimproved scenario in which planned maintenance projects are deferred, resulting in reduced river transportation efficiency; (3) and a degraded scenario in which river maintenance is neglected, resulting in a substantial decrease in river transportation efficiency. The differences in transportation costs and economic activity across the baseline and alternative operating scenarios will help to inform the appropriate level of maintenance and marine investment required to support job creation and sustainability in the region.

## Commodities Evaluated

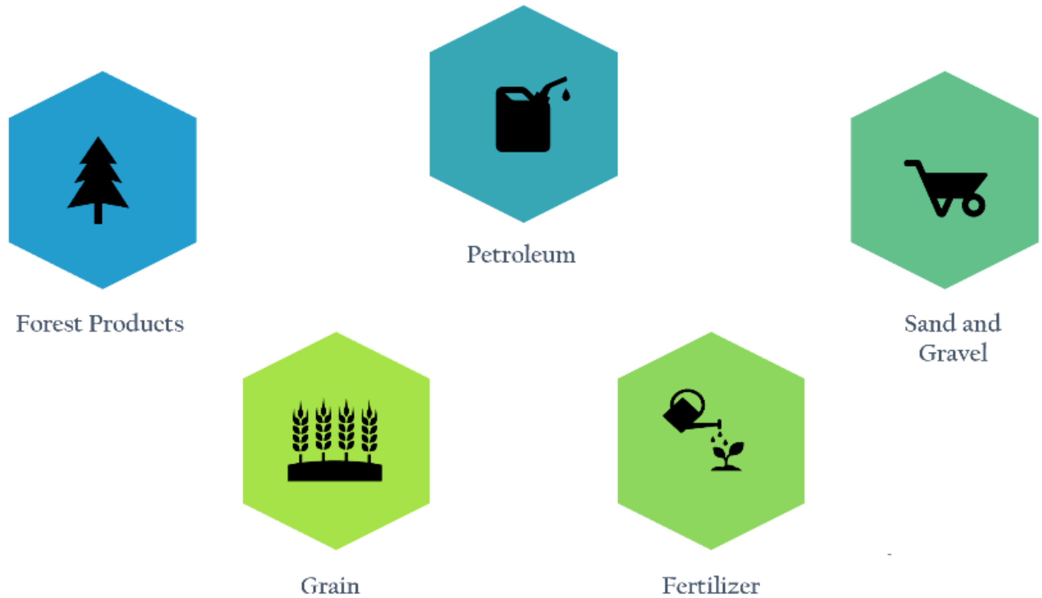



*Figure 2: Commodities Analyzed*

## Current Operating Conditions

In 2019–2020 vessels on the Columbia-Snake River System (CRS) faced an average 29-minute delay at each lock (USACE Lock Performance Monitoring System).[1] Delays contribute to increased costs for tugs and can create supply chain delays if subsequent connections are missed in an export move.

On average, the Columbia-Snake River navigation system experiences 40 outages annually, totaling 337 hours in unavailable time (USACE Lock Performance Monitoring System). These outages can be either planned, or unplanned. The majority (92%) of outages are unplanned, though unplanned outages make up only a small share (6%) of total unavailable time (21 hours of unplanned outages per year). Most unplanned outages are resolved relatively quickly; the average unplanned outage lasts approximately 35 minutes. Planned outages, on the other hand, account for only 8% of total outages, but are responsible for 94% of total unavailable time (315 hours of planned unavailable time per year).

The Columbia-Snake River System is in relatively good operating condition and does not experience the frequent unplanned outage or long lockage delays that are experienced on the Mississippi and Missouri River Systems.

To mitigate the risks of unplanned outages and keep up on general maintenance, the Columbia-Snake River navigation system typically closes for 3 weeks each year, at the beginning of March. These outages do disrupt the navigation system, but they are planned, relatively routine, and are therefore well prepared for by shippers and producers/manufacturers.

## Commodity Baseline Cost Analysis

A regional commodity flow model was developed to understand the total transportation cost by mode for the primary commodities moved on the Columbia-Snake River System. Each model was calibrated to represent baseline commodity flows observed in the region, based on production data (USDA) and river

[1] Lock delays represent the time between barge arrival and the start of lockage.

commodity flow data (USACE) from 2015-2019. The baseline model represents lock and dam maintenance schedules continued at their current levels, resulting in no change in transportation efficiency (i.e., no cost savings realized at baseline by barge operators/shippers). Below is a summary estimate of costs to move the key commodities in the region under the baseline (current, 2019) operating conditions.

- Baseline transportation costs for ***grain** total* $139,979,332/year; of this, barge transportation costs total $53,528,242 (38.2% of total grain transportation costs).
- Baseline transportation costs for ***petroleum*** total $265,106,250/year; of this, barge transportation costs total or $9,891,467/year (3.7% of total petroleum transportation costs).
- Baseline transportation costs for ***fertilizer*** total $4,384,515/year; of this, barge transportation costs total $481,394/year (10.9% of total fertilizer transportation costs).
- Baseline barge transportation costs for ***sand and gravel*** are $12,434,895/year (total baseline transportation costs for sand and gravel are unknown).
- Baseline barge transportation costs for ***forest products*** are $10,077,523/year (total baseline transportation costs for forest products are unknown).

### Impacts of Alternative Operating Scenarios

In addition to the baseline scenario, three alternative operating scenarios were evaluated to estimate the economic impact of additional investment or a lack of investment in the Columbia River navigation system. The system currently operates very smoothly, and there are not obvious investments to be made to reduce delay times (of which there currently are next to none) that would translate into shipper cost savings. Instead, the scenarios were developed by analyzing planned and unplanned outages on the river system under three hypothetical operating conditions resulting from investment in currently planned maintenance projects. For modeling purposes, an arbitrary value (based on historical observations) was assigned to quantify the percent change in transportation costs under each hypothetical scenario using U.S. Army Corps of Engineers' estimates of investment impacts on operating efficiencies (outages/delays), and thus barge/shipper operating costs.

The three alternative operating scenarios are defined below:

- Alternative Operating Scenario 1: an improved scenario in which all planned, outstanding, and proposed maintenance projects are completed, improving river transportation efficiency and reducing barge transportation costs by 6%.
- Alternative Operating Scenario 2: an unimproved scenario in which planned maintenance projects are deferred, resulting in reduced river transportation efficiency and increasing barge transportation costs by 6%.
- Alternative Operating Scenario 3: a degraded scenario in which river maintenance is neglected resulting in a substantial decrease in river transportation efficiency and increasing barge transportation costs by 12%.

Total economic impacts measured for each scenario include the direct impacts of increased/decreased barge transportation costs on shippers, and the indirect impacts of changes in spending, production, job creation, etc., on the regional economy. At baseline, the Columbia-Snake River System is estimated to contribute $346 million dollars to the regional economy annually. As expected, the improved scenario in which barge transportation costs are reduced by 6%, resulted in an additional $56 million/year in increased value-added to the regional economy (value added is a measure that is similar to GDP but for the regional level). The unimproved scenario, in which barge transportation costs are increased by 6%, resulted in a $21 million/year reduction in the value added to the regional economy. The degraded scenario, in which barge transportation costs are increased by 12%, resulted in an even steeper $36 million/year reduction to value-added in the regional economy.

# 1. INTRODUCTION

The Columbia-Snake River System in the Pacific Northwest provides an efficient means of transportation that has advanced trade, commerce, and economic development throughout the region. Commercial navigation on the Columbia-Snake River System was made possible by the construction of eight locks and dams, beginning in 1933 with Bonneville Dam just upriver of Portland, Oregon and ending in 1975 with Lower Granite Dam, just downriver of Lewiston, Idaho (Figure 1). Since its completion in 1975, this network of locks and dams has facilitated the safe and consistent operation of large vessels and barges on the Columbia-Snake River System.

## History

The Columbia-Snake River navigation channel serves an important role in providing a cost-effective way to move large quantities, heavy commodities, and bulky oversized shipments. Barging is also timely, quite safe relative to truck and rail transport, and has low energy demands, requiring less fuel per ton of commodity shipped (Kruse et al., 2021).

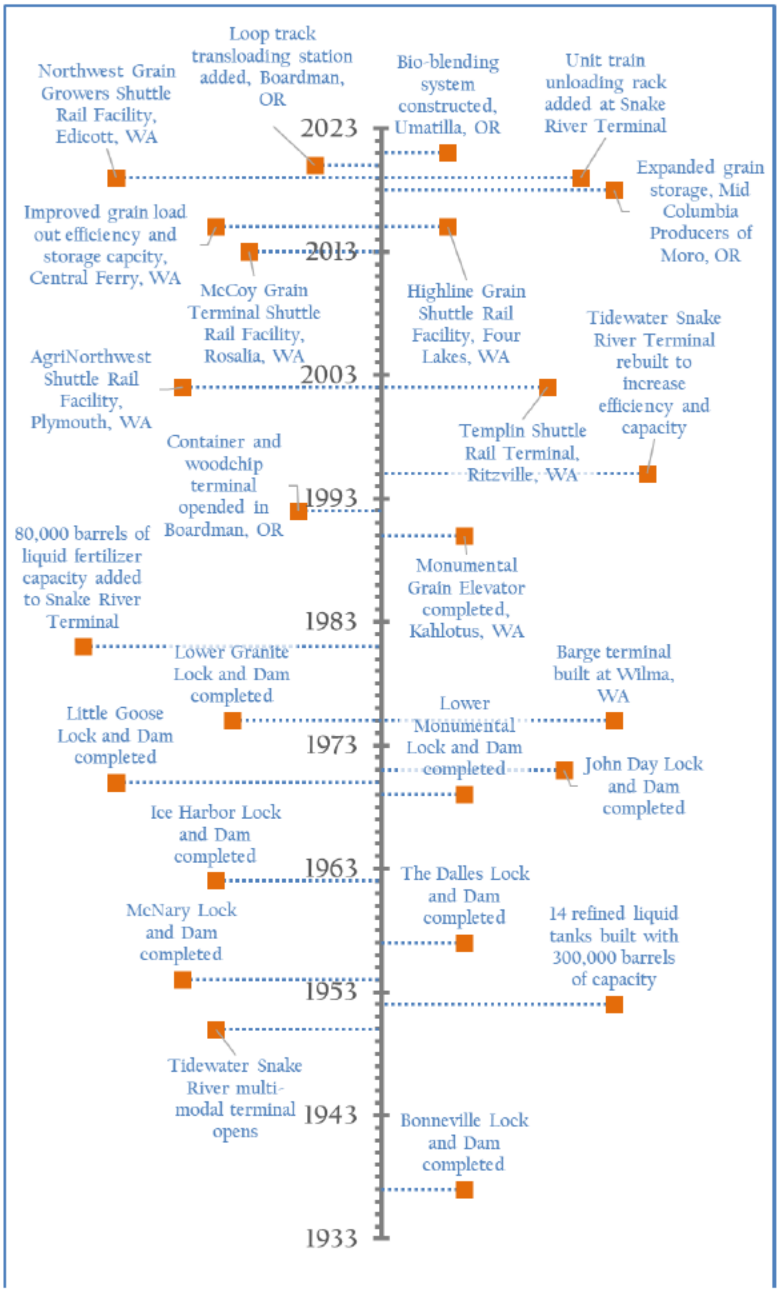



*Figure 3: Pacific Northwest Freight Timeline*

Most freight transiting the inland waterway starts or ends its journey at one of four lower Columbia River ports: the ports of Portland, Vancouver, Kalama, and Longview. With access to foreign import/export markets, these ports connect the inland waterway to global markets. In 2019, 6.9 million tons of freight (mostly grain) transited downriver through the Columbia-Snake River System to be exported (mostly to Asian markets). In the same year upbound barge shipments from lower Columbia River ports totaled 3.9 million tons.

Historically lower Columbia River ports served both breakbulk and containerized shipments. In 2015, however, containerized shipment services at the port of Portland were stopped. The stoppage was due in part to a labor dispute that resulted in falling dock productivity, and in part to the industry's shift to larger vessels requiring drafts too deep for Columbia River ports. In January of 2020, weekly container service was resumed at the Port of Portland with service from Korean-based SM Line, though the service currently handles less than one quarter of pre-2015 volumes and does not service any ports upriver of Portland.

## Networks and Competition

As part of the region's intermodal transportation system, barge shipping is dependent on truck and rail shipping. Trucks are essential for first and last mile service. The railroad network, historically fierce competitors, now in some cases, works with marine service providers to extend and customize services based upon supply chain requirements.


*Figure 5: BNSF Shuttle Train Loader - Source: BNSF.Com*

In recent decades the region has seen improvements in rail infrastructure. The introduction of shuttle grain trains (dedicated 110-unit hopper grain trains) in the early 2000s, provided cost effective rail transport as a competitive alternative to barge shipping. Since 2002, the region has added 5 grain shuttle rail facilities. The map below shows the region's 5 grain export shuttle facilities.

- Templin Terminal (Ritzville Warehouse Co.), Ritzville, WA – Constructed in 2002 and located on the BNSF main line just east of Ritzville.
- AgriNorthwest (Crop Production Services), Plymouth, WA – Constructed in 2002, located 30 miles south of Richland/Kennewick, WA and just across the Columbia River from Umatilla, OR. Also serviced by BNSF.
- McCoy Grain Terminal, Rosalia, WA – Constructed in 2013 and located 39 miles south of Spokane in Rosalia, WA with access to BNSF tracks via the P&L shortline.
- Highline Grain, Four Lakes, WA – Constructed in 2015 and located in Cheney, WA about 12 miles west of Spokane, with access to the BNSF mainline.
- Northwest Grain Growers (LaCrosse Grain), Endicott, WA – Constructed in 2019 and located in Endicott, WA, about 70 miles south of Spokane, with shortline access to the BNSF mainline.

*Figure 6: Grain Truck*

*Figure 7: Grain Barge*

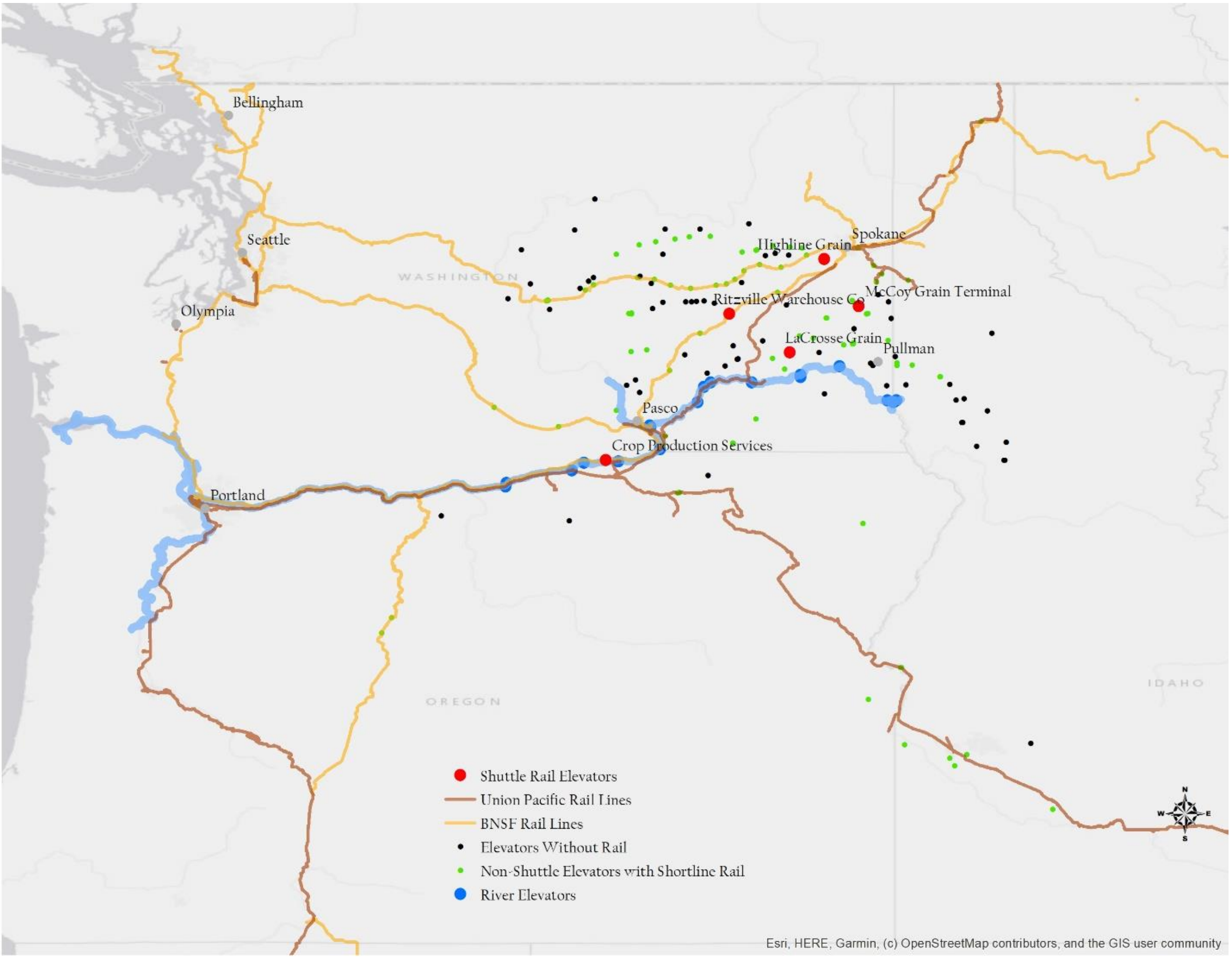



*Figure 7: PNW Rail Network*

Nonetheless, Columbia-Snake River navigation continues to play an important role in the region's intermodal freight transportation system. The recent Columbia River Environmental Impact Statement estimated that barge shipping on the Snake River saves the region's grain producers approximately $14 – 48 million/year, and avoids 0.077-0.090 MMT of $CO_2$ emissions (valued at $3.2-3.8 million) per year (Columbia River Systems Operations, Environmental Impact Statement, 2020).

Barge shipping also provides jobs at inland ports, stimulating regional economies, and is integral in maintaining competitive markets in the region's multimodal transportation system. In total, Snake River navigation was estimated to provide $37-93 million in benefits to the region's economies through decreased transportation costs and increased farm incomes (Columbia River Systems Operations, Environmental Impact Statement, 2020).

## 2. OBJECTIVE

The objective of this analysis is to assess how changes in infrastructure investment on the Columbia-Snake River impact shipping costs and the regional economy of the Pacific Northwest.

The U.S. inland navigation system serves a vital transportation service for businesses relying upon efficient and cost-effective transportation. These transportation corridors, however, are often overlooked relative to the benefits they provide. This research will complement similar work which studied the importance of inland waterways with a focus on the Mississippi River system (Importance of Inland Waterways to U.S. Agriculture, Agribusiness Consulting for USDA, 2019)

*This report evaluates the economic impacts of maintaining the Columbia-Snake River navigation system at baseline (current operating conditions) and under three alternative operating scenarios.*

**Alternative Secnario 1**
An improved scenario in which all planned, outstanding and proposed maintenance projects are completed, improving river transportation efficiency
**Reducing Barge Transportation Costs by 6%**

**Alternative Scenario 2**
An unimproved scenario in which planned maintenance projects are deferred resulting in reduced river transporation efficiency.
**Increasing Barge Transportation Costs by 6%**

**Alternative Scenario 3**
A degraded scenarion in which river maintenance is neglected resulting in a substantial decrease in river transportation efficiency.
**Increasing Barge Transportation Costs by 12%**

*Figure 8 Alternative Operating Scenarios*

## 3. STUDY METHODOLOGY AND WORK TASKS

The study was conducted as follows:

1. Assemble regional advisory committee (comprised of appropriate shippers, producer organizations, port officials, grain commissions, regional and state transportation planners, barge operators, USACE, etc.) to guide/shape the study effort and to advance access to critical information/data. This advisory committee will also help shape the communications/outreach efforts once the study has been completed.
2. Summarize prior studies that have estimated the economic value of the Columbia-Snake River System for navigation and provide a context/comparison of how the results of these studies have differed relative to the approach and methodology utilized here.
3. Inventory and evaluate Columbia-Snake River System improvements (lock/dam) and current list of USACE project improvements awaiting funding.
4. Compile historical river movements, up and down the Columbia-Snake River System by river section and provide explanations as to factors impacting river volume movements.
5. Develop a transportation model to evaluate a baseline and three alternative operating scenarios.

6. Estimate how freight flows are altered as a result of each scenario and the resulting impact on shipper costs and how the contribution to the regional economy is changed. Economic impacts were measured using IMPLAN to provide direct, indirect, and induced impacts.
7. Summarize results and findings in a research report, including illustrative examples and detailed narratives of impacts by commodity type and river section and made available via web and PowerPoint or other mediums as needed. This will include infographic visuals that summarize study findings in the most effective and concise manner to stakeholders and policy planners.


*Figure 9: Work Tasks*

## 4. LITERATURE REVIEW

There is a long history of studies focused on estimating the various costs/benefits of the Columbia-Snake River System across competing uses. Most of these studies have taken a broad look at *all* the costs and benefits of the different uses of the rivers including recreation, irrigation, flood control, power generation, fish habitat, *and* navigation (among others). With such breadth, these studies have generally been unable to analyze the impacts of navigation with sufficient rigor and detail. Additionally, most existing studies have focused on the costs and benefits of the lower Snake River system, as the dams on this river segment have been under contentious debate. As result, while the focus of this report are the navigable sections of *both* the Columbia and Snake Rivers, much of the literature is focused only on the Snake River. Furthermore, this project focuses solely on the transportation and navigation aspects of the Columbia-Snake River System and estimating the economic value generated.

The costs/benefits of river navigation can be decomposed into five categories: 1) shipping costs, 2) maintenance and infrastructure costs, 3) congestion and safety, 4) emissions, 5) and regional economic impacts. The evidence and valuations for each cost/benefit category are discussed below and presented in Table 1.

- **Shipping Costs** – For many producers, shipping via barge on the Columbia-Snake River provides considerable cost advantages: barge rates (price paid by shipper) average $0.04/ton-mile, while rail and trucking rates average $0.06/ton-mile and $0.14/ton-mile respectively. Barging on the Snake River has been estimated to save shippers $6-$48 million annually (USACE Columbia River System EIS, 2020; FCS Group, 2020; ECONorthwest, 2019; Earth Economics, 2017; Rocky Mountain Econometrics, 2015; USACE, 2002).

- **Maintenance and Infrastructure Costs** – Accommodating a share of total shipments on the Columbia and Snake River system results in fewer ton-miles traveled by truck and rail. These road and rail miles saved through barge transit result in less wear and tear, requiring less maintenance. Road and rail miles may also put pressure on network capacities, requiring additional infrastructure. Snake River navigation is estimated to save $2-$15 million in road and rail maintenance costs annually, and $30-$872 million in increased infrastructure costs (Columbia River System EIS, 2020; ECONorthwest, 2019; USACE, 2002).

  River navigation does, however, require substantial infrastructure as well in the form of locks and dams. In its current state, the lock and dam systems on the lower Snake River have annual capital expenses of $31 million. This aging infrastructure also requires routine maintenance totaling $75 million per year (Columbia River System EIS, 2020). Not all these costs, however, can be attributed to transportation/navigation, as the dam systems serve multiple other uses (irrigation, recreation, power generation, etc.). These costs also omit the expenditures required to maintain the lower Columbia River Navigation System.

- **Congestion and Safety** – Barge transport also relieves roadway congestion and is far safer than shipping via rail or truck. With less traffic on roadways, Snake River navigation is estimated to save drivers approximately $6 million/year in reduced roadway incidents (Columbia River System EIS, 2020; ECONorthwest, 2019).

- **Emissions** – Barges have low-energy demands, requiring less fuel per ton of commodity shipped compared to alternative shipping modes. Snake River navigation is projected to reduce greenhouse gas emissions by 15%-30% annually within the region, generating savings of $3.2-$7.1 million/year (Columbia River System EIS, 2020).

- **Regional Economic Impacts** – River navigation supports many regional producers and provides many local jobs. Loss of commercial navigation is estimated to cost regional economies $22-77 million/year (Columbia River System EIS, 2020). Loss of cruise line operation is estimated to reduce regional expenditures by $15 million per year (Macuck 2019; Pacific Northwest Waterways Association)

*Table 1: Literature Review*

| Study | Methods | Shipping Costs | Maintenance and Infrastructure | Congestion and Safety | Emissions | Regional Economic Impacts |
|---|---|---|---|---|---|---|
| Columbia River System Environmental Impact Study by USACE (2020) | Transportation optimization model | Without Snake River navigation, the cost of wheat transport (accounting for over 90% of volumes along the Snake) would increase by $0.07-$0.24/bushel (a 10-33% price increase). In total, wheat shipping costs would increase by $13-$48 million/year. | Increased demand on the rail network would necessitate short rail improvements costing a total $30-$36 million and may require increased rail terminal capacity costing $0-$50 million. Increased demand on the road network is projected to increase road maintenance costs by $2-$10 million/year. The report does not detail navigation-related operation and maintenance costs of the Snake River System.[2] | Snake River navigation reduces highway congestion, which increases highway safety. Truck travel is expected to increase by 87-391 million ton-miles without Snake River navigation. | Greenhouse gas emissions would increase by 15%-30% annually (0.077-0.090 MMT $CO_2$) without Snake River navigation. The social costs of these emissions are $3.2-$3.8 million/year. | Reduced farm incomes caused by increased shipping costs are projected to reduce regional economic output by $22-$77 million/year. Loss of cruise line operation may reduce regional expenditures by $15 million/year. |
| National Transportation Impacts & | Expert interviews | Interviewees projected that without Snake River navigation, their | Based on adjusted values from the 1999 Lund HDR Drawdown Study, road | Without Snake River navigation, | Barging on the Snake River results in fewer | This report does not detail the net effect of |

[2] Operation and maintenance costs for the Snake River Dams are $75 million/year and annual equivalent capital costs are $31 million/year. In addition to operation and maintenance, and capital costs the Columbia and Snake River systems also incur a $233 million/year expense as part of their Strategic Asset Management Plan. This report does not detail cost allocations by river section or by dam use (i.e., a portion of these costs can be attributed to navigation on the Snake River, but not all of them). The report does clarify that non-routine navigation-related operating expenses of the lower Snake River dams cost $10 million/year.

| | | | | | | |
|---|---|---|---|---|---|---|
| Regional Economic Impacts Caused by Breaching Lower Snake River Dams by FCS GROUP (2020) | | shipping costs would increase by $0.20-$0.40/bushel. | and rail infrastructure capital costs are projected to be $872 million. It's worth noting, however, that since 1999 Lund HDR Study several infrastructure projects have already been completed including increased elevator capacity and new shuttle rail terminals. | highway miles driven will increases, resulting in increased traffic incidents costing an additional $5.9 million/year. | emissions than the rail and trucking alternatives. These reduced emissions are valued at $7.1 million/year. | Snake River navigation on the regional economy but does note that many counties and business rely on the Snake River to ship their products. |
| Lower Snake River Dams Economic Tradeoffs of Removal by ECONorthwest (2019) | Shipping mode choice model | The shift to higher cost shipping modes increases total shipping costs by $6.2 million/year. Notably, commodity data used in this report is restricted to grain shipments originating in western Washington.[3] | Additional road and rail infrastructure projects are projected to cost $14-$17 million and $113-$136 million, respectively. Road maintenance costs are projected to increase by $13-$15 million. | Car crashes are projected to increase costing $43.7-$49.2 million from 2026-2045. | The shift to more ton-miles traveled by truck increases emissions with equivalent to total economic loss of $17.8-$20.4 million from 2026-2045. | This study conducts an IMPLAN analysis of dam removal. Removal of the four lower Snake River dams is projected to decrease total output by $237 million, decrease value added by $99 million, and decrease labor income by $76 million. |
| The Value of Natural Capital in the Columbia River Basin: A | Assume all ton-miles traveled by barge | Columbia and Snake River navigation is estimated to provide | Lock operation and maintenance costs on the Columbia and Snake | N/A | N/A | N/A |

[3] If the report included all commodity originations across Washington, Oregon, and Idaho, the net change in shipping costs would likely be higher.

| | | | | | | |
|---|---|---|---|---|---|---|
| Comprehensive Analysis by Earth Economics (2017) | are transferred to rail | shipping cost savings of $13.2 million/year. | Rivers are $47.9 million/year. | | | |
| Lower Snake River Dam Navigation Study by Rocky Mountain Econometrics (2015) | Assume all ton-miles traveled by barge are transferred to rail | Snake River navigation is projected to provide shipping cost savings equal to $7.6 million/year. | Lower Snake River dam maintenance and infrastructure costs total $227 million/year. Maintenance and infrastructure costs attributable to Snake River navigation are estimated to be $17.8-$21.2 million/year. | N/A | N/A | N/A |
| Lower Snake River Juvenile Salmon Migration Feasibility Report and Environmental Impact Statement by USACE (2002) | Assume 29% of grain is diverted to rail transport, with the remaining being shipped by truck. | By shifting grain to rail and truck transport, shipping costs are projected to increase by $0.06-$0.21/bushel. Total transportation costs are projected to increase to $38 million/year. | Snake River dam breaching was projected to require $50-$89 million in rail infrastructure improvements, and $84-$101 million in highway improvements. Grain elevator capacity would also need to be expanded costing $60-$352 million. | Increased traffic as a result of dam breaching would decrease highway safety. | Emissions would increase due to the loss of barge transportation. | N/A |

Much of the existing literature has focused on the impacts of closure (dam breaching) on the Lower Snake River. Closure of the Lower Snake River to navigation (dam breaching) is not considered in this research. ***This project, instead, examines the economic impacts of navigation on the Columbia-Snake River System under a baseline scenario and three alternative operating scenarios.***

## 5. DATA

For this project, several datasets and industry experts were used to compile accurate information on shipment volumes, commodity prices, transportation costs, and transportation infrastructure. This information is used to describe current operations on the river system in particular, and the transportation network as a whole. This information is also used to develop and parameterize transportation optimization models, for evaluating the three operational scenarios.

The United States Army Corps of Engineers (USACE) maintains two primary sources of data pertaining to river shipments.

- The first are monthly lock reports, which total monthly tonnages moving through each lock on the Columbia-Snake Rivers across 8 commodity categories: Food and Farm Products; All Manufactured Equipment and Machinery; Chemicals and Related Products; Crude Materials, Inedible, except Fuels; Petroleum and Petroleum Products; Primary Manufactured Goods; Waste Material, Garbage, Landfill, Sewage Sludge and Waste Water; and Others, NEC (Not Elsewhere Classified). This lock data is useful in providing tonnages at specific points in time and at specific locations, but does not capture intra-pool movements or provide river segment aggregate volumes, and is only available for 2020-2021.

- A second data source produced by the USACE are system-wide annual reports, which aggregate tonnages for each year for each river segment across 142 commodity categories. These reports provide detailed commodity categories, include intra-pool movements, and provide aggregate volumes for each river segment for each year. Data from the reports was used for the period 2000-2019. For the Columbia-Snake River System, the USACE reports on 5 river segments: the Columbia River, from the Mouth to the International Boundary; the Columbia River from the Mouth to Vancouver on the Columbia River, and to Portland on the Lower Willamette River; the Columbia River between Vancouver, WA and The Dalles, OR; the Columbia River from The Dalles, WA to McNary Dam; and the Snake River from Pasco, WA to Lewiston, ID. The USACE also report two aggregate measures for the entire river system: Total Waterborne Commerce within the Columbia River Basin; and Total Waterborne Commerce on the Columbia River System, including the Lower Snake and Lower Willamette Rivers. Because the focus of this report is on movements upriver of the lower Columbia River ports (Portland/Vancouver), most summary data will focus on movements on these upriver segments: the Columbia River between Vancouver, WA and The Dalles, OR; the Columbia River from The Dalles, WA to McNary Dam; and the Snake River from Pasco, WA to Lewiston, ID. Unless otherwise noted, quoted volumes for the Columbia-Snake River System are for the segment between Vancouver, WA and The Dalles, OR (this captures most traffic transiting the network of locks).

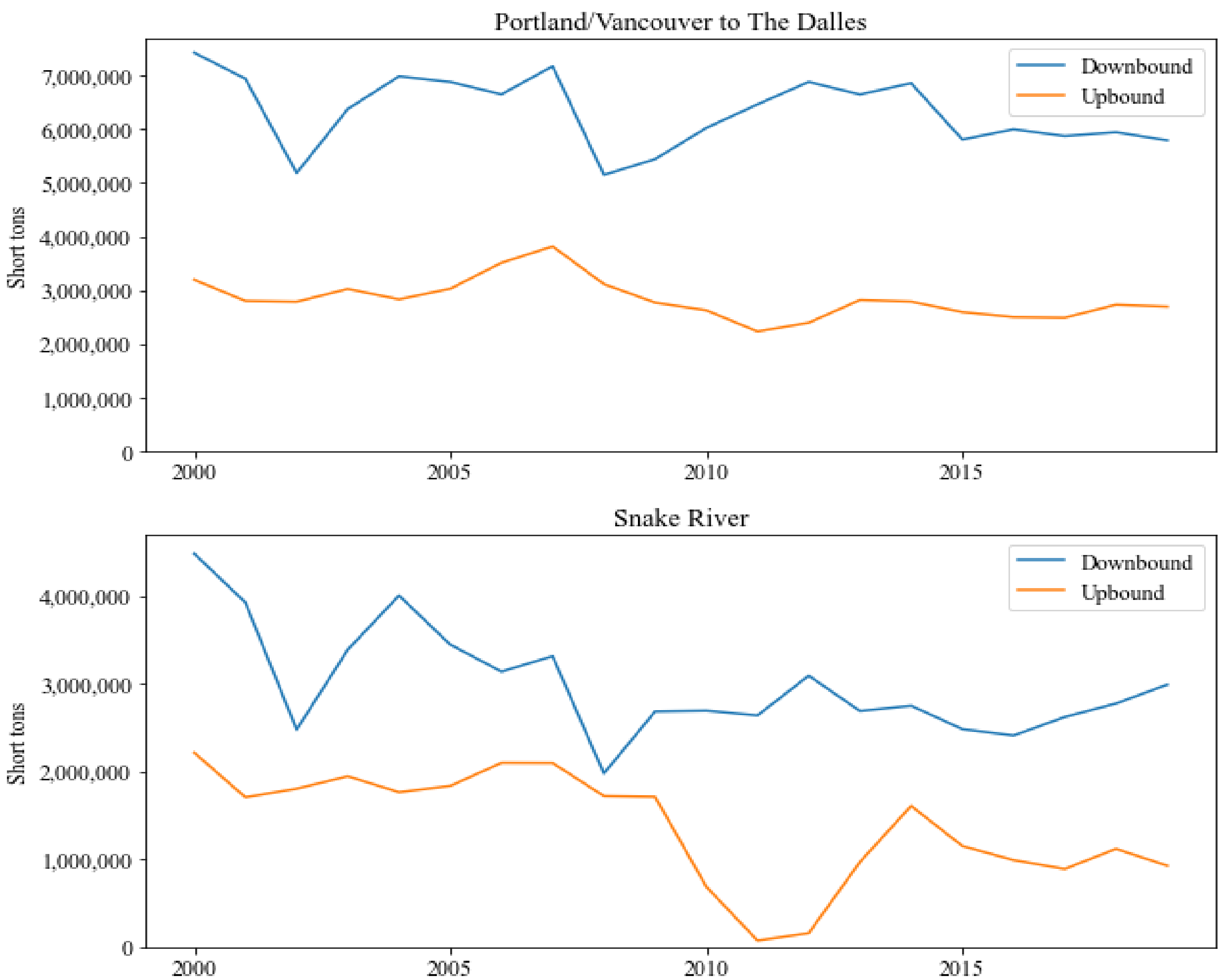
From 2000 to 2019, barge volumes on both the Columbia and Snake Rivers have been on the decline (Figure 10). Total volumes on the Columbia River upriver of Portland/Vancouver to The Dalles declined 11% between 2000-2019, from 9,577,005 tons/year between 2000-2005 to 8,486,169 tons/year from 2015-2019. Over the same time frame, total volumes on the Snake River declined from 5,503,670 tons/year to 3,674,646 tons/year, a 33% reduction. This decline in volumes is attributed to the reduction in container service at the Port of Portland, improvements in rail infrastructure in the region, and growing fuel production in the interior U.S., among other factors.

Historically downbound traffic has been much higher than upbound traffic. In 2019 downbound traffic on the Columbia River upriver of Portland/Vancouver to The Dalles totaled 5,791,843 tons, nearly double the upbound traffic of 2,696,997 tons.

### Highest Volume Commodities

The highest volume commodity moving on the river systems is by far Wheat, Barley & Rye (Figure 12). These volumes are produced in the arid regions of Eastern Oregon and Eastern Washington, before being trucked to river ports where they are loaded onto barges and transported to lower Columbia River ports for export. Approximately 4,401,257 tons/year of Wheat, Barley & Rye moved downbound Columbia River between Portland/Vancouver and The Dalles from 2015-2019, a 9% reduction relative to 2000-2005 volumes. Meanwhile the Snake River saw a 30% reduction in Wheat, Barley & Rye volumes over the same time period, from 3,366,435 tons/year in 2000-2005 to 2,373,807 tons/year from 2015-2019.

*Figure 10: Total barge volumes (2000-2019)*




The second highest volume commodity moving on the river system is Sand & Gravel. Sand & Gravel moves both upbound and downbound, mostly between Vancouver and Pasco, to serve construction needs in the region (large volumes of Sand & Gravel move below Vancouver, but movements on these lower river segments are beyond the scope of this report). From 2015-2019, downriver Sand & Gravel volumes totaled

552,468 tons/year (Figure 12). Over the same time frame upbound Sand & Gravel tonnages totaled 1,045,430 tons/year.


*Figure 11 Barge on Columbia-Snake River*

In addition to Sand & Gravel, considerable volumes of Gasoline & Distillate Fuel Oil are moved upbound on the river system (Figure 13). Fuel movements, however, have also been on the decline. Between 2000 and 2005, approximately 2,066,059 tons of fuel were moved each year, whereas from 2015-2019 the river system saw an average of only 1,036,275 tons/year. Over the same time period tonnages of Sand & Gravel shipped increased from 367,024 tons/year between 2000-2005 to 1,045,430 tons/year from 2015-2019.

Together grains, fuel, sand and gravel account for 83% of total tonnages moving on the Columbia River system, and 88% of total tonnages moving on the Snake River. Grains alone account for over 84% of all tonnages moving on the Snake River upriver of Ice Harbor Dam.

Other downbound products on the river system include: Wood in the Rough, 182,961 tons/year; and Wood Chips, 96,195 tons/year. Recent years have also seen an uptick in volumes of Alcohols, mostly ethanol, moving downriver, accounting for 275,014 tons in 2019. Other products moving upbound include: Waste and Scrap NEC, 298,816 tons/year; Fertilizer, 82,096 tons/year; and Wood Chips, 28,969 tons/year.

Volumes of river shipments by commodity vary throughout the year (Figure 15). Wheat (Food & Farm Products) and fertilizer (Chemicals & Related Products), for example have high volumes hitting the river during the harvest and planting seasons respectively. Peaks in fuel deliveries can also be seen that correspond to peak summer demand periods. Because of the time sensitivity of many products moving on the river it is important that the river system can operate at peak capacity to move high volumes within tight time windows.

*Figure 12: Downbound barge volumes (2000-2019)*

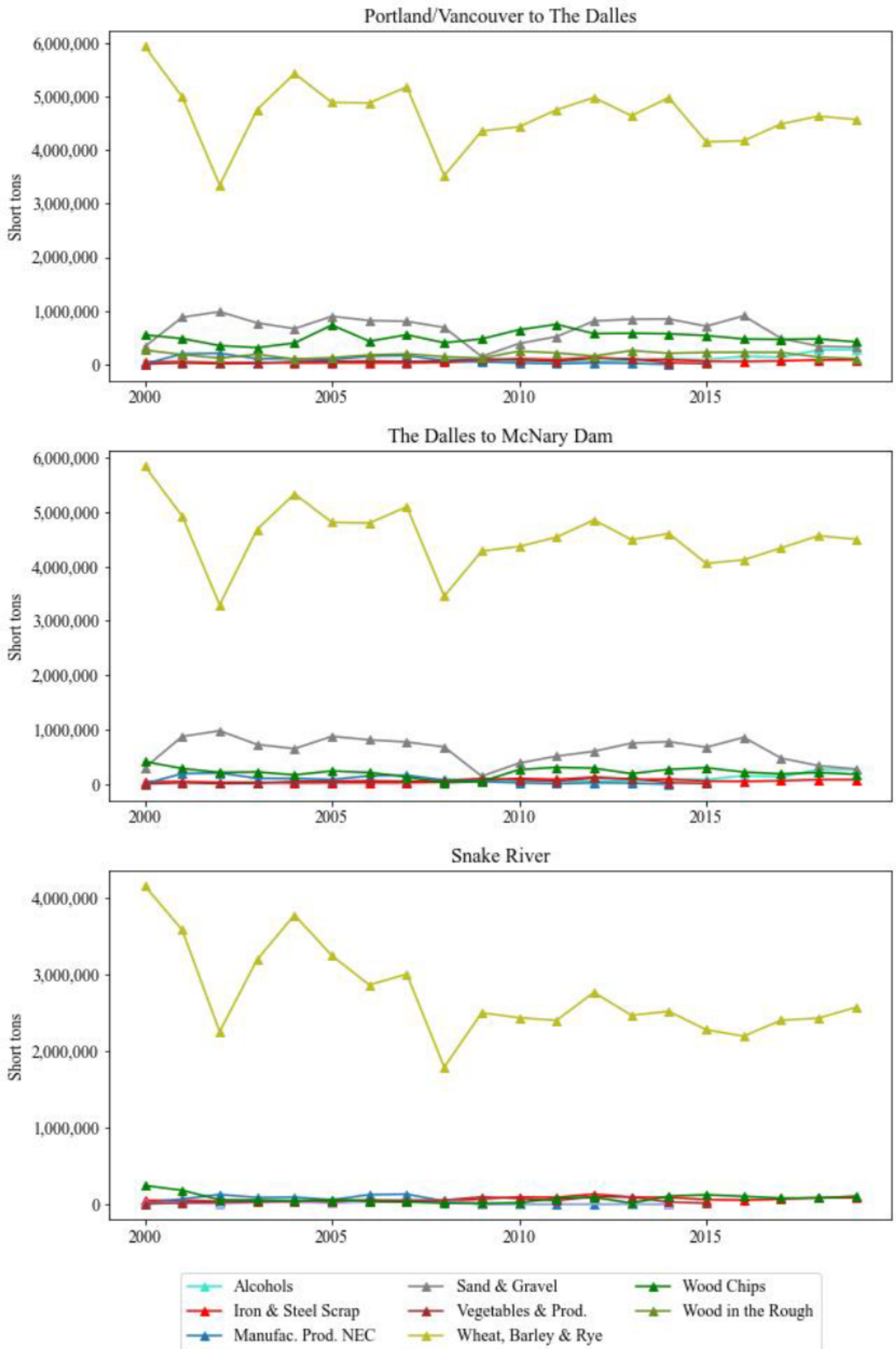


*Figure 13: Upbound barge volumes (2000-2019)*

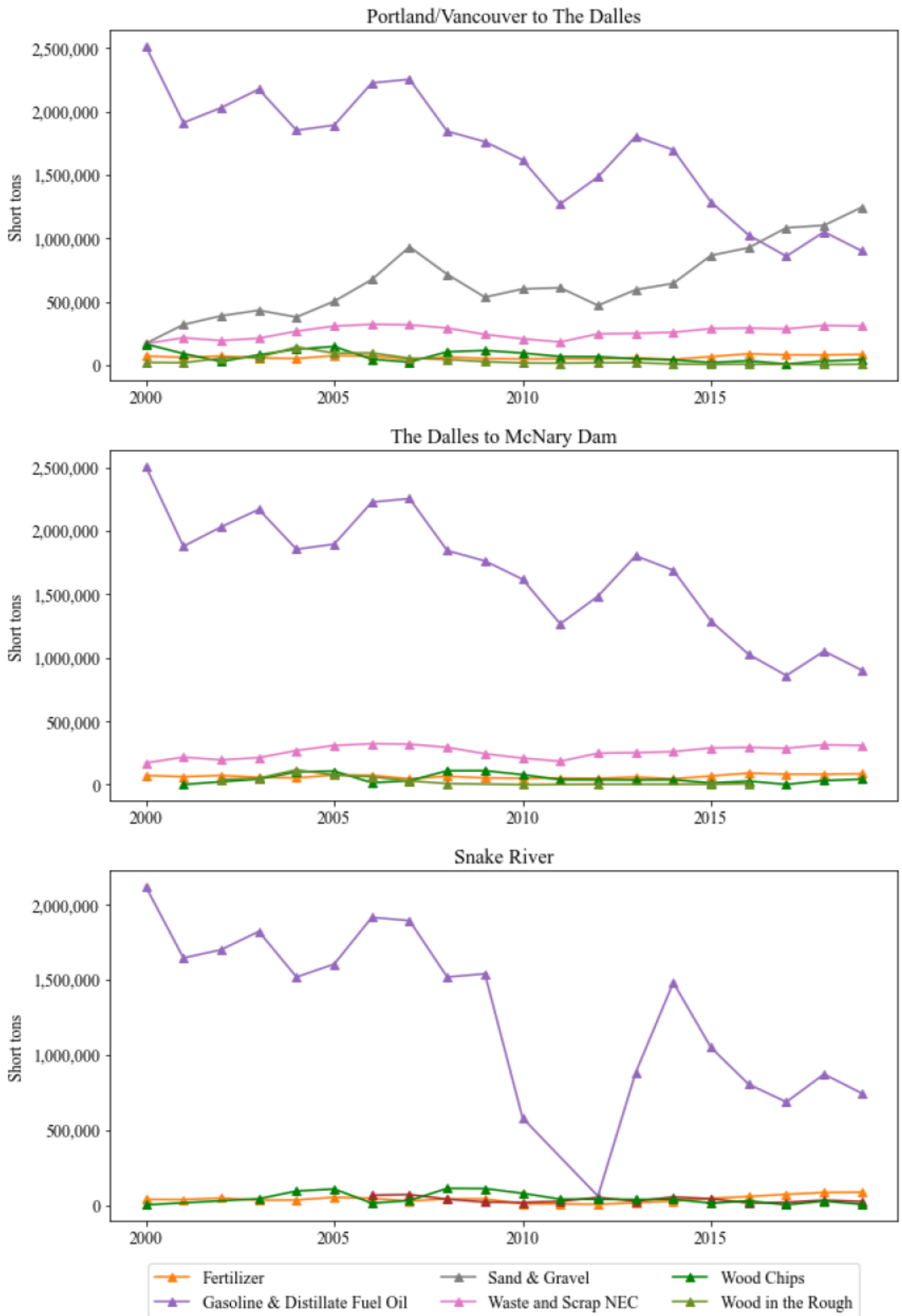


*Figure 14: Barge volumes by lock (2020)*

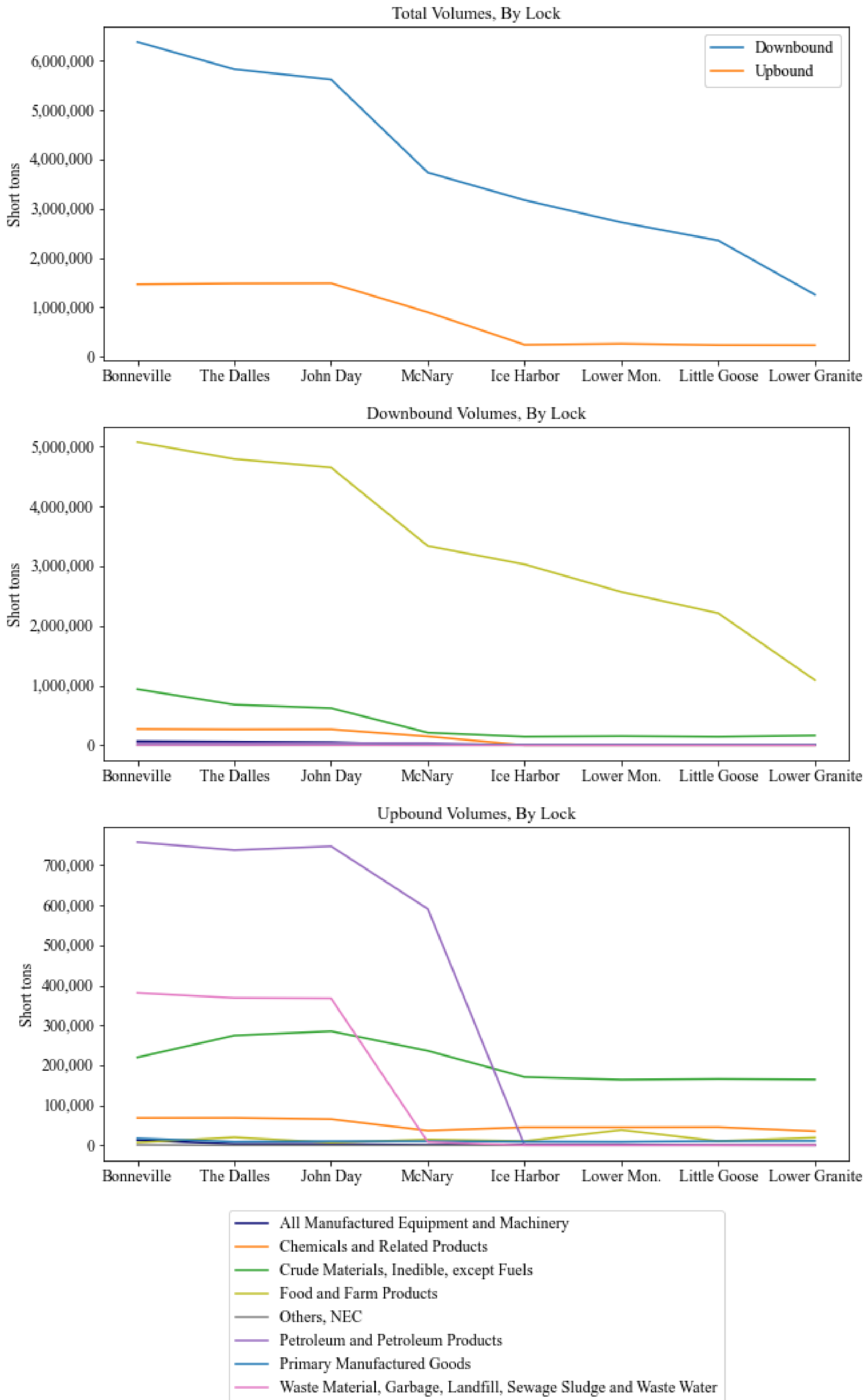
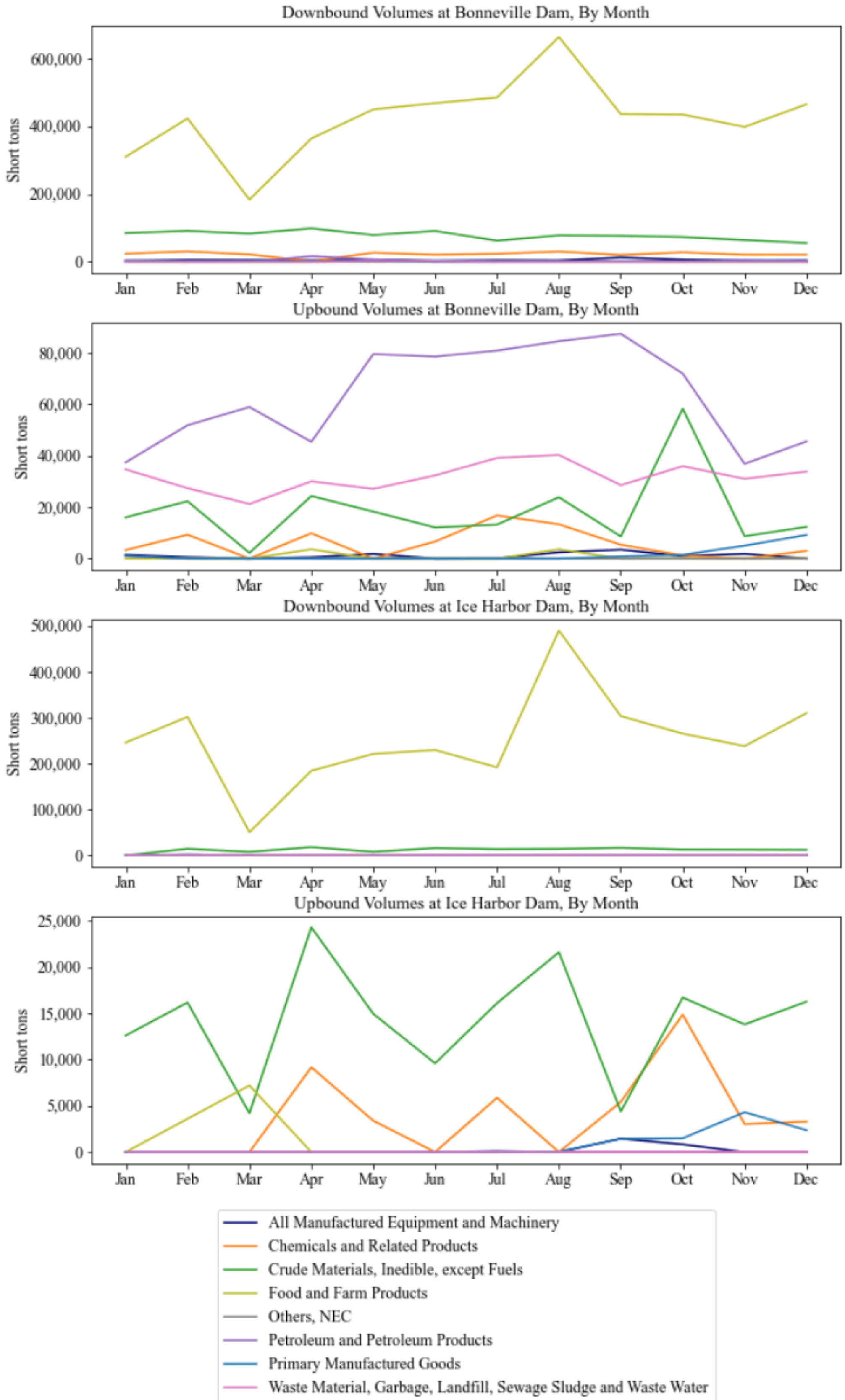


*Figure 15: Monthly barge volumes by lock (2020)*

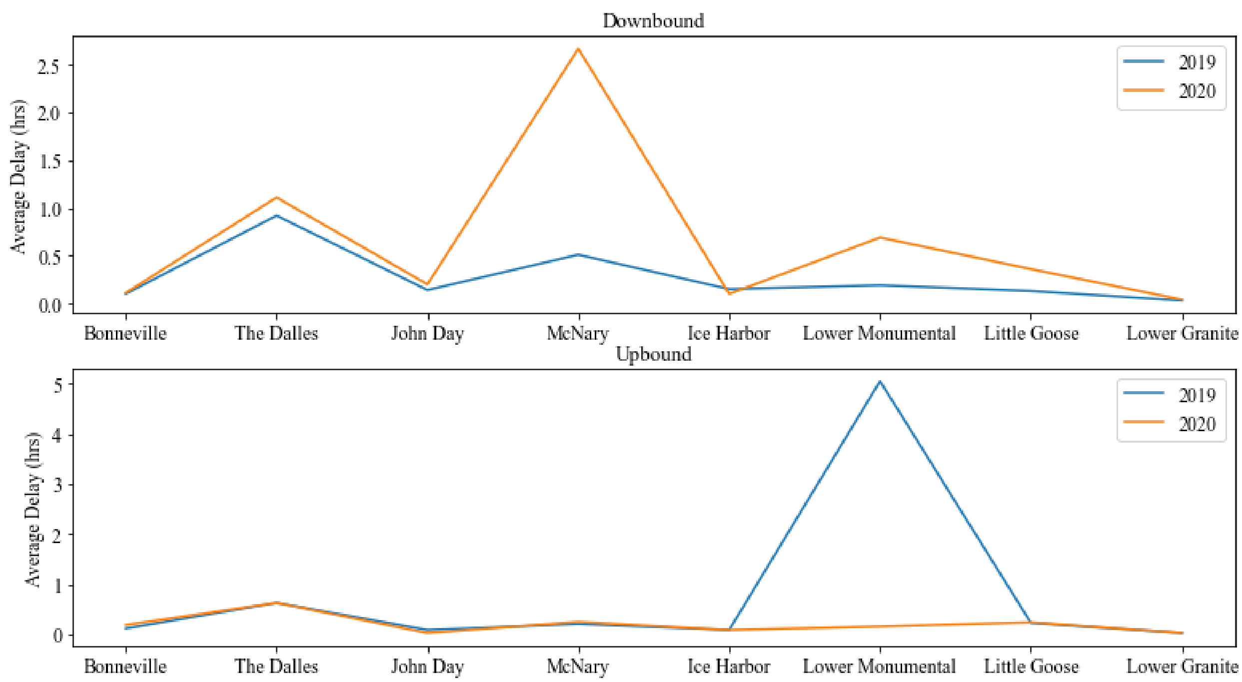


## 6. CURRENT OPERATING CONDITIONS

The Columbia-Snake River System is in relatively good operating condition and does not experience the frequent unplanned outage or long lockage delays that are experienced on the Mississippi and Missouri River Systems.

Columbia-Snake River shipments faced on average 29-minute delays at each lock in 2019 and 2020 (Figure 16) (USACE Lock Performance Monitoring System). [4] In 2019, upbound shipments faced longer delays on average, caused by high delay times at McNary Dam. In 2019, downbound shipments also faced longer delays on average, caused by high delay times at Lower Monumental Dam. Both upbound and downbound delays contribute to increased operating costs for tugs, resulting in increased shipping costs. Delays also result in late deliveries, which can require the repositioning of ocean liners at the lower Columbia River ports, holdups in production supply chains, and in some cases missed delivery time windows.

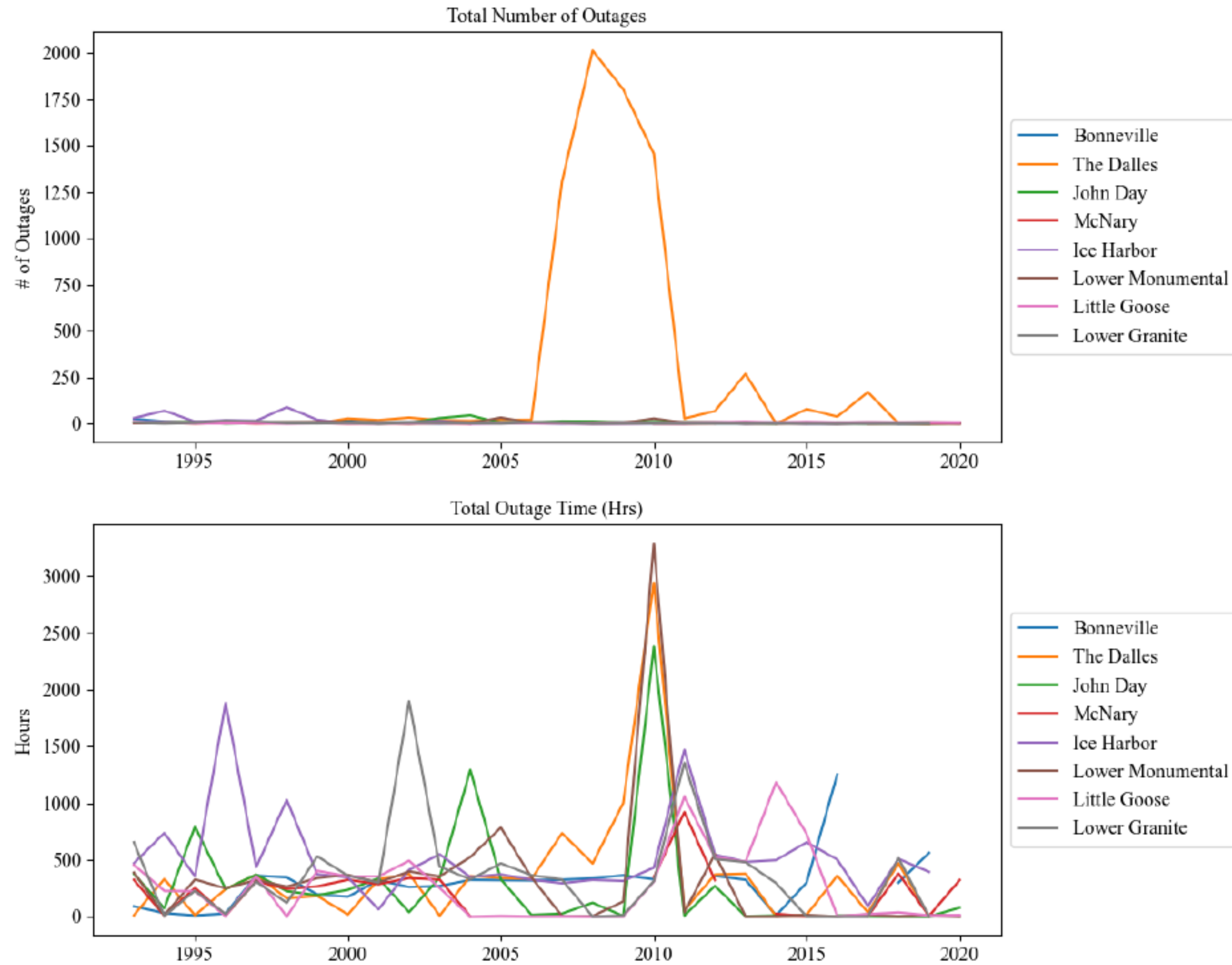
*Figure 16: Average Delay Time*




In addition to routine delays, the Columbia-Snake River System also faces both scheduled and unscheduled outages. Since 1993, the quantity and time of outages on the Columbia-Snake River System have been relatively constant (Figure 17). On average, the Columbia-Snake River navigation system experiences 40 outages annually, totaling 337 hours in unavailable time (USACE Lock Performance Monitoring System). These outages can be either planned, or unplanned. The majority (92%) of outages are unplanned, though unplanned outages make up only a small share (6%) of total unavailable time (21 hours of unplanned outages per year). Most unplanned outages are resolved relatively quickly; the average unplanned outage lasts approximately 35 minutes. Planned outages, on the other hand, account for only 8% of total outages, but are responsible for 94% of total unavailable time (315 hours of planned unavailable time per year).

[4] Lock delays represent the time between barge arrival and the start of lockage.

*Figure 17: Outage by Lock*




Planned and unplanned outages affect shippers differently. For planned outages, shippers can typically adjust their shipment volumes, modes, and timing, to mitigate the cost of the outage. For unplanned outages, shippers are forced to either face the delay if their barge shipment is already underway, delay their shipment until the outage is resolved, or schedule an alternate transport mode. Each of these outcomes are costly to shippers who may incur fees for delayed deliveries or face additional operating costs (tug crew time, etc.). Unplanned outages are also costly for the manufacturers/farmers/producers that rely on barge shipments as inputs to their production, as late shipments may disrupt supply chains (e.g., late arrival of fertilizer can dramatically affect yields.)

To mitigate the risks of unplanned outages and keep up on general maintenance, the Columbia-Snake River navigation system typically closes for 3 weeks each year, at the beginning of March. These outages do disrupt the navigation system, but they are planned, relatively routine, and are therefore well prepared for by shippers and producers/manufacturers.

A longer, and much more disruptive planned outage occurred with the closures of Bonneville, The Dalles, and John Day locks from December, 2010, through March of 2011. To mitigate the impacts of this closure, barge shipments were increased in the months prior- and post-outage, to defer some of the costs of mode switching required to ship during the outage. With these mitigation strategies employed, the 2010-2011 extended lock outage resulted in the average cost of wheat shipment to increase by $0.06/bushel (13%) (Simmons et al., 2012). Notably, total wheat shipments during this time-period were also increased due to supply shortages (Russia) and increased commodity prices.

## 7. METHODOLOGY

Economic impacts of Columbia-Snake River Navigation are estimated using a two-stage approach. In the first stage, shippers' transportation decisions and costs are evaluated using a transportation optimization model to estimate shipping costs for each commodity under the baseline and three alternative operating scenarios. Then, in the second stage, the economic impacts of changes in shipping costs across each scenario are estimated for each state and commodity using a regional economic input-output model (IMPLAN).

Baseline commodity flows represent production and river shipment volumes in model year 2019. Baseline transportation costs represent shipping costs by mode for each commodity in model year 2019. Baseline costs assume no change in investment levels on the river system, resulting in no change in barge shipping efficiencies (costs).

The transportation optimization models, commodity flows, and baseline transportation cost estimates are provided for each commodity in Section 8. Appendix Section A1 provides additional detail about the transportation optimization models. Section 9.1 provides estimates of commodity flows and transportation costs for each commodity for each alternative operating scenario. Section 9.2 provides estimates for economic impacts of Columbia-Snake River navigation at baseline and under the three alternative operation scenarios for each state and commodity.

## 8. TRANSPORTATION OPTIMIZATION MODEL

To measure economic impacts of Columbia-Snake River navigation under different operating scenarios, constrained transportation optimization models are developed to capture the choices that the region's shippers face. These models identify the shipment mode, route, and costs for each commodity and each shipper.

Three models are developed, each representing one of the primary markets served by Columbia-Snake River System: grains, petroleum products, and nitrogenous fertilizer. These transportation optimization models are designed to capture the choices faced by shippers moving products to market. Other commodities including aggregates (sand and gravel), and forest products are also considered, but the necessary information to generate rigorous transportation models are not available. Instead, for these commodities only existing river moves are analyzed. In total, grain (wheat), fuel, fertilizer, forest products, and aggregates comprise more than 92% of the tonnage moved on the river system.

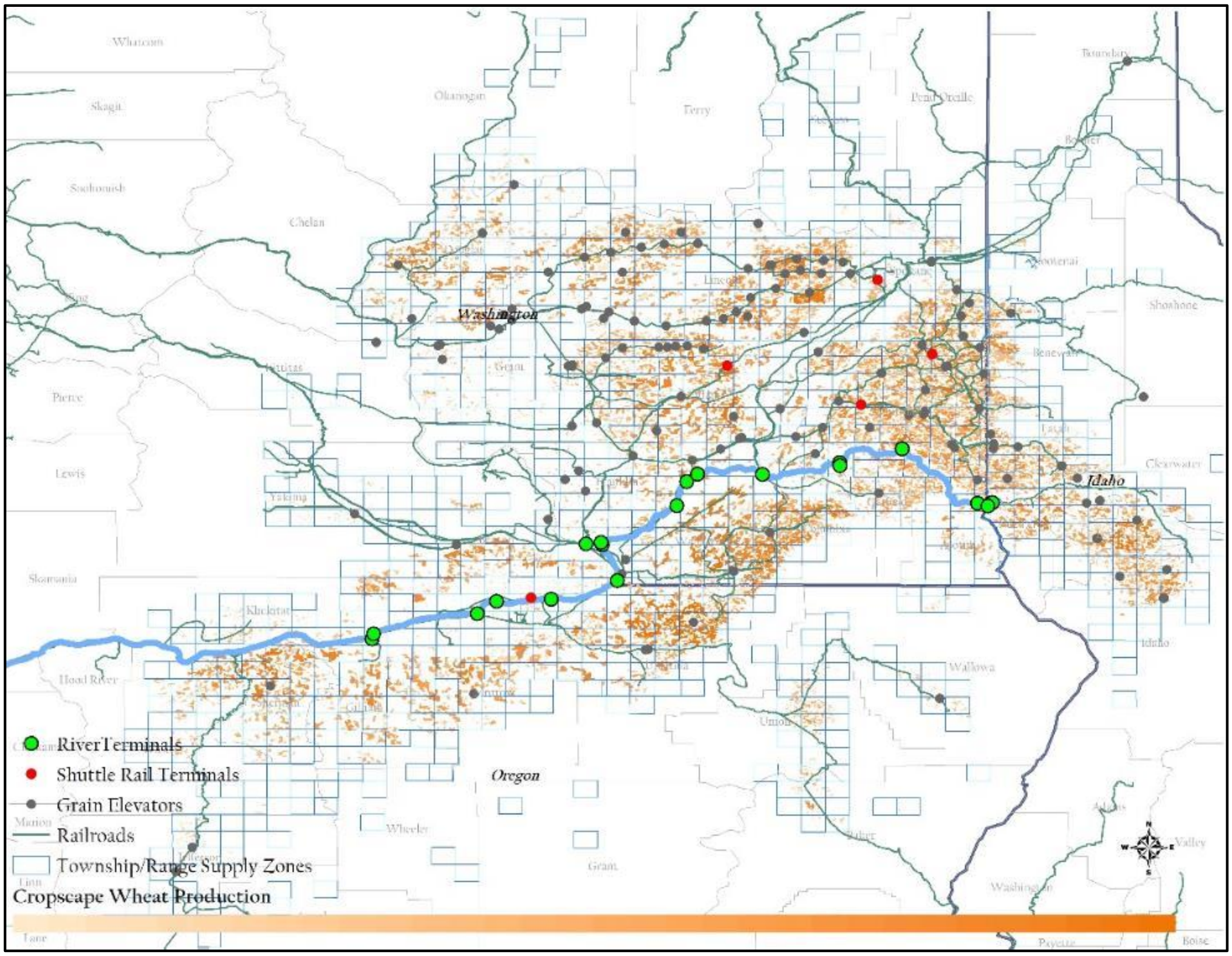
Data is compiled from a variety of sources to parameterize each model and establish the constraints and choice alternatives, representing current conditions, as they exist. At baseline each model is parameterized to reflect existing river movements provided by the USACE. Each of the following sections describe the relevant markets, their transportation networks, and details on how the models are developed.

## 8.1 Grain

The region's grain production is concentrated in the arid regions of Eastern Washington and Eastern Oregon (Figure 19). These regions account for 202,583,270 bushels or 6.1 million tons of grain production (USDA). Most of this production is shipped to Lower Columbia River ports to be exported. To reach these export ports, grain is typically trucked from the farm (production/supply zone) to elevators, shuttle rail terminals, or river terminals. Grain arriving first at elevators is aggregated and then moved to either export terminals directly via truck or rail, or onto shuttle terminals or river terminals. Grain arriving at shuttle rail or river terminals is typically shipped directly to export ports.

*Figure 18: Loading Barge with Wheat on Columbia -Snake River*

*Figure 19: PNW Wheat Production and Facilities*




USDA's CropScape Database provides detailed location-based grain production estimates. Using information from producers and satellite imagery, the CropScape Database identifies grain production for more than 17,000 land parcels within the study region (in orange in Figure 19). For modeling purposes, these individual land parcels are grouped and aggregated into Township/Range Supply Zones (blue rectangles in Figure 19). In total there are 991 Supply Zones, each representing a production location from which grain is shipped.

To move grain from production regions to export ports, shippers rely on the intermodal transportation network comprised of highways, railroads, and barge shipping channels. Shippers are assumed to make their decisions about how to transport their product to export ports by considering the costs of shipping via each mode (truck, non-shuttle rail, shuttle rail and barge) and selecting the mode/route combination that minimizes their expected transportation costs.

The costs of each shipping mode depend on the distances travelled and the per-mile shipping rates. Information on grain shipping rates was collected by a survey of grain shippers (USACE Columbia River System EIS, 2020 (Appendix L)), and used to construct ton-mile rate functions for grain shipping via truck, rail, and barge. Grain shipping via truck is the most expensive mode costing on average $0.0044/bushel-mile ($0.14/ton-mile) (Figure 20). Trucking, though, is often the most convenient/versatile mode, allowing shippers to move product between the farm and terminals. Rail and barge shipping is typically more cost competitive, especially when shipping large volumes over long distances; non-shuttle rail shipping costs on average \$0.0016/bushel-mile (\$0.052/ton-mile) and barge shipping costs on average \$0.00128/bushel-mile (\$0.042/ton-mile) (Figure 21 and 22). The average shuttle rail rate across the 4 rail shuttle facilities is \$0.001345/bushel-mile (\$0.044/ton-mile). A handling charge of five cents per bushel is also included for any shipment delivered to grain elevators, shuttle facilities or river ports. These costs assume no change in investment in transportation infrastructure (no gains in efficiency on the river system).

Information on the location and capacities of grain elevators and river ports was collected from USDA grain facilities and the states warehousing licensing division. This information serves as capacity constraints in the transportation optimization model. Baseline shipment and processing volumes were collected from the shipper survey.

*Figure 20: Estimated Grain Truck Rates*

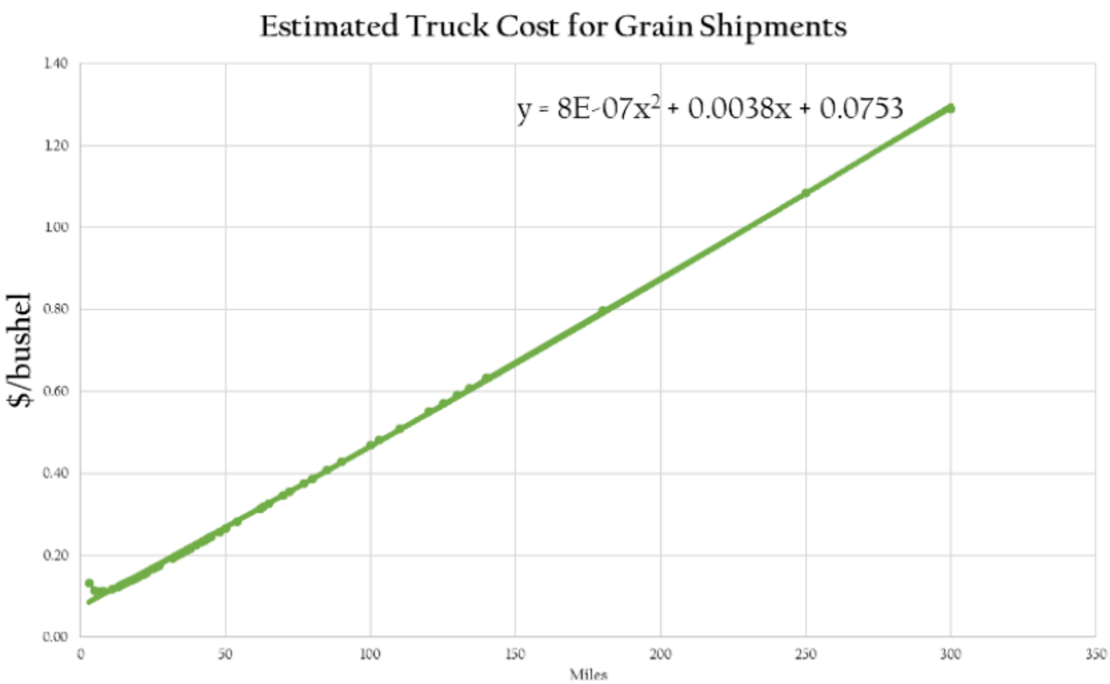


*Figure 21: Estimated Non-Shuttle Rail Cost Function*

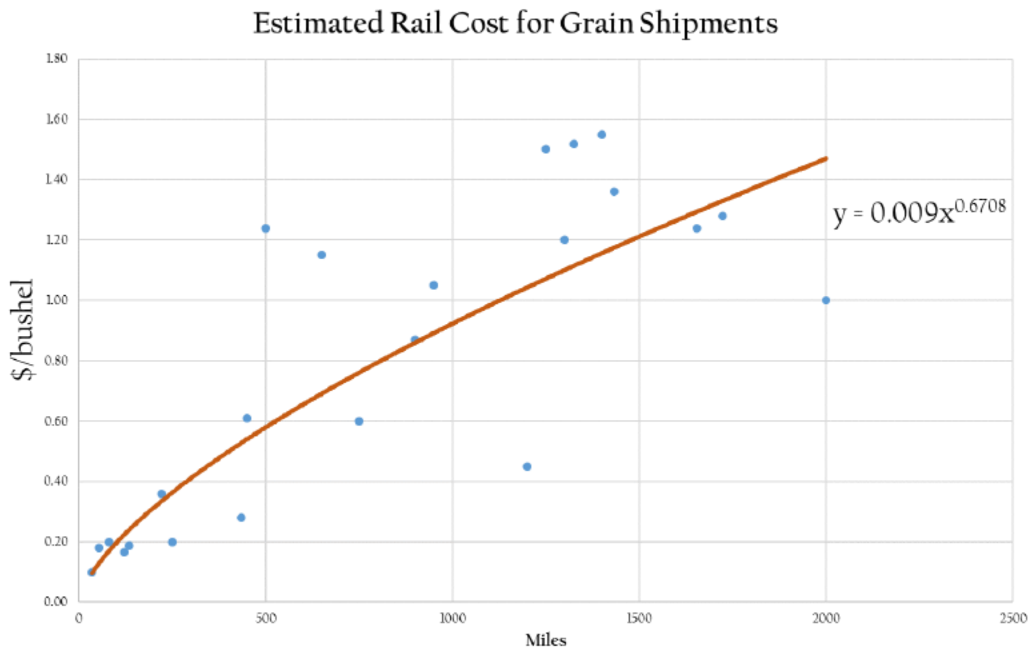
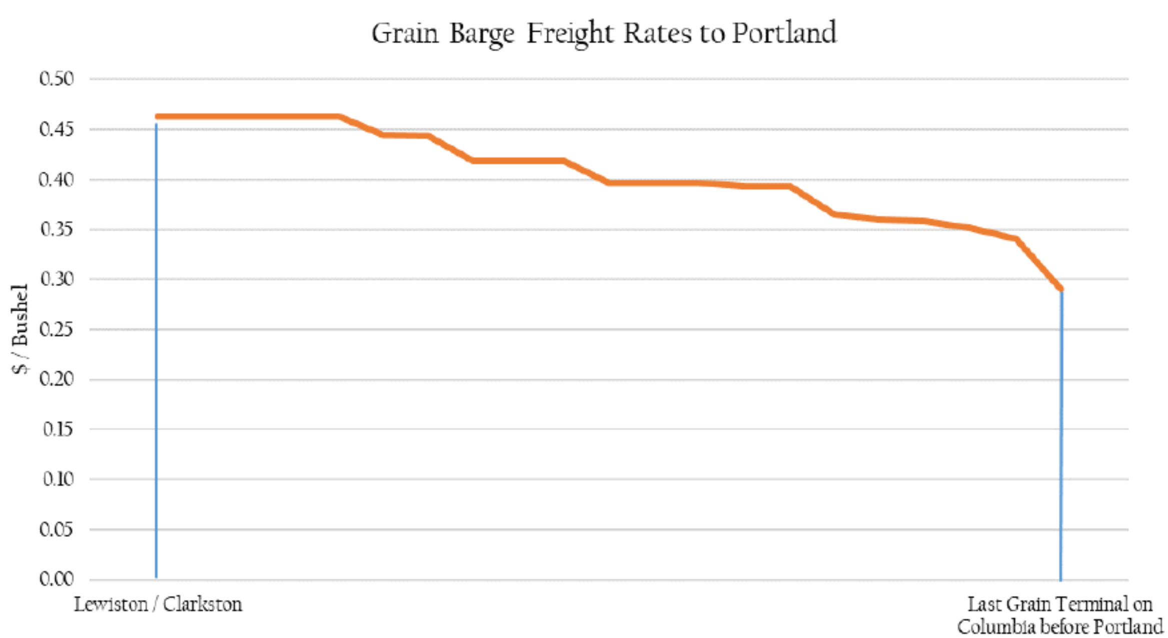



*Figure 22: Barge Freight Rates*



### 8.1.1 Baseline Results

Baseline grain flows are constrained within the model to replicate model year 2019 conditions. This is achieved through constraints on supply, intermediate facility capacity and final demand. The total flow through the model represents one year of grain production and the choice of mode-combination is determined by minimizing transportation costs. Each supply point is constrained by the volume of grain produced and each of the intermediate facilities are constrained by the volume they can process. All volumes produced (6.1 million tons) are assumed to be shipped to the final demand point of Portland, OR.

The results of baseline grain flows are presented below. Table 2 provides volumes and expenditures by mode. Approximately 65 percent of grain production within the study region is moved to export via barge. The other 35 percent of grain volumes are moved to export via shuttle rail. Most volumes arriving at river port barge facilities and shuttle rail facilities arrive via truck transport off the farm. Non-shuttle rail, however, also serves as an intermediary between the farm and the river ports and the farm and the shuttle rail facilities.

While the transportation cost to move grain from production to final market varies depending on specific geographic location, in aggregate the cost to move all 6.1 million tons to market is $23.84 per ton (72 cents per bushel). Total grain transportation costs and average unit costs/ton by county are shown in Figures 24 and 25 respectively. The ton-miles generated across all modes is just above 2 billion ton-miles and approximately 8 percent of those ton-miles are on the highway (truck). Total region-wide transportation costs under the baseline scenario are $144,905,880.

*Table 2: Baseline Grain Volumes and Expenditures by Mode*

| | Tonnage | Expenditure ($) |
|---|---|---|
| Road | 6,258,690 | 53,327,600 |
| Barge | 3,933,470 | 52,126,800 |
| Rail | 398,690 | 3,193,280 |
| Shuttle Rail | 2,144,030 | 36,258,200 |

The specific highways utilized and the volume of grain moving on highways is illustrated in the baseline scenario map below (Figure 23). The map also illustrates the volumes moving through river port facilities, shuttle rail facilities and elevators that have rail access (but not shuttle rail). The thicker lines and darker colors indicate heavier volumes, as grain shipments become concentrated around river terminals and shuttle rail facilities.

*Figure 23: Grain Baseline Flows*

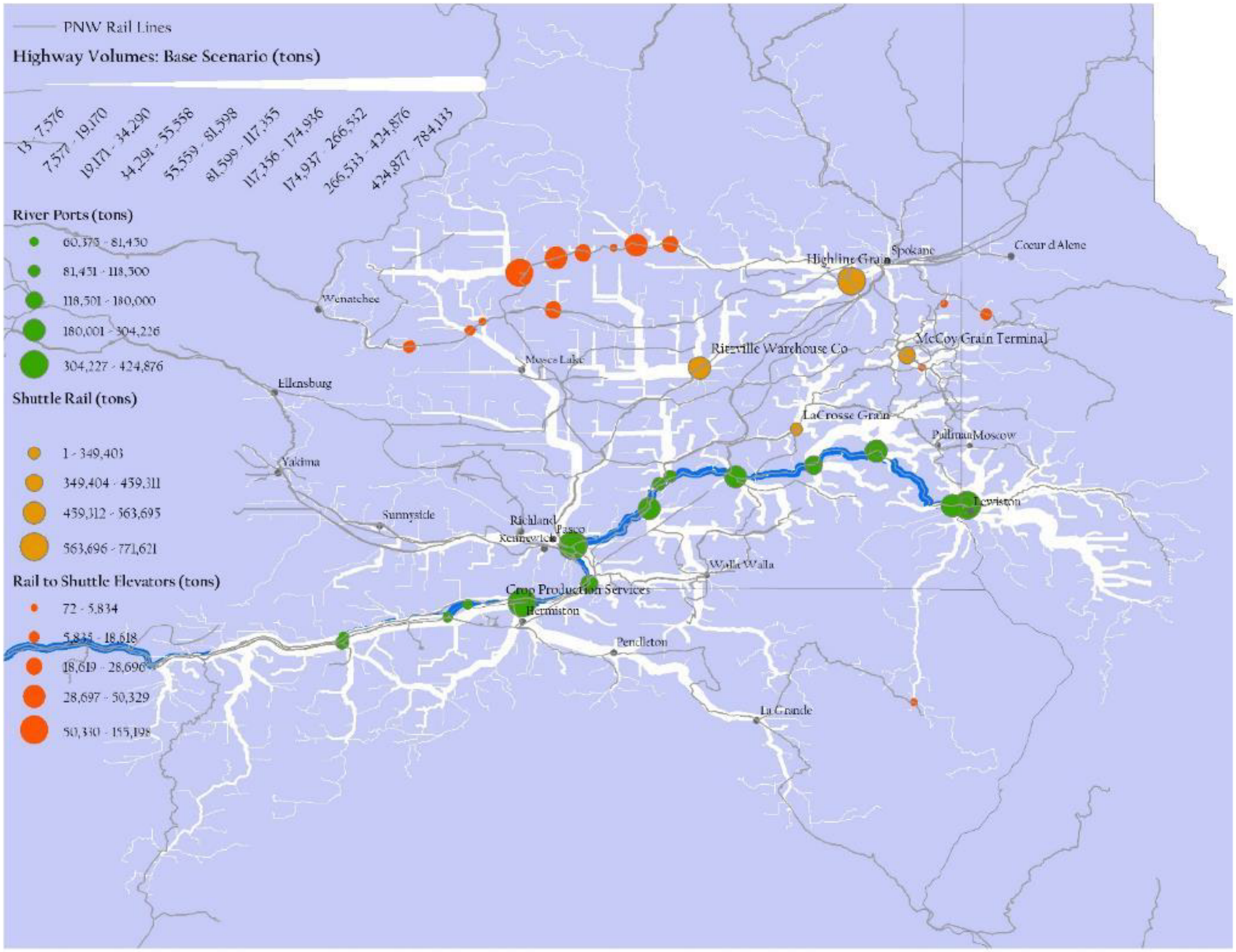


*Figure 24: Grain Baseline Total Transportation Costs by County*

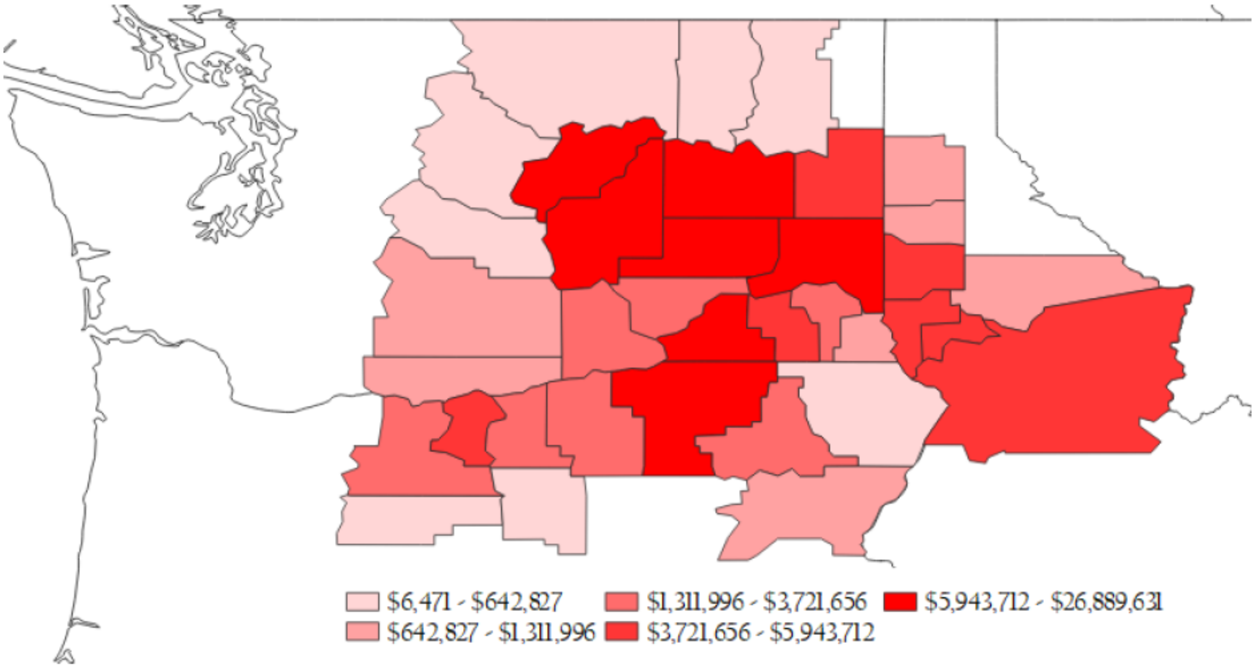
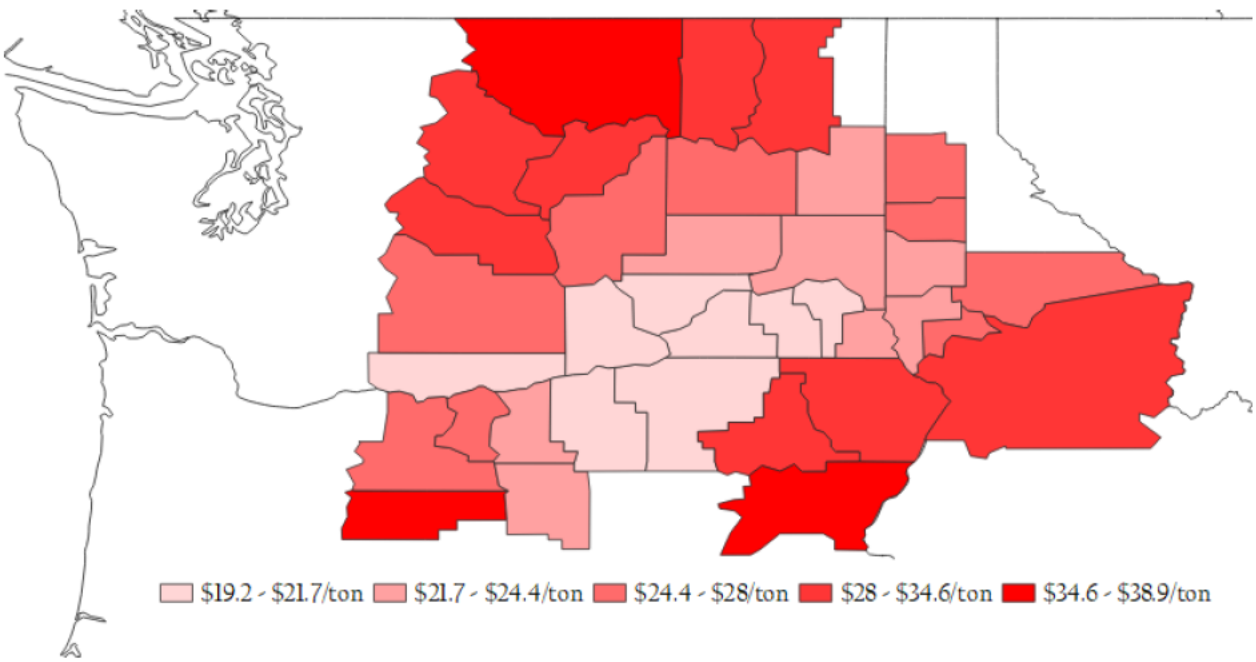



*Figure 25: Grain Baseline Unit Transportation Costs by County*



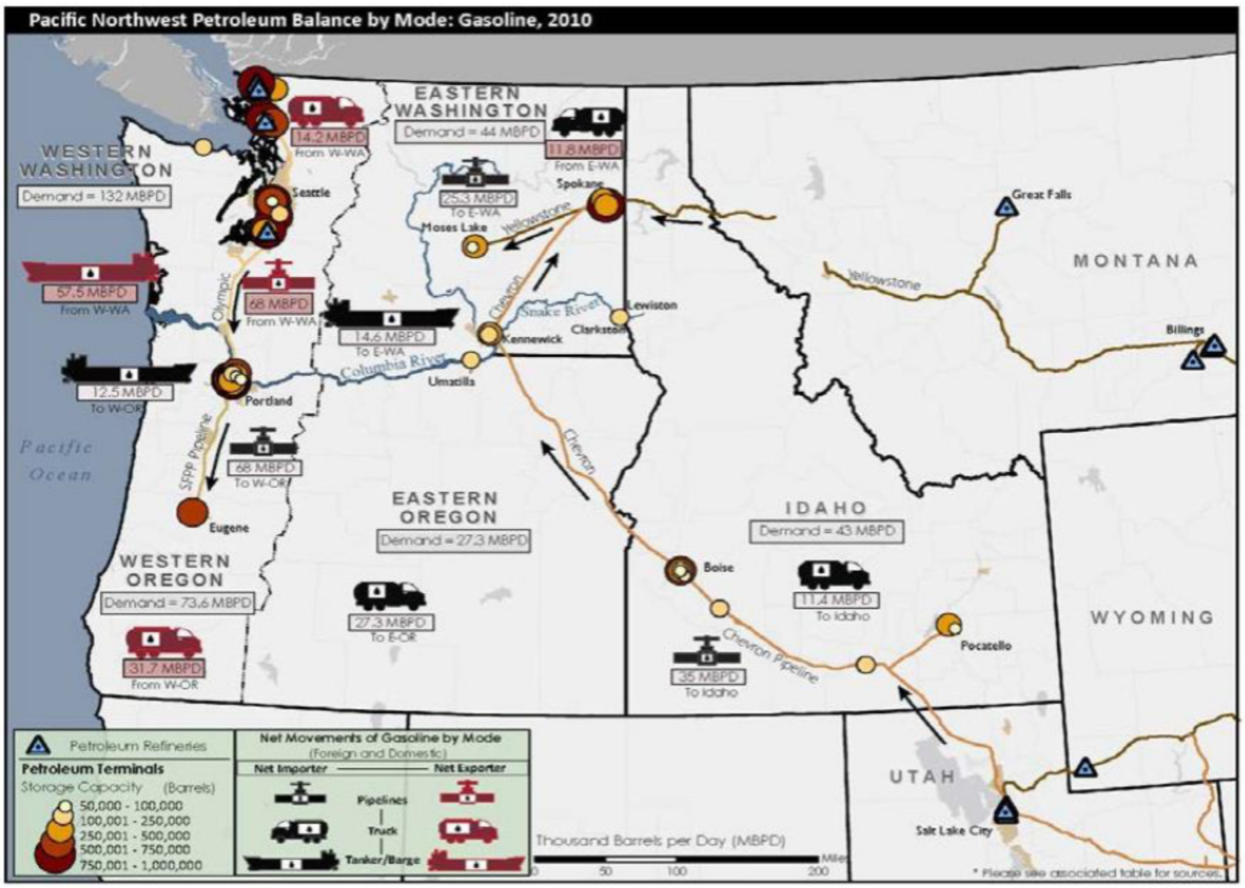

## 8.2 Petroleum

Petroleum movements in the Pacific Northwest originate primarily from production facilities (refineries) in Washington, Montana, and Utah. Transporting finished petroleum products from refineries to fuel stations throughout the Pacific Northwest typically involves trucks, pipelines and in some cases railroads or barges.

There are four main pipelines within the Pacific Northwest (Figure 26):

1. The Olympic Pipeline runs from northwestern Washington, where most WA production is located, to Portland, OR.
2. The Chevron Pipeline runs from Salt Lake City, UT through Idaho, to Kennewick, WA, and terminates in Spokane, WA.
3. The Yellowstone Pipeline runs from Billings, MT to Spokane, WA and terminates in Moses Lake, WA. (The Yellowstone Pipeline is no longer operational between Missoula, MT and Thompson Falls, MT; shipments are transported by rail over this section.)
4. The Kinder Morgan SFPP Oregon Line runs from Portland, OR to Eugene, OR.

*Figure 26: Petroleum Movements and Infrastructure in the Pacific Northwest (EIA)*

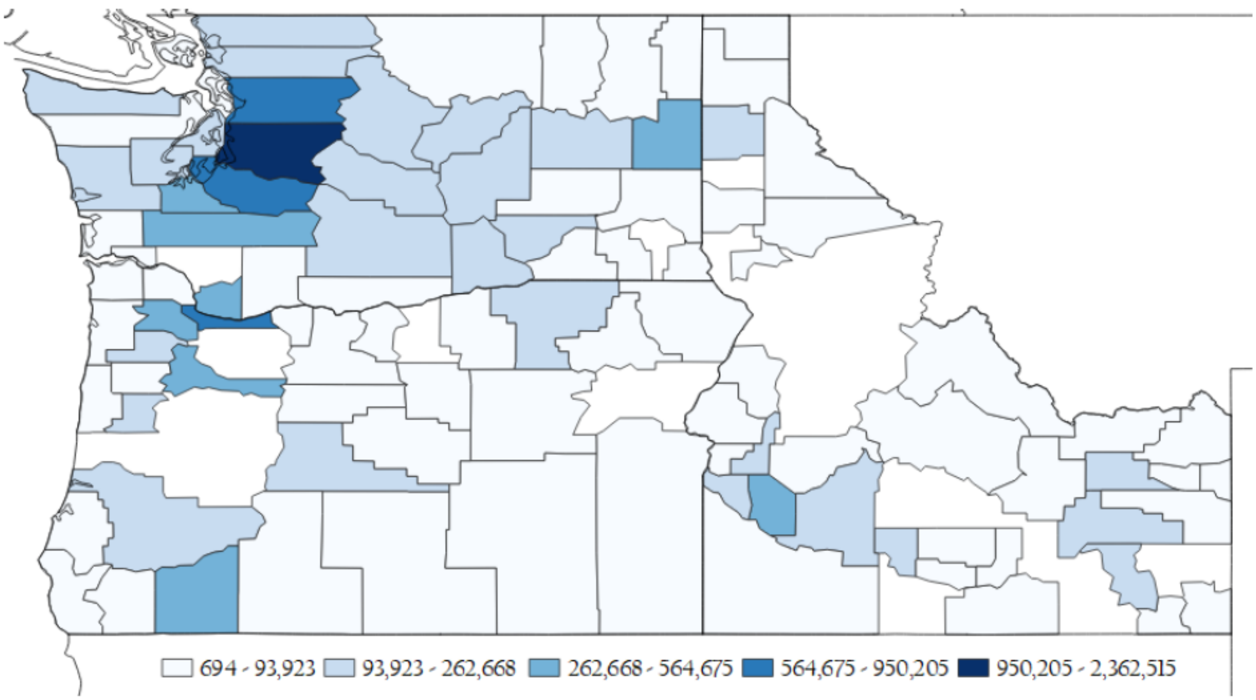



Notably, the pipeline network does not include lines running from northwestern Washington to eastern Washington or eastern Oregon. Transporting petroleum products refined in northwestern Washington to these inland regions, requires either long truck hauls, shipping by rail, or a combination of pipeline and barge shipping.

To transport refined petroleum from western Washington refineries to inland manufacturing, farming, and population centers, shippers often rely on barge shipping on the Columbia River. Barge shipping on the Columbia River (combined with the pipeline network) is a cost-effective way to transport petroleum from western Washington refineries inland. Petroleum movements account for 38% of upbound tonnages on the Columbia-Snake River System. These shipments originate at the Port of Portland and are offloaded to fuel racks at the Ports of Umatilla and Pasco. In addition to barge shipments serving eastern Washington and eastern Oregon, the regions are also served by trucks from western Washington and Idaho, and pipelines originating in Utah and Montana.

Annual petroleum demand is 9,039,812 tons (69,973 thousand-barrels) per year in Washington, 4,902,502 tons (37,948 thousand-barrels) per year in Oregon, and 2,460,294 tons (19,044 thousand-barrels) per year in Idaho (EIA, 2019). County- or zip-code level data on petroleum consumption is not available but is estimated by allocating statewide petroleum demand to zip-codes according to the number of miles driven in each zip-code. Zip-code-level petroleum consumption is assumed to be proportional to total miles driven within each zip code. Aggregate petroleum demand for each county in the study region is shown in Figure 27.

*Figure 27: Petroleum Total Volume Demanded by County (tons/year)*




Transportation costs are estimated to be $0.16/ton-mile for truck shipments, $0.12/ton-mile for rail shipments, $0.06/ton-mile for pipeline shipments, $0.07/ton-mile for barge shipments, $0.03/ton-mile for tanker shipments. Information on actual petroleum transportation costs is limited. Truck rates are estimated using the Iowa State Agricultural Truck Transportation Cost Calculator (Edwards, 2015), and the American Transportation Research Institute's Analysis of the Operational Cost of Trucking (ATRI, 2020). Rail rates are estimated using the Surface Transportation Board's Waybill Sample. Pipeline rates estimated using reported rates from Kinder-Morgan from a FERC ICA Oil Tariff filing (FERC No. 200.19.0), where the reported $0.7797/barrel tariff is converted to a ton-mile cost. Surveyed ton-mile rates from the USACE EIS Grain Shipper Survey (USACE Columbia River System EIS, 2020), and the relative carrying capacity of a petroleum barge, are used to estimate barge-mile transportation costs on the river system, which are then converted to a ton-mile rate. Puget Sound and Olympic Peninsula petroleum tanker costs are imputed to match the observed volume flow.

### 8.2.1 Baseline Results

Baseline petroleum flows are constrained to replicate existing conditions. Total throughput in the model represents one year of refined petroleum shipments throughout the Pacific Northwest. Shipment origins, destinations, volumes, and transportation modes are determined through a network cost minimization problem, subject to logistical (production, capacity) and demand constraints.

In total, the model captures 16.4 million tons of refined petroleum moved annually throughout the Pacific Northwest, costing a total of $265,106,250/year. Most shipment volumes (85%) are moved by pipeline before being moved by trucks to their final destination. Petroleum barge movements on the Columbia Snake River originate from Portland, OR and travel upstream to Umatilla, OR and Pasco, WA; approximately 902,240 tons of fuel were transported on this route in 2019. The baseline model estimates 753,434 tons of fuel moved by barge, approximately 16% less than the volumes observed in 2019, but higher than 2020 volumes (737,983) and consistent with the observed downward trend in fuel shipment volumes (Figure 13). Total volumes and expenditures by mode are shown in Table 3. Petroleum highway flows and terminal throughput are shown in Figure 28.

*Table 3: Petroleum Baseline Volumes and Expenditures by Mode*

| | Tonnage | Expenditure ($) |
|---|---|---|
| Road | 16,402,600.00 | 124,326,000 |
| Rail | 1,064,210.00 | 12,357,600 |
| Barge | 753,434.00 | 9,891,470 |
| Tanker | 1,744,710.00 | 21,601,900 |
| Pipe | 14,065,800.00 | 96,929,800 |

*Figure 28: Petroleum Baseline Flows*

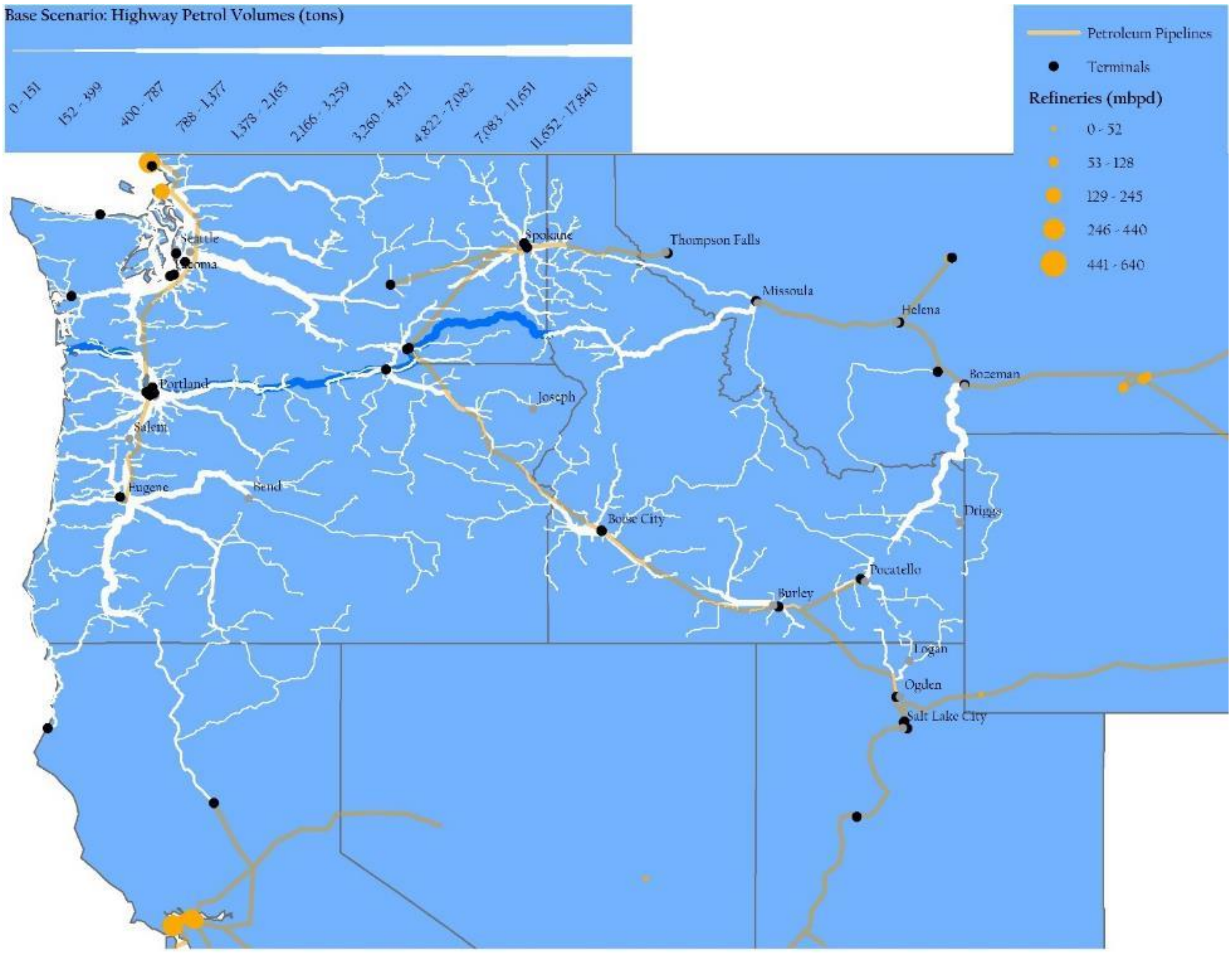


*Figure 29: Petroleum Baseline Total Transportation Costs by County*

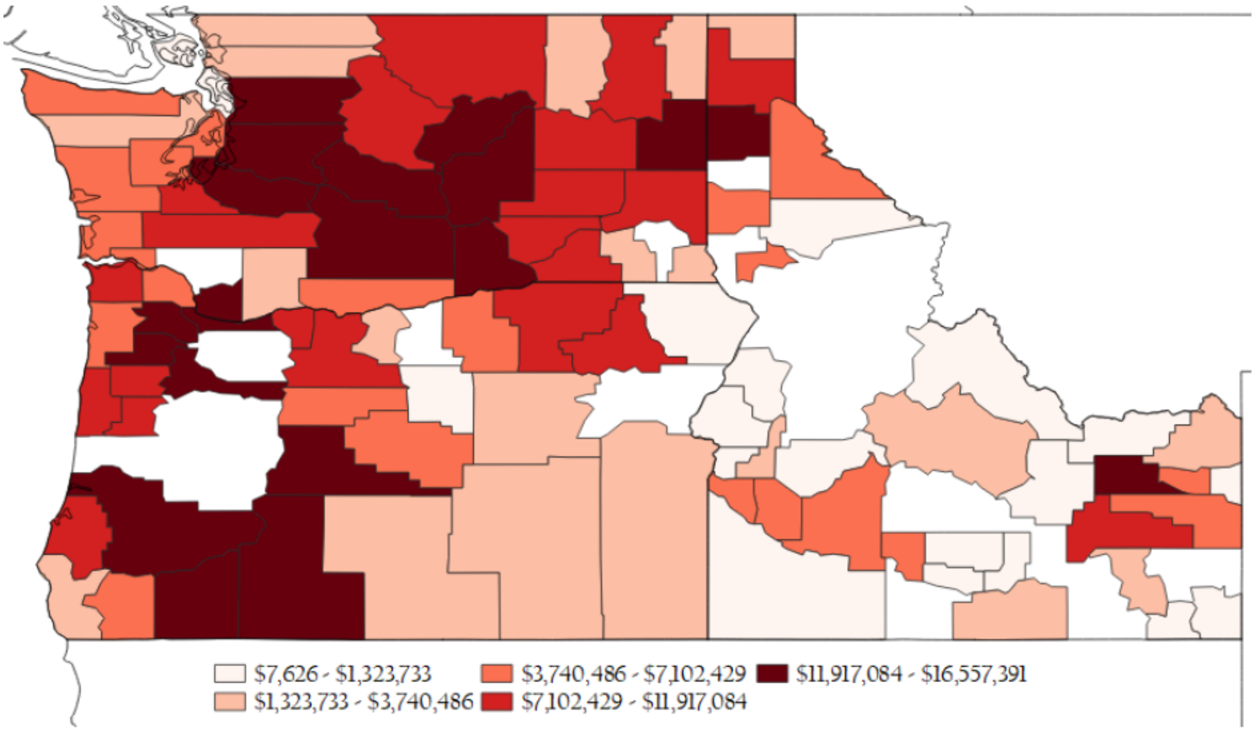
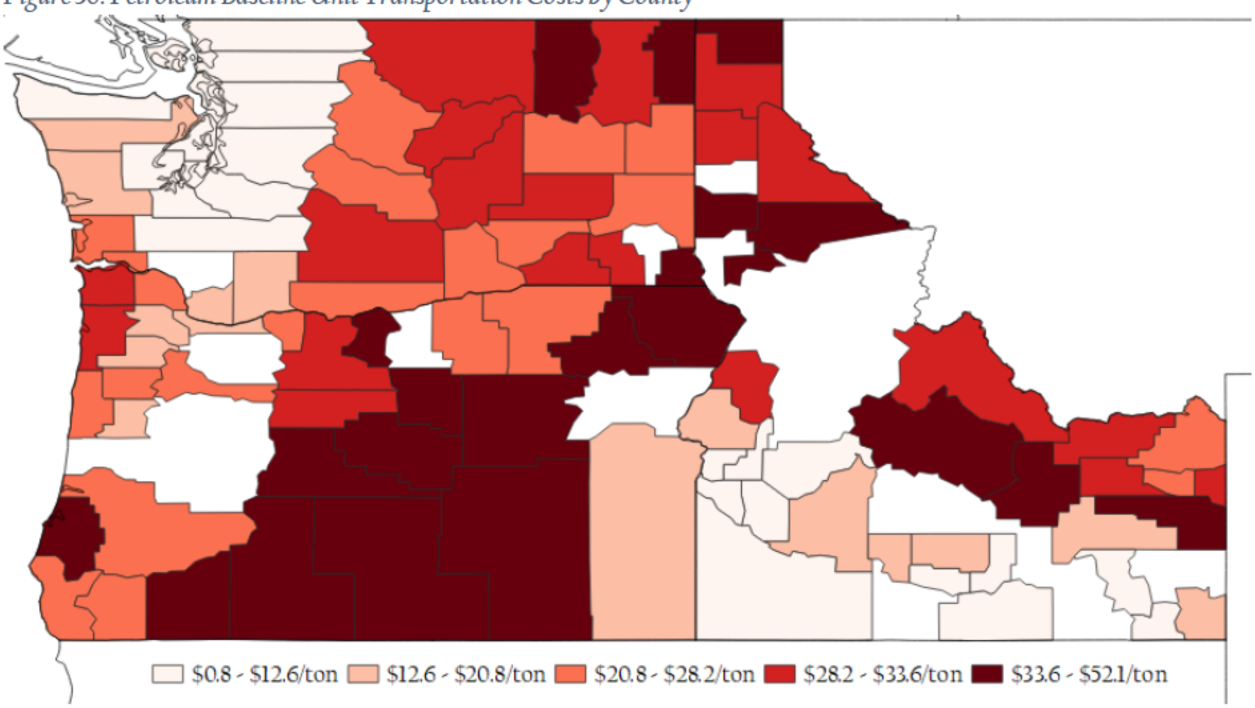



*Figure 30: Petroleum Baseline Unit Transportation Costs by County*



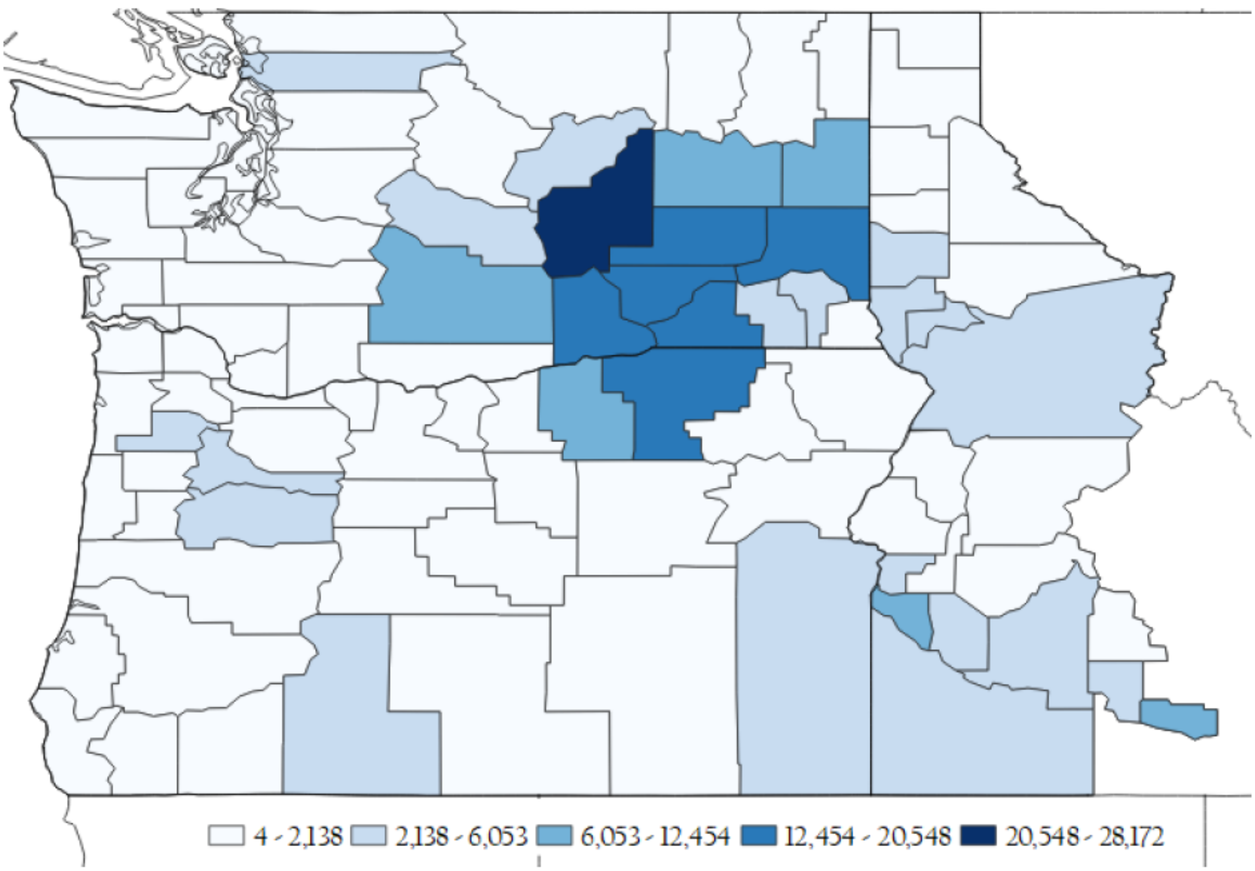

## 8.3 Fertilizer

The Columbia-Snake River System supports shipments of liquid urea-ammonium nitrate (UAN) fertilizer. Within the region, there are two UAN production facilities: one in St. Helens, OR, which produces approximately 110,000 tons of UAN annually, and one in Kennewick, WA, which produces approximately 200,000 tons of UAN/year. An additional 15,000 tons of UAN are imported at lower Columbia River ports each year. Between the production facilities in St. Helens, OR, and Kennewick, WA, regional production exceeds demand in Washington and Oregon. In 2019, Washington farmers applied 165,599 tons of UAN to their fields and Oregon farmers applied 69,423 tons (WSDA and ODA). Excess UAN supply is likely shipped to retailers in nearby states; Idaho applied over 286,838 tons of UAN in 2019.

Fertilizer shipments on the Columbia-Snake River System move UAN from production/import terminals upriver to one of 5 river ports (excluding production facilities): Portland, Umatilla, Pasco, Central Ferry, and Wilma. From these river ports, product is offloaded onto trucks to be shipped to retail locations where it is finished, marketed, and then delivered to fields. Across Washington, Oregon, and Idaho, there are over 250 retail fertilizer locations.

Retail fertilizer locations supply fertilizer to meet farmers' demand. On-farm UAN demand is only reported at the aggregate state level. To recover county-level UAN demand, state-level UAN demand is allocated to counties according to the county-level share of total nitrogenous fertilizer consumption, which is estimated following Stewart et al., (2018, USGS).[5] County-level UAN demand estimates are illustrated in Figure 32, where darker shaded regions correspond to counties with higher UAN demand. Regional UAN demand is concentrated within the Columbia Basin and Palouse regions.

*Figure 31: Estimated UAN Fertilizer Demand by County (tons/year)*




[5] The authors use commercial fertilizer sales, watershed attributes, and cropping practices to estimate county-level nitrogenous fertilizer application. These county-level estimates are used to allocate current state-level fertilizer consumption data to the county-level, for use in the transportation optimization models.

### 8.3.1 Baseline Results

Regional fertilizer supply from production and import facilities is moved to fertilizer terminals, retail locations, and eventually to the farm for use. The transportation flow of fertilizer from production and import facilities to farms within each county is assumed to follow the least cost transportation mode subject to shipping rates and capacity constraints.

Truck shipping rates are estimated to be \$0.094/ton-mile, rail shipping rates are estimated to be \$0.042/ton-mile, and barge shipping rates are estimated to be \$0.03/ton-mile. Information on actual fertilizer transportation costs is limited. Truck rates are estimated using the Iowa State Agricultural Truck Transportation Cost Calculator (Edwards, 2015), and the American Transportation Research Institute's Analysis of the Operational Cost of Trucking (ATRI, 2020). Rail rates are estimated using the Surface Transportation Board's Waybill Sample. Surveyed ton-mile rates from the USACE EIS Grain Shipper Survey (USACE Columbia River System EIS, 2020), and the relative carrying capacity of a fertilizer barge, are used to estimate barge-mile transportation costs on the river system, which are then converted to a ton-mile rate.

The model represents one year of UAN transportation in the region, accounting for 305,000 tons of UAN. Of the 305,000 tons transported through the region, approximately 81,154 tons are estimated to be moved via barge on the Columbia-Snake River System from production facilities in St. Helens and Kennewick to terminals in Umatilla, Central Ferry, and the Port of Wilma. All volumes of UAN must ultimately be loaded onto trucks from river ports or production terminals, where it is shipped to retail facilities and onto farms. Baseline fertilizer flows are shown in Figure 32, where thicker lines indicate a higher concentration of fertilizer truck volumes. River terminal throughput is indicated by the size of the marker on the map.

Baseline transportation costs total \$4,384,515/year; of this, barge transportation costs total \$481,394/year. Figures 33 and 34 show total transportation cost for delivered UAN fertilizer by county, and average unit costs/ton respectively. Counties located within the Columbia Basin pay the most in total fertilizer costs, as they are the highest users, but they also pay the lowest unit costs as they benefit from close proximity to the river, and thus do not have to truck product very far to retail locations/fields.

*Figure 32: Baseline Fertilizer Flows*

*Figure 33: Fertilizer Baseline Total Transportation Costs by County*

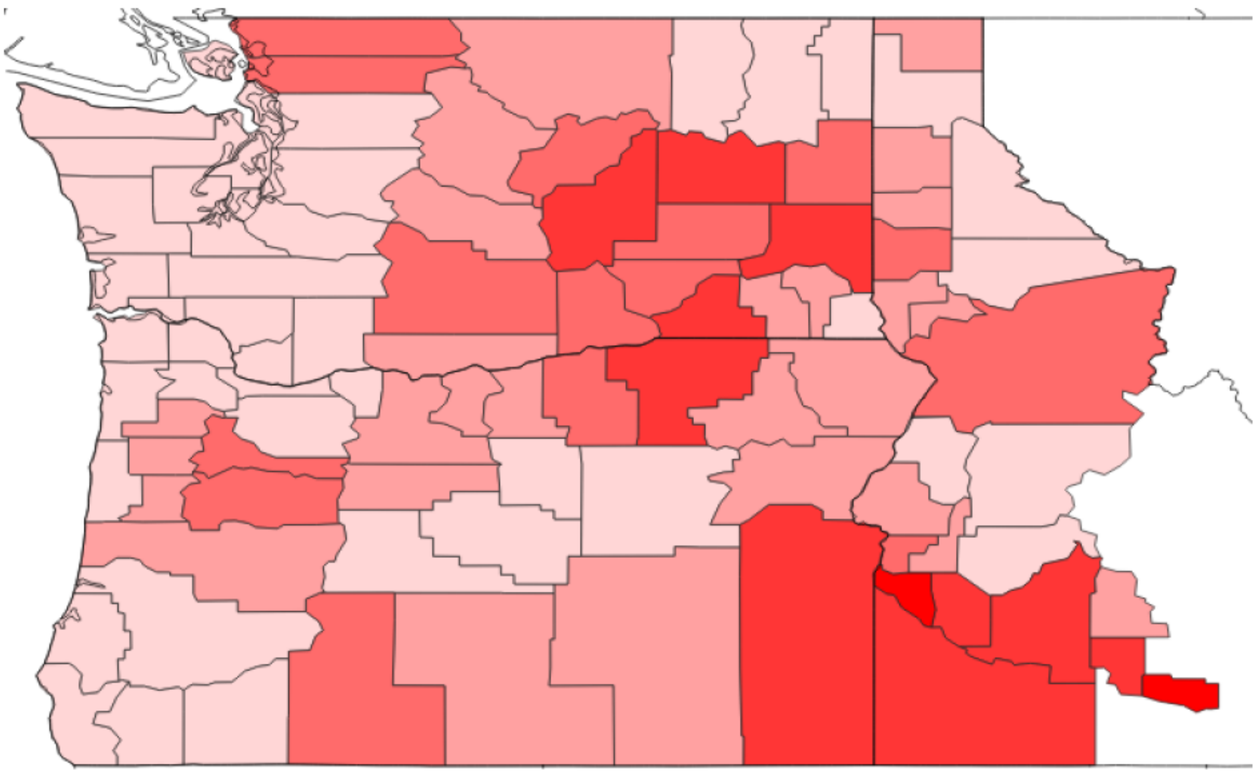
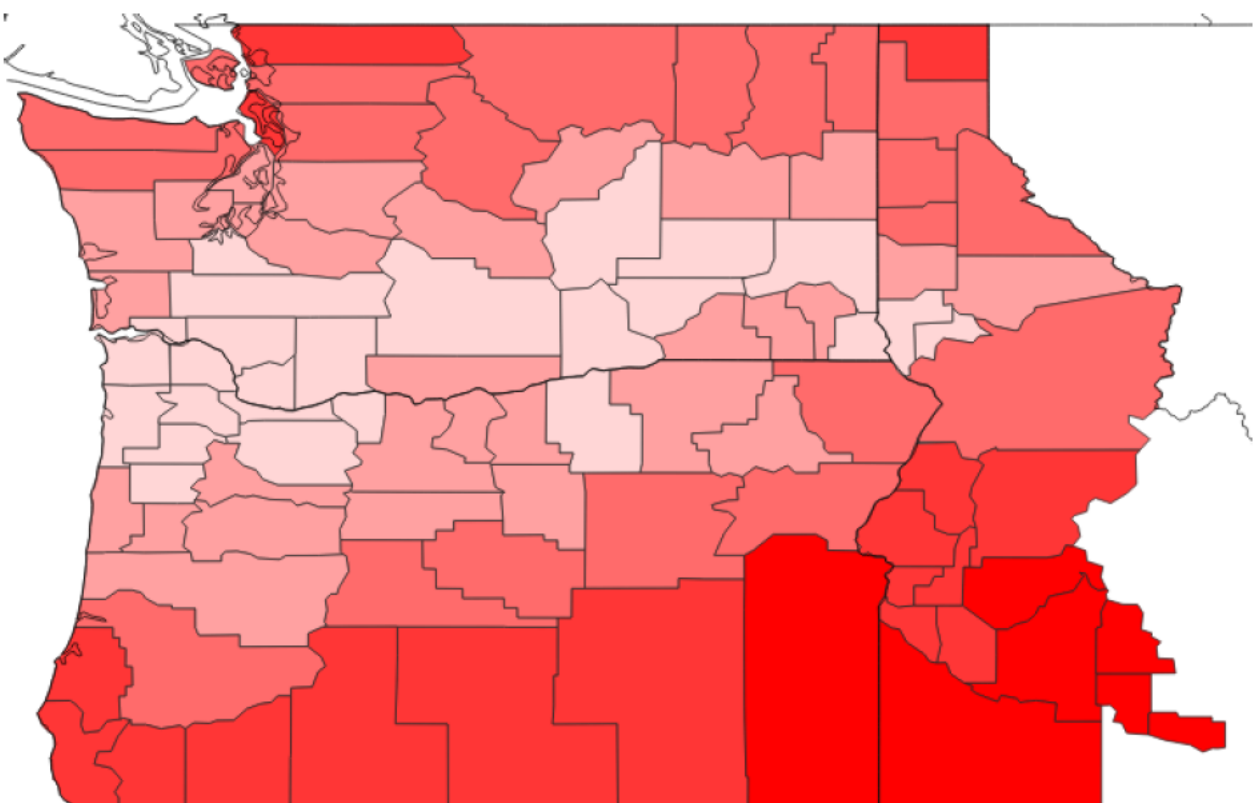


*Figure 34: Fertilizer Baseline Unit Transportation Costs by County*



$1.8 - $9.2/ton | $9.2 - $15.9/ton | $15.9 - $22.5/ton | $22.5 - $31.5/ton | $31.5 - $40.4/ton

## 8.4 Sand & Gravel

Sand and gravel movements are primarily concentrated on the Columbia River. Of the 1.6 million tons of sand and gravel moved annually on the river system from 2015-2019, most movements (65%, 1 million tons) were upbound, transiting from below Bonneville Dam in the Portland/Vancouver area to the Bonneville Pool (just upriver of Bonneville Dam) (Table 4). These upbound movements travel on average 34 miles. Most downbound volumes of sand and gravel (552,468 tons) move from upriver of The Dalles Dam (The Dalles, John Day and McNary pools) to below Portland/Vancouver. These shipments on average originate 33 miles upriver of The Dalles Dam (9 miles upriver of John Day Dam) and travel on average a total of 201 miles (to the mouth of the Columbia River).

Exact origin-destination pairs for sand and gravel movements could not be identified. Instead, transportation costs are calculated from average ton-mile volumes and an estimate ton-mile rate of $0.10/ton-mile

*Table 4: Sand and Gravel Baseline Volumes and Cost (Barge)*

| Origin | Destination | Volume (tons) | Cost |
|---|---|---|---|
| Portland/Vancouver, OR/WA | Bonneville Pool | 1,044,147 | $2,923,611 |
| Portland/Vancouver, OR/WA | The Dalles/ McNary/John Day Pools | 1,238 | $10,777 |
| The Dalles/ McNary/John Day Pools | Lower Columbia River (the mouth) | 526,915 | $9,168,318 |
| Bonneville Pool | Lower Columbia River (the mouth) | 25,553 | $322,189 |
| Total | | 1,597,898 | $12,434,895 |

## 8.5 Forest Products

Two types of forest products are moved on the river system: wood chips, primarily used by paper mills, and wood in the rough (harvested trees) destined for timber mills. Wood in the rough is moved downbound on the Columbia-Snake River System, with approximately 10,529 tons originating on the Snake River (Lewiston, ID), 10,187 tons originating in The Dalles, John Day and McNary pools (Pasco, WA), and the overwhelming majority (162,244 tons) originating from below The Dalles, in the Bonneville pool. Wood in the rough movements entering the lower Columbia River (below Bonneville Dam) travel on average 184 miles to the mouth of the Columbia River.

Wood chips are also primarily a downbound movement. Approximately 96,194 tons were moved downbound annually on the Snake River (from Lewiston, ID); approximately 125,722 downbound tons were moved annually originating from The Dalles, John Day and McNary pools; and approximately 252,519 originated below The Dalles, in the Bonneville pool. Wood chips are also moved upbound: approximately 28,969 tons of chips are moved upriver each year, about half of which are shipped all the way to Lewiston, ID, with the remaining half being offloaded above The Dalles Dam in The Dalles, John Day and McNary pools.

Exact origin-destination pairs for wood chips and wood in the rough movements could not be identified. Instead, transportation costs are calculated from average ton-mile volumes and an estimated $0.10/ton-mile rate.

*Table 5: Forest Products Baseline Volumes and Cost (Barge)*

| | Origin | Destination | Volume (tons) | Cost |
|---|---|---|---|---|
| Wood in the Rough | Lewiston, ID | Lower Columbia River | 10,529 | $377,991 |
| | The Dalles/ McNary/John Day Pools | Lower Columbia River | 10,187 | $203,744 |
| | Bonneville Pool | Lower Columbia River | 162,444 | $188,157 |
| Wood Chips | Lewiston, ID | Portland/Vancouver, OR/WA | 96,194 | $3,453,386 |
| | The Dalles/ McNary/John Day Pools | Portland/Vancouver, OR/WA | 125,722 | $2,514,428 |
| | Bonneville Pool | Portland/Vancouver, OR/WA | 252,519 | $2,449,434 |
| | Portland/Vancouver, OR/WA | The Dalles/ McNary/John Day Pools | 13,647 | $201,701 |
| | Portland/Vancouver, OR/WA | Lewiston, ID | 15,322 | $550,067 |
| Total | | | 694,453 | $10,077,523 |

## 9. ECONOMIC IMPACTS OF ALTERNATIVE OPERATING SCENARIOS

Three alternative operating scenarios were evaluated to estimate the economic impacts of changes in operating costs due to increases or decreases in investments in the Columbia-Snake River navigation system. Changes in the level of investment in the navigation system directly impact navigation efficiencies through planned and unplanned outages and routine delays on the river system. Due to a historically strong level of investment in navigation on the river system, delays are minimal and prolonged outages are uncommon. Outages, however, when they do occur can be costly to shippers.

- From December 2010 through March 2011, navigation was closed at Bonneville, The Dalles and John Day locks for scheduled maintenance. To mitigate the impacts of this closure, barge shipments were increased in the months prior- and post-outage, to defer some of the costs of mode switching required to ship during the outage. Leading up to the outage one of the five major towboat lines charged an additional 7% in shipping rates (disruption tax) to help makeup for revenues that were expected to be lost during the outage. During the outage, shippers were forced to ship via alternative modes (rail and truck) causing the average cost of wheat shipments to increase by $0.06/bushel (13%). Notably, total wheat shipments during this time-period were also increased due to supply shortages (Russia) and increased commodity prices (Simmons, Casavant, and Sage 2013). The alternative operating scenarios defined below closely draw from these observed changes in rates/costs to simulate a range of operating conditions by which to measure how transportation costs and economic impacts would change under three hypothetical scenarios:
- Alternative Operating Scenario 1 (AOS 1): an improved scenario in which all planned, outstanding, and proposed maintenance projects are completed improving river transportation efficiency and reducing barge transportation costs by 6%.
- Alternative Operating Scenario 2 (AOS 2): an unimproved scenario in which planned maintenance projects are deferred resulting in reduced river transportation efficiency and increasing barge transportation costs by 6%.
- Alternative Operating Scenario 3 (AOS 3): a degraded scenario in which river maintenance is neglected resulting in a substantial decrease in river transportation efficiency and increasing barge transportation costs by 12%.

Using the transportation optimization models outlined above and Input-Output IMPLAN analysis, total transportation costs and total economic impacts are estimated for each commodity transported on the river system under each alternative operating scenario.

## 9.1 Transportation Costs

Under each alternative operating scenario, shippers face different barge rates because of increases or decreases in operating efficiencies on the river system. These changes in rates affect shippers' mode choice decision. For example, shippers facing higher barge rates may transition away from barge shipping to minimize their transportation costs. This will result in lower volumes being transported by barge, and higher total transportation costs. For each operating scenario and each commodity, volumes, total expenditures and unit cost are estimated by mode and by county.

### 9.1.1 Grain

Expenditures and volumes by mode for grain shipping are shown in Table 6. At baseline, barge shipping accounts for 3.9 million tons of grain shipped annually and $52 million in total expenditures. A 6% decrease in barge rates under AOS 1 results in a 2% increase in barge volumes shipped, but a 3.9% decrease in barge expenditures due to the lower rates. A 6% increase in barge rates under AOS 2 results in a 2.4% decrease in barge volumes shipped, but a 3.3% increase in barge expenditures due to higher rates. The 6% decrease in barge rates decreases total expenditures by $3.15 million (2.2%) or $0.519/ton ($0.016/bushel) and the 6% increase in barge rates increases total expenditures by $3.09 million (2.1%) or $0.508/ton ($0.015/bushel).

*Table 6: Grain Baseline Volumes and Expenditures by Mode*

| | Baseline | AOS 1 (-6%) | AOS 2 (+6%) | AOS 3 (+12%) |
|---|---|---|---|---|
| Volume (tons) | | | | |
| Road | 6,258,690 | 6,271,740 | 6,232,150 | 6,232,150 |
| Barge | 3,933,470 | 4,010,810 | 3,835,120 | 3,628,270 |
| Rail | 398,690 | 395,105 | 444,407 | 496,922 |
| Shuttle Rail | 2,144,030 | 2,066,690 | 2,242,380 | 2,449,230 |
| Expenditures ($) | | | | |
| Road | $53,327,600 | $53,500,800 | $52,690,400 | $52,036,000 |
| Barge | $52,126,800 | $50,080,700 | $53,848,300 | $53,666,800 |
| Rail | $3,193,280 | $3,166,770 | $3,537,170 | $3,897,730 |
| Shuttle Rail | $36,258,200 | $35,001,900 | $37,920,400 | $41,332,800 |
| Total Expenditures | $144,905,880 | $141,750,170 | $147,996,270 | $150,933,330 |

Changes in transportation costs are heterogenous across the region. Shippers that rely more on barge shipping typically will receive greater benefits, under AOS 1, due to increased efficiencies on the river system, while those who rely less heavily on barge shipping or have easy access to alternative shipping modes are less affected. Figures 35-37 show changes in unit costs relative to the baseline scenario for each county for each alternative operating scenario.

*Figure 35: Grain - Change in Unit Cost/Ton by County Under 6% Decrease in Barge Rates (AOS 1)*

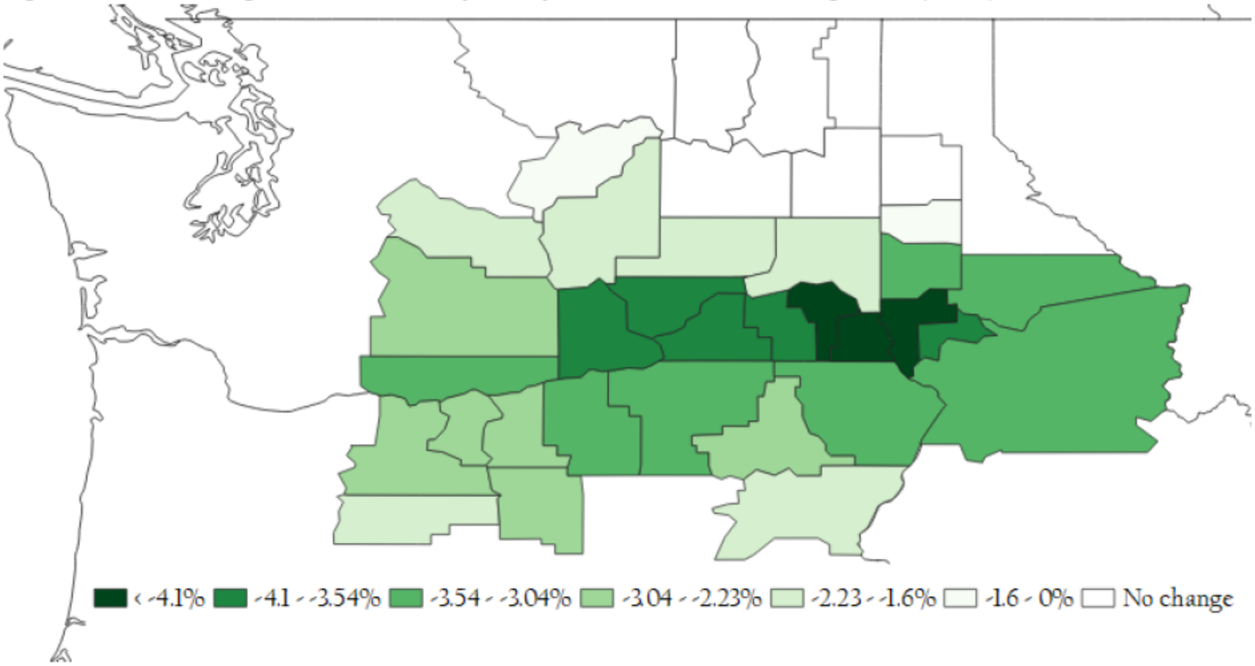


*Figure 36: Grain - Change in Unit Cost/Ton by County Under 6% Increase in Barge Rates (AOS 2)*

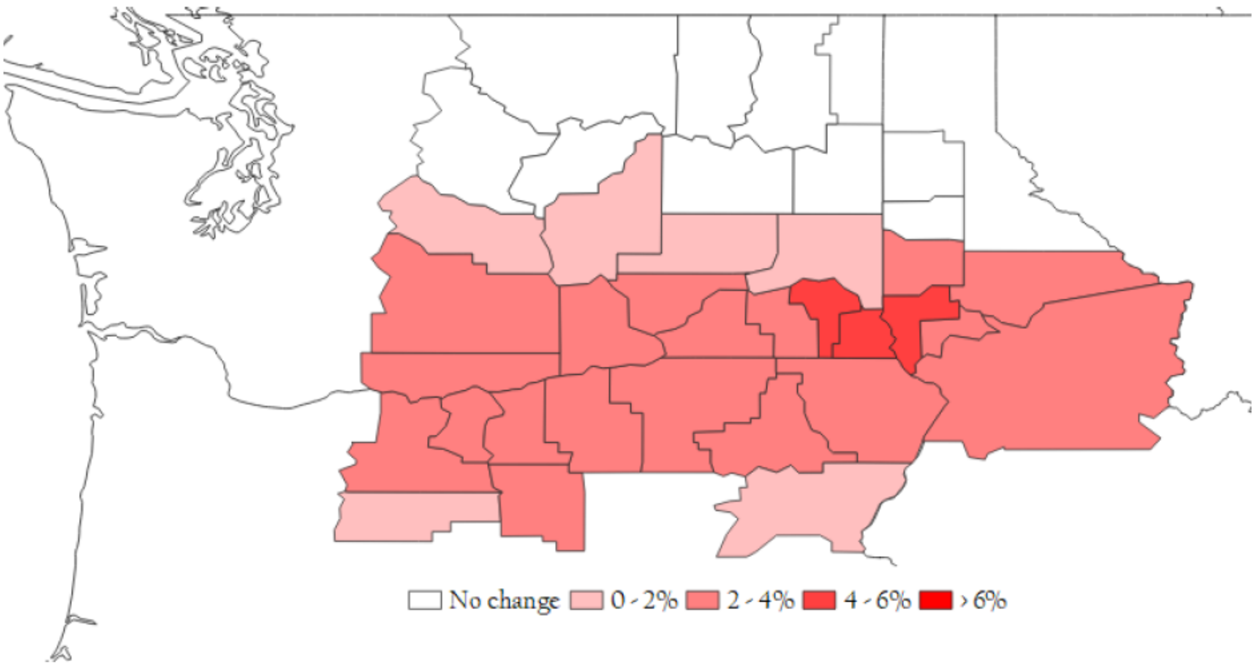
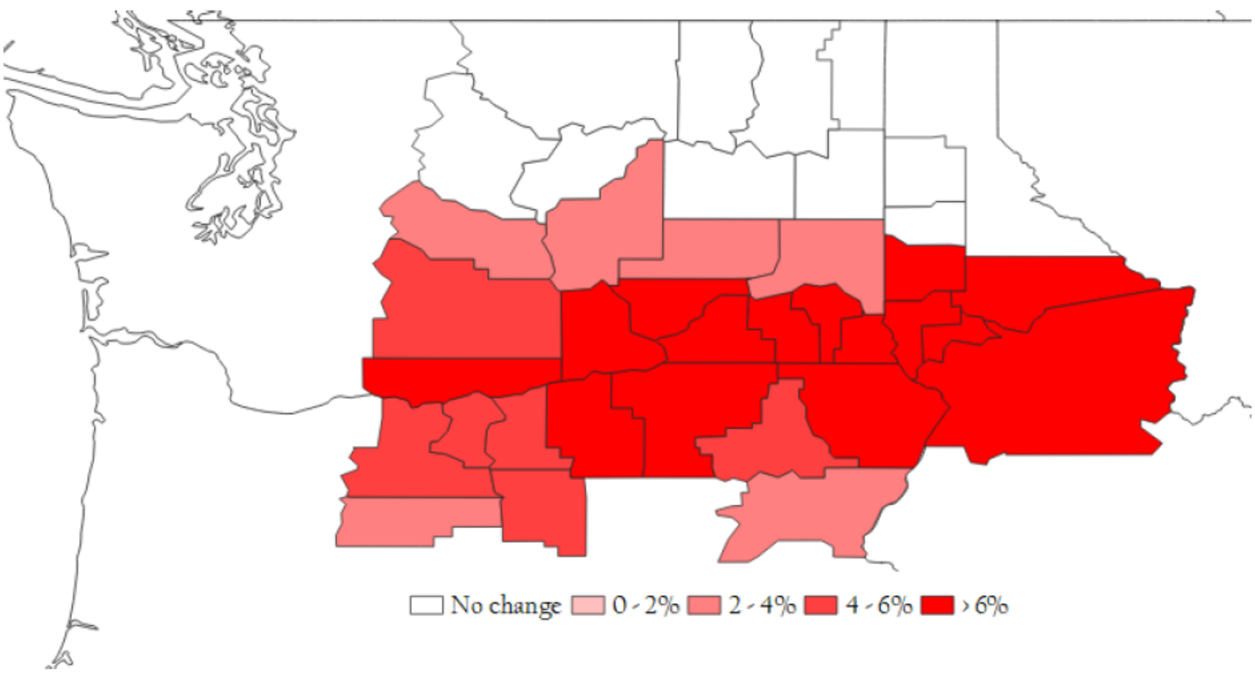



*Figure 37: Grain - Change in Unit Cost/Ton by County Under 12% Increase in Barge Rates (AOS 3)*




### 9.1.2 Petroleum

Expenditures and volumes by mode for petroleum shipments are shown in Table 7. At baseline, barge shipping accounts for 753,434 tons of petroleum shipped annually and $9.89 million in total expenditures. A 6% decrease in barge rates under AOS 1 results in a 2% increase in barge volumes shipped, but a 4.25% decrease in barge expenditures due to the lower rates. A 6% increase in barge rates under AOS 2 results in a 20% decrease in barge volumes shipped, and a 17% decrease in barge expenditures. This dramatic transition away from barge is likely due to the availability of alternative shipping modes, primarily pipeline. The 6% decrease in barge rates decreases total expenditures by $601,260 (0.2%) and the 6% increase in barge rates increases total expenditures by $493,140 (0.18%).

*Table 7: Petroleum Baseline Volumes and Expenditures by Mode*

| | Baseline | AOS 1 (-6%) | AOS 2 (+6%) | AOS 3 (+12%) |
|---|---|---|---|---|
| Volume (tons) | | | | |
| Road | 16,402,600 | 16,402,600 | 16,402,600 | 16,402,600 |
| Rail | 1,064,210 | 1,063,120 | 1,214,810 | 1,214,810 |
| Barge | 753,434 | 768,568 | 601,036 | 570,249 |
| Tanker | 1,744,710 | 1,744,710 | 1,744,710 | 1,744,710 |
| Pipeline | 14,065,800 | 14,061,500 | 14,659,100 | 14,673,900 |
| Expenditures ($) | | | | |
| Road | $124,326,000 | $124,048,000 | $124,373,000 | $125,085,000 |
| Rail | $12,357,600 | $12,344,900 | $14,100,200 | $14,100,200 |
| Barge | $9,891,470 | $9,470,610 | $8,145,110 | $8,107,010 |
| Tanker | $21,601,900 | $21,601,900 | $21,601,800 | $21,601,800 |
| Pipeline | $96,929,800 | $97,040,100 | $97,379,800 | $97,148,900 |
| Total Expenditures | $265,106,770 | $264,505,510 | $265,599,910 | $266,042,910 |

Figures 38-40 show average cost/ton of delivered petroleum by county for each alternative operating scenario relative to the baseline scenario. As expected, the 6% decrease in barge rates from AOS 1 results in reduced costs for counties relying on petroleum shipments via the river system. Results for AOS 2 and AOS 3, show some counties having increased unit costs but others having decreased unit costs; this is an artifact of the network optimization problem. Under the network optimization problem, total delivered costs are minimized across the study region, which means subject to the supply/demand constraints, some counties may face increased costs at the expense of other counties experiencing decreased costs. In reality, the changes in these unit costs are likely to have much less variation and be shared more evenly across the region.

*Figure 38: Petroleum - Change in Unit Cost/Ton by County Under 6% Decrease in Barge Rates (AOS 1)*

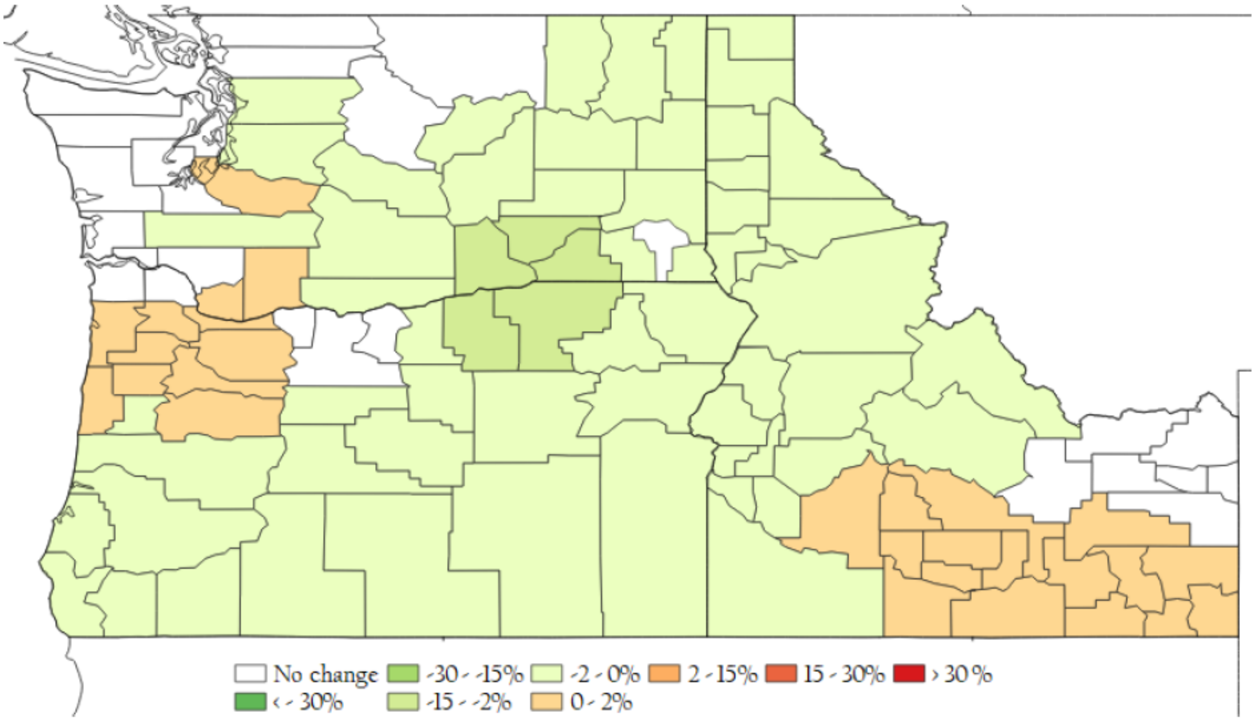



*Figure 39: Petroleum - Change in Unit Cost/Ton by County Under 6% Increase in Barge Rates (AOS 2)*

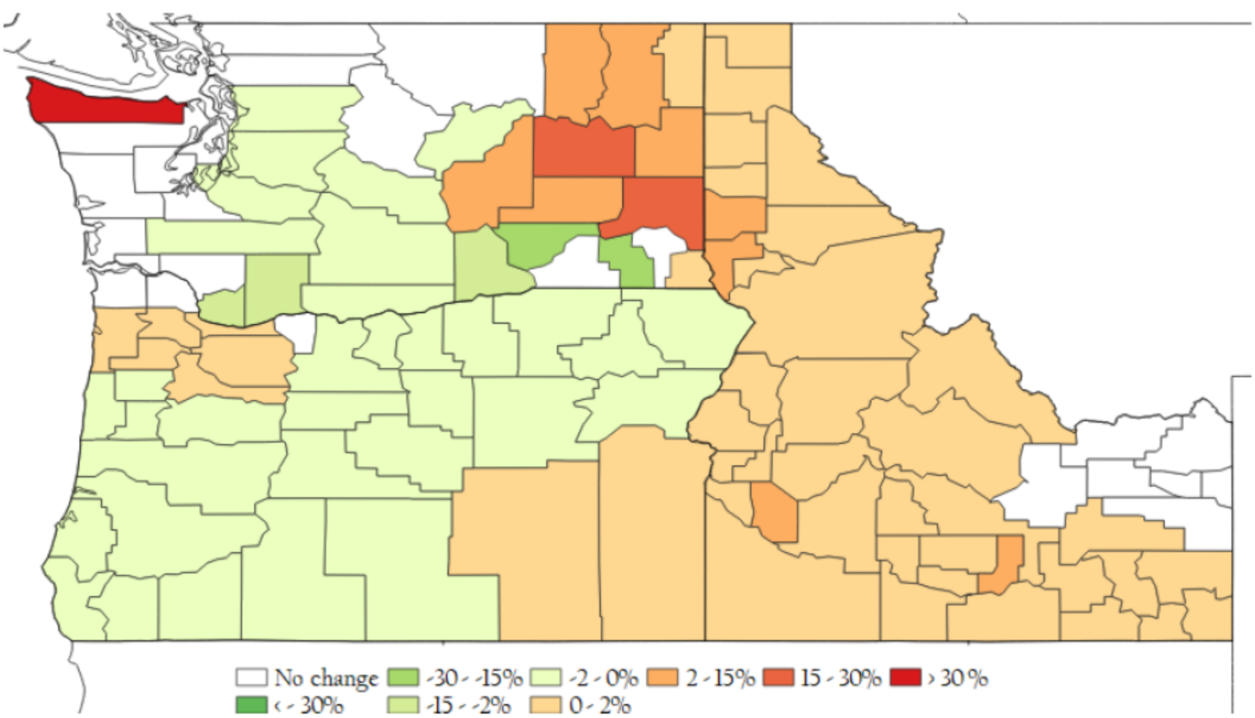
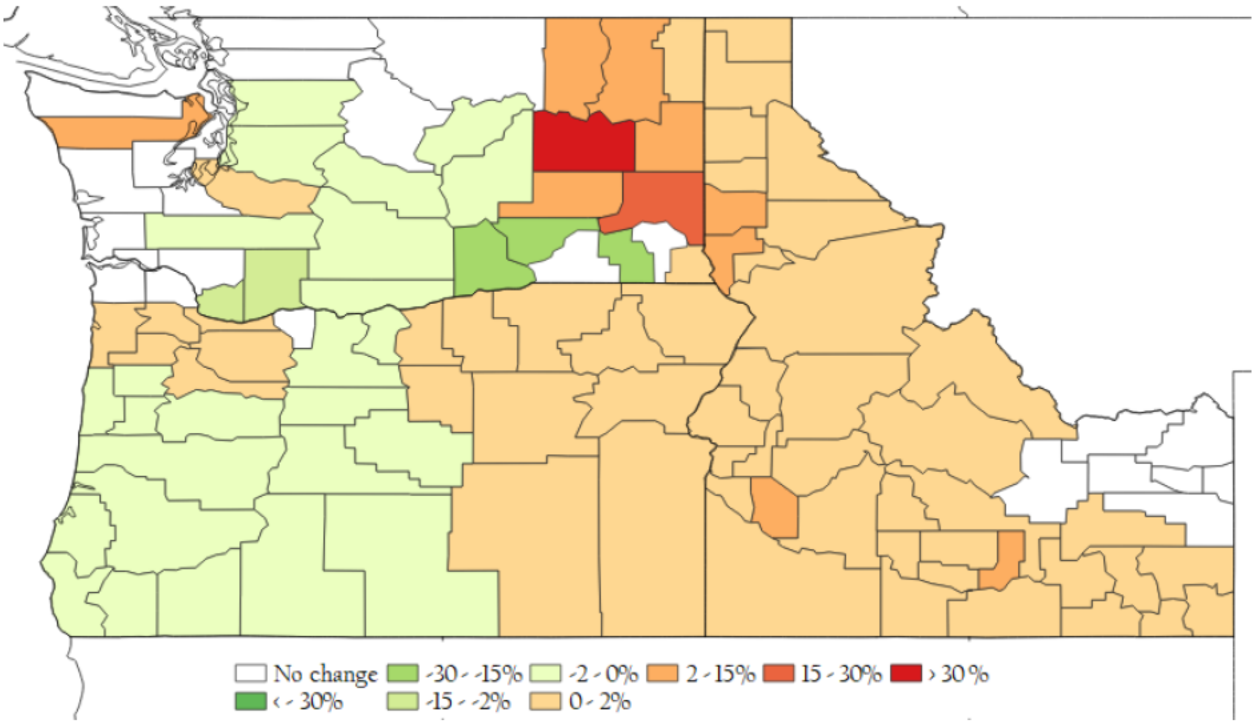


*Figure 409: Petroleum - Change in Unit Cost/Ton by County Under 12% Increase in Barge Rates (AOS 3)*




### 9.1.2 Fertilizer

Expenditures and volumes by mode for fertilizer shipments are shown in Table 8. At baseline, barge shipping accounts for 81,154 tons of UAN fertilizer shipped annually and $481,394 in expenditures. A 6% decrease in barge rates under AOS 1 results in no change in barge volumes shipped due to the production capacity constraint, and a 6% decrease in barge expenditures due to the lower rates. A 6% increase in barge rates under AOS 2 results in a 0.2% decrease in barge volumes shipped, and a 5.8% increase in barge expenditures. The 6% decrease in barge rates decreases total expenditures by $28,883 (0.6%) and the 6% increase in barge rates increases total expenditures by $28,848 (0.7%).

*Table 8: Fertilizer Baseline Volumes and Expenditures by Mode*

| | Baseline | AOS 1 (-6%) | AOS 2 (+6%) | AOS 3 (+12%) |
|---|---|---|---|---|
| Volume (tons) | | | | |
| Road | 305,000 | 305,000 | 305,000 | 305,000 |
| Barge | 81,154 | 81,154 | 81,012 | 80,183 |
| Expenditures ($) | | | | |
| Road | $3,903,120 | $3,903,120 | $3,904,180 | $3,910,800 |
| Barge | $481,394 | $452,511 | $509,182 | $531,238 |
| Total Expenditures | $4,384,514 | $4,355,631 | $4,413,362 | $4,442,038 |

Figures 41-43 show average cost/ton of delivered UAN fertilizer by county for each alternative operating scenario relative to the baseline scenario. As expected, the 6% decrease in barge rates from AOS 1 results in reduced costs for counties relying on fertilizer shipments via the river system (Figure 41). Figures 42-43 show changes in unit costs under increased barge rates (AOS 2 and AOS 3). As expected, we see increased rates most impact counties relying on the river system to access fertilizer shipments.

*Figure 41: Fertilizer - Change in Unit Cost/Ton by County Under 6% Decrease in Barge Rates (AOS 1)*

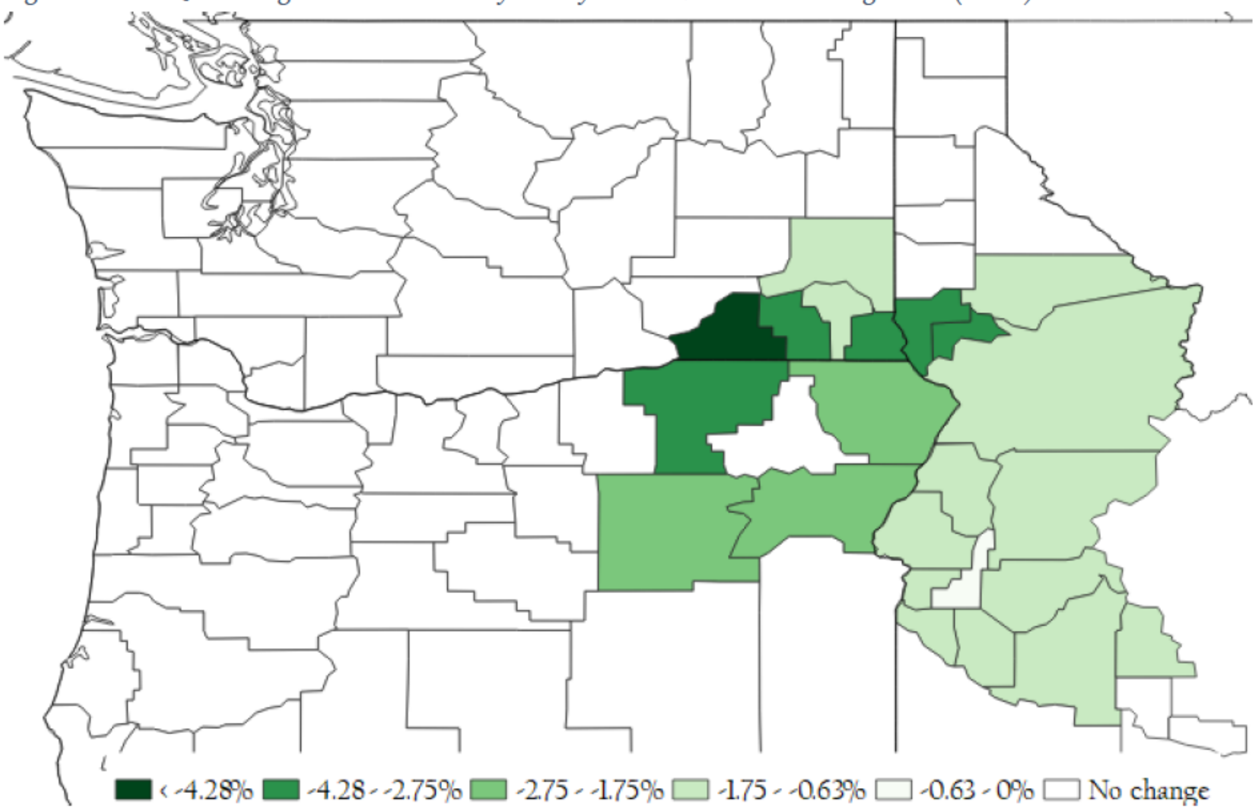


*Figure 1042: Fertilizer - Change in Unit Cost/Ton by County Under 6% Increase in Barge Rates (AOS 2)*

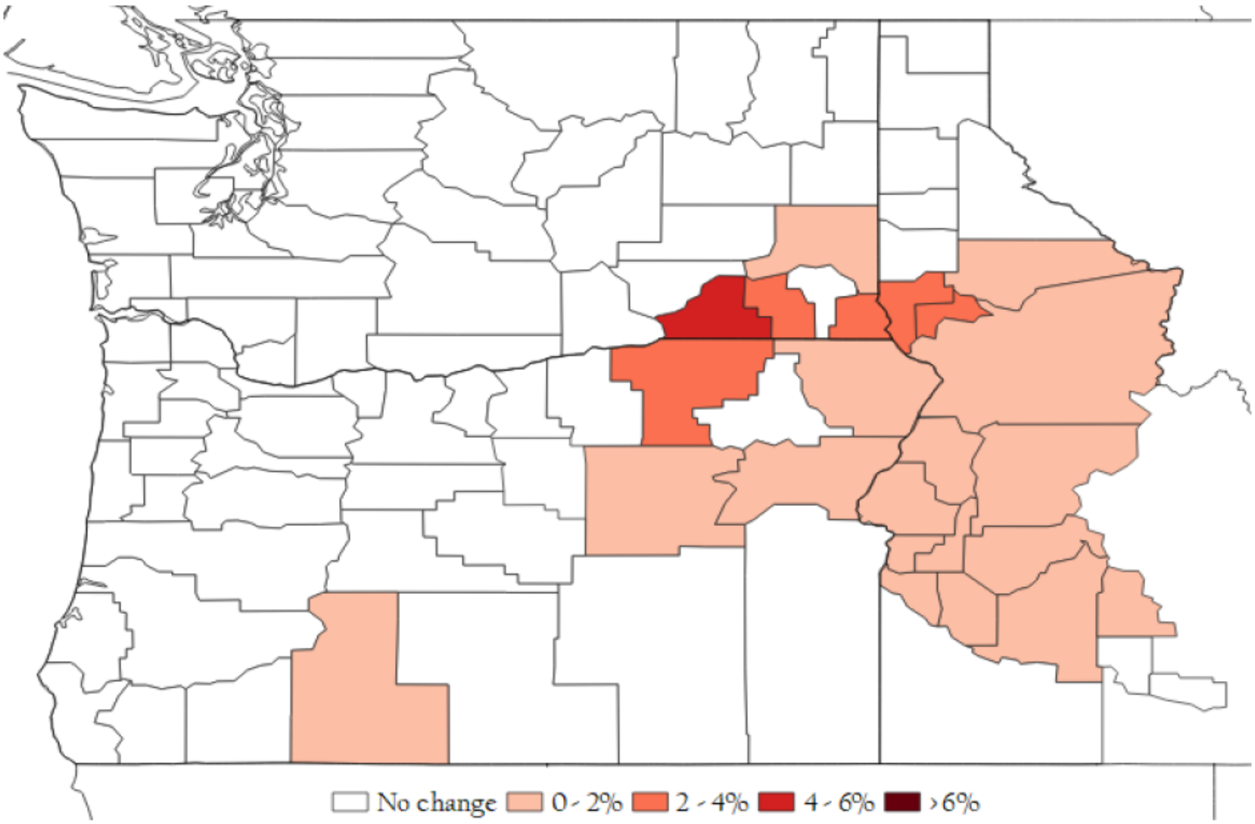
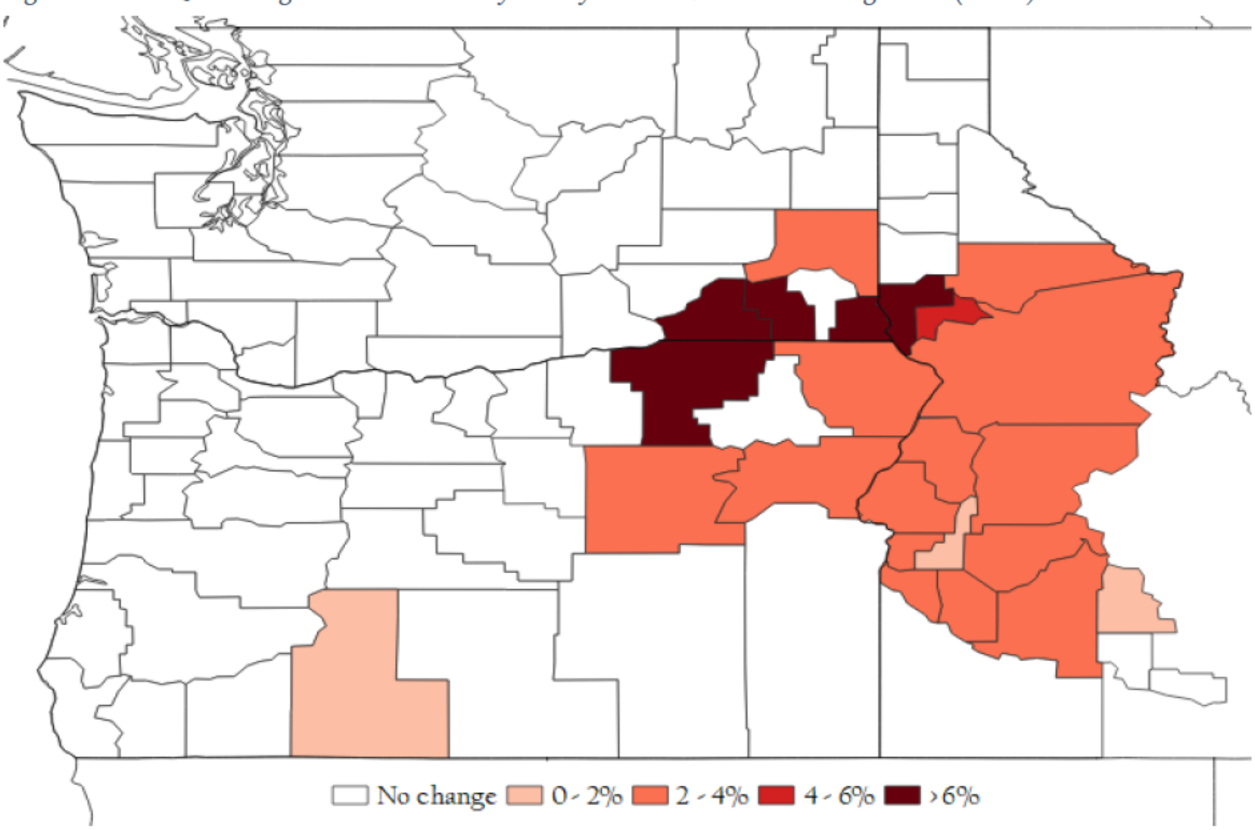



*Figure 43: Fertilizer - Change in Unit Cost/Ton by County Under 12% Increase in Barge Rates (AOS 3)*



### 9.1.4 Sand & Gravel, and Forest Products

Due to lack of sufficient information, robust transportation models were not developed for Sand & Gravel or Forest Products. Therefore, the mode switching opportunities that may be taken to reduce cost burden or to take advantage of discounted barge rates are not accounted for. Instead, the change in barge rates are assumed to be passed on directly resulting in equivalent increases in transportation costs. Therefore, under AOS 1 (6% decrease in barge rates), Sand & Gravel and Forest products are estimated to experience a 6% decrease in transportation costs. Likewise, under AOS 2 and AOS 3 (6% and 12% increase in barge rates), transportation costs are estimated to increase by 6% and 12% respectively.

## 9.2 Economic Impact Analysis of Navigation Funding Scenarios

The economic impacts resulting from differing levels of investment in navigation go well beyond transportation costs and the operations at the river. This analysis used an IMPLAN[6] based input-output approach that relied upon the spatial analysis of the region for barge transportation of grain, petroleum, fertilizer, forest products, and sand-gravel. The analysis evaluates three different types of contributions to the regional economy:

- **Direct Impacts**: the economic activity that occurs directly within the focus industry, which in this case is the barge transportation sector.
- **Indirect Impacts**: the economic activity needed to support the barge industry. This is everything from ship building to heavy equipment services and business banking that the barge industry needs to operate.
- **Induced Impacts**: the economic activity from the spending of labor income and profits. This includes the increased income that is realized from having access to a low-cost transportation method such as the inland barge sector.

Total economic impacts are the summation of the direct, indirect, and induced impacts described above.

The economic impact analysis presents the results of the impacts on the number of jobs, value-added in the economy, and total output. Jobs is measured as an industry-specific mix of full-time, part-time, and seasonal employment on an annual basis. Value-added [7]is the summation of labor income, profit, and taxes (akin to a regional measure of gross domestic product (GDP)). Output is the total revenue of the businesses that is generated in the focus region for the impact or scenario being analyzed.

### 9.2.1 Baseline Scenario

The baseline scenario accounts for the current economic activity on the Columbia-Snake River System including job creation, economic value added, and economic output. The baseline scenario accounts for the jobs created through the inland waterway barging industry, and the added incomes provided to shippers through affordable shipping opportunities. The baseline analysis findings showed that the Columbia-Snake River inland barge shipping sector supports the regional economy through the employment of 1,718 people. Business in Idaho, Oregon, and Washington have $370 million in revenues that can be linked back

[6] IMPLAN was originally developed by the US Forest Service and was later privatized. It is an accepted analysis platform that is widely used for similar U.S. economic impact projects.

[7] Value added is often used by economists to measure the economic activity without double counting. Output is the summation of the business revenue at each step along the supply chain. For example, if a farmer sells a bushel of wheat for $10 to a local elevator and then that elevator sells it for a $11 to an export terminal and the export terminal sells the grain for $12 to the end user, then total output is $33, while the total value added would be $12 for the bushel of wheat (assuming all the inputs to grow that bushel of wheat originated in the PNW).

to the barge industry. The value-added contribution is particularly significant because changes in transportation costs impact the profit margins of other industries. Lower freight costs allow for additional profits on the same or similar revenues for the businesses that are reliant on the river.

For every $1 in revenue to the barge industry on the Columbia-Snake River, an additional $3.35 of revenue is created by other industries. This additional revenue is generated by industries that support the barge industry as well as from industries that benefit from the income effect created by access to low-cost barge transportation. The multiplier for jobs is larger as the barge industry requires few direct jobs but is supported by and supports a wide variety of industries in the broader economy. For every one job in the barge sector there were 14 jobs supported elsewhere in the economy. The estimated multiplier for value-added is 1.93, meaning that for every $1 of value added directly in the barge sector there is $0.93 of economic activity supported elsewhere in the economy.

*Table 9: Columbia River Barge Industry Baseline Economic Contribution to the Pacific Northwest*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 121 | $178,798,264 | $85,012,098 |
| Indirect | 348 | $35,131,850 | $66,993,490 |
| Induced | 1,249 | $131,638,081 | $218,337,762 |
| Total | 1,718 | $345,568,196 | $370,343,350 |

Grain shipments had the largest share of the economic contributions. The contributions in Table 9 are the total contributions (direct, indirect, and induced). This means that the jobs created for grain shipments include the barge employees shipping the grain, workers who service the barge industry, and jobs in the general economy that are supported by labor income, profits, and the relatively higher incomes of farmers from access to barge transportation.

*Table 10: Columbia River Baseline Economic Contributions by Shipment Type*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Grain | 1,180 | $244,014,000 | $249,409,784 |
| Petroleum | 165 | $31,395,389 | $36,965,492 |
| Fertilizer | 8 | $1,468,832 | $1,757,941 |
| Forest | 163 | $30,748,576 | $36,800,779 |
| Sand and Gravel | 201 | $37,941,398 | $45,409,355 |
| Total | 1,718 | $345,568,196 | $370,343,350 |

The analysis for more than one state, such as the Pacific Northwest (PNW), is known as a multi-regional-input-output analysis or MRIO. It takes into consideration the supply chains in the focus area and provides estimates as to how much interstate trade for goods and services are taking place between the three states. The analysis can also be separated into the contributions provided by a specific area. However, each area has an impact on itself as well as the areas around it. Therefore, if we simply added the impact each state has on itself it will be less than the total in our analysis due to not accounting for interstate trade. The state tables in Table 1111, Table 1212, and Table 1313 list the contribution each state had on itself. The contributions in Table 14 captures the effects of cross state supply chain relationships between these three states, which is needed to reconcile with our total PNW contribution findings.

*Table 11: Columbia River Baseline Economic Contributions for Idaho*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 17 | 14,760,503 | 10,421,640 |
| Indirect | 43 | 3,006,589 | 6,318,623 |
| Induced | 113 | 8,910,446 | 16,529,304 |
| Total | 173 | 26,677,538 | 33,269,567 |

*Table 12: Columbia River Baseline Economic Contributions for Oregon*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 43 | 46,400,171 | 30,379,028 |
| Indirect | 119 | 9,655,853 | 18,217,781 |
| Induced | 345 | 31,498,058 | 53,690,162 |
| Total | 507 | 87,554,082 | 102,286,970 |

*Table 13: Columbia River Baseline Economic Contributions for Washington*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 62 | 117,637,590 | 44,211,430 |
| Indirect | 149 | 17,525,081 | 32,199,819 |
| Induced | 734 | 85,038,389 | 136,747,591 |
| Total | 944 | 220,201,061 | 213,158,841 |

*Table 14: Columbia River Baseline Economic Contributions for Interstate Trade (Idaho, Oregon, & WA)*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | - | - | - |
| Indirect | 36 | 4,944,326 | 10,257,268 |
| Induced | 57 | 6,191,188 | 11,370,705 |
| Total | 93 | 11,135,514 | 21,627,973 |

Table 14 only shows indirect and induced impacts in the baseline model. This is because the direct impacts are accounted for within each state that the direct impact occurs.

The baseline scenarios were divided into two impact types. One impact was the impact from operating barges (Barge Output) on the Columbia River. The other impact was the income effect (Income Effect) to area shippers from access to a lower cost transportation alternative. The baseline results for the Barge Output model and the Income Effect Model are shown in Table 15 and when combined reconcile with our total impact in Table 9.

*Table 15: Baseline Contribution to the Pacific Northwest from Direct Barge Output*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 121 | $22,513,869 | $85,012,098 |
| Indirect | 348 | $35,131,850 | $66,993,490 |
| Induced | 184 | $18,657,731 | $31,184,744 |
| Total | 653 | $76,303,450 | $183,190,333 |
| | | | |
| + Baseline | | | |
| Income Effect | 1,065 | $269,264,745 | $187,153,018 |
| Total Impact | 1,718 | $345,568,196 | $370,343,350 |

### 9.2.2 Alternative Operating Scenarios

The economic impacts of Alternative Operating Scenario 1 (6% decrease in barge rates) were positive in that, when combined, Idaho, Oregon, and Washington were the economic beneficiaries of the greater income to the supply chain from the ability to ship the five commodities at lower per unit prices. The higher profits do not create additional direct jobs, but the spending and investment of the additional scenario profits does create economic activity, which includes additional induced jobs added to the economy.

The spatial model used to estimate the direct economic impacts takes into consideration the various modal options available to move freight to final destinations as well as the costs and capacity constraints associated with each freight option. Using this model to develop the direct impacts was important as it brings real world considerations into the analysis. The total costs of shipping the five selected commodities were based on average production or demand of those commodities depending on whether they are shipped upstream or down. The difference in the total costs from the constrained model was used to estimate the income effects from each scenario.

*Table 16: Alternative Operating Scenario 1 Net Economic Impact to the Pacific Northwest*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 121 | $211,942,456 | $85,012,098 |
| Indirect | 348 | $35,131,850 | $66,993,490 |
| Induced | 1,514 | $154,960,112 | $259,123,104 |
| Total | 1,983 | $402,034,418 | $411,128,693 |
| | | | |
| Net Impact Relative to the Baseline | 265 | $56,466,223 | $40,785,342 |

*Table 17: Alternative Operating Scenario 1 Net Impact to the PNW Economy by State*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Idaho | 10 | $2,130,724 | $1,436,084 |
| Oregon | 311 | $69,328,774 | $49,690,385 |
| Washington | (55) | -$14,993,276 | -$10,341,127 |
| Total | 265 | $56,466,223 | $40,785,342 |

The total economic impacts of Scenarios 2 and 3 (6% increase in barge rates, and 12% increase in barge rates) were negative as expected. The river still has an overall positive economic impact to the area under

Scenario 2 and 3, but the net impact relative to the baseline is negative and is shown at the bottom of each table.

*Table 18: Alternative Operating Scenario 2 Net Economic Contribution to the Pacific Northwest*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 121 | $166,532,608 | $85,012,098 |
| Indirect | 348 | $35,131,850 | $66,993,490 |
| Induced | 1,166 | $122,796,776 | $203,715,526 |
| Total | 1,635 | $324,461,235 | $355,721,115 |
| Net Impact Relative to the Baseline | (83) | -$21,106,961 | -$14,622,236 |

*Table 19: Alternative Operating Scenario 2 Net Impact to the PNW Economy by State*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Idaho | (10) | -$2,074,185 | -$1,397,978 |
| Oregon | (16) | -$3,590,840 | -$2,573,682 |
| Washington | (57) | -$15,441,936 | -$10,650,576 |
| Total | (83) | -$21,106,961 | -$14,622,236 |

*Table 20: Alternative Operating Scenario 3 Net Economic Contribution to the Pacific Northwest*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Direct | 121 | $157,938,388 | $85,012,098 |
| Indirect | 348 | $35,131,850 | $66,993,490 |
| Induced | 1,106 | $116,715,418 | $193,489,901 |
| Total | 1,575 | $309,785,656 | $345,495,490 |
| Net Impact Relative to the Baseline | (143) | -$35,782,540 | -$24,847,860 |

*Table 21: Alternative Scenario 3 Net Impact to the PNW Economy by State*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Idaho | (19) | -$4,183,892 | -$2,819,897 |
| Oregon | (39) | -$8,654,256 | -$6,202,811 |
| Washington | (85) | -$22,944,392 | -$15,825,152 |
| Total | (143) | -$35,782,540 | -$24,847,860 |

While both Scenario 1 and Scenario 2 are based on a six percent change in barge rates, the magnitudes of the economic impacts are not equal. The 6% decrease in barge rates benefits all existing shippers, and also increases the draw area of the river as shipping becomes more affordable. The impacts of a 6% increase on barge rates, on the other hand, can be mitigated by shifting to alternative shipping modes. Results for each scenario are presented below.

*Table 222: Comparison of Alternative Scenario 1, 2, & 3 Net Impacts to the PNW*

| Impact Type | Scenario | Direct | Indirect | Induced | Total | Net Impact Relative to the Baseline |
|---|---|---|---|---|---|---|
| Jobs | Scenario 1: -6% | 121 | 348 | 1,514 | 1,983 | 265 |
| | Scenario 2: +6% | 121 | 348 | 1,166 | 1,635 | (83) |
| | Scenario 3: +12% | 121 | 348 | 1,106 | 1,575 | (143) |
| Value-Added | Scenario 1: -6% | $211,942,456 | $35,131,850 | $154,960,112 | $402,034,418 | $56,466,223 |
| | Scenario 2: +6% | $166,532,608 | $35,131,850 | $122,796,776 | $324,461,235 | -$21,106,961 |
| | Scenario 3: +12% | $157,938,388 | $35,131,850 | $116,715,418 | $309,785,656 | -$35,782,540 |
| Output | Scenario 1: -6% | $85,012,098 | $66,993,490 | $259,123,104 | $411,128,693 | $40,785,342 |
| | Scenario 2: +6% | $85,012,098 | $66,993,490 | $203,715,526 | $355,721,115 | -$14,622,236 |
| | Scenario 3: +12% | $85,012,098 | $66,993,490 | $193,489,901 | $345,495,490 | -$24,847,860 |

*Table 233: Comparison of Alternative Scenario 1, 2, & 3 Net Impacts to the PNW by State*

| Impact Type | Scenario | Idaho | Oregon | Washington | Total |
|---|---|---|---|---|---|
| Jobs | Scenario 1: -6% | 10 | 311 | (55) | 265 |
| | Scenario 2: +6% | (10) | (16) | (57) | (83) |
| | Scenario 3: +12% | (19) | (39) | (85) | (143) |
| Value-Added | Scenario 1: -6% | $2,130,724 | $69,328,774 | -$14,993,276 | $56,466,223 |
| | Scenario 2: +6% | -$2,074,185 | -$3,590,840 | -$15,441,936 | -$21,106,961 |
| | Scenario 3: +12% | -$4,183,892 | -$8,654,256 | -$22,944,392 | -$35,782,540 |
| Output | Scenario 1: -6% | $1,436,084 | $49,690,385 | -$10,341,127 | $40,785,342 |
| | Scenario 2: +6% | -$1,397,978 | -$2,573,682 | -$10,650,576 | -$14,622,236 |
| | Scenario 3: +12% | -$2,819,897 | -$6,202,811 | -$15,825,152 | -$24,847,860 |

The net impacts for each scenario relative to the commodity groups are also provided (Tables 24-26). When barge rates decrease, Petroleum products are responsible for the largest impacts followed by Grain, Sand and Gravel, Forest products, and Fertilizer. Under lower barge rates petroleum shippers (and ultimately consumers) benefit as more refined petroleum can be moved from WA refineries inland through the inland waterway, rather than relying on shipments from Montana and Utah. When barge rates increase, Grain are responsible for the largest impacts, followed by Petroleum, Sand and Gravel, Forest products, and Fertilizer.

*Table 24: Alternative Operating Scenario 1 Net Impacts to the Baseline Contribution to the Pacific Northwest Economy*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Grain | 51 | $10,853,289 | $7,839,290 |
| Petroleum | 203 | $43,262,524 | $31,248,360 |
| Fertilizer | 0 | $49,208 | $35,543 |
| Forest | 5 | $1,030,117 | $744,049 |
| Sand and Gravel | 6 | $1,271,085 | $918,100 |
| Total | 265 | $56,466,223 | $40,785,342 |

*Table 245: Alternative Operating Scenario 2 Net Impacts to the Baseline Contribution to the Pacific Northwest Economy*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Grain | (44) | -$11,331,264 | -$7,849,942 |
| Petroleum | (29) | -$7,401,674 | -$5,127,646 |
| Fertilizer | (0) | -$49,636 | -$34,386 |
| Forest | (4) | -$1,040,495 | -$720,822 |
| Sand and Gravel | (5) | -$1,283,891 | -$889,439 |
| Total | (83) | -$21,106,961 | -$14,622,236 |

*Table 256: Alternative Operating Scenario 3 Net Impacts to the Baseline Contribution to the Pacific Northwest Economy*

| | Jobs | Value Added | Output |
|---|---|---|---|
| Grain | (90) | -$22,493,916 | -$15,620,068 |
| Petroleum | (34) | -$8,555,874 | -$5,941,310 |
| Fertilizer | (0) | -$98,677 | -$68,522 |
| Forest | (8) | -$2,074,409 | -$1,440,497 |
| Sand and Gravel | (10) | -$2,559,663 | -$1,777,463 |
| Total | (143) | -$35,782,540 | -$24,847,860 |

Economic impacts can also be shown by county of product origination, though it should be noted these impacts spill over into other counties across the region (Tables 27-29 and Figure 44). The dollar amounts listed in the county tables are the increase/(decrease) to the economy from the transportation savings or, if negative, higher costs. It includes the economic impact within the county as well as that county's contribution to the Pacific Northwest economy. The impacts are based on the wealth generated from lower transportation costs and so each amount can be thought of as the dollars that the supply chain is able to keep in the area from the lower costs plus the economic activity from spending and investing those savings in the local and regional economy.

*Table 267: County Impacts on the PNW Economy from Grain Shipping (Value-Added Impacts)*

| | | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|
| Idaho | Benewah | $899 | $0 | $0 |
| | Clearwater | $37,071 | -$37,068 | -$74,129 |
| | Idaho | $237,692 | -$237,442 | -$475,008 |
| | Kootenai | $0 | -$1,258 | -$4,021 |
| | Latah | $310,630 | -$244,199 | -$523,264 |
| | Lewis | $216,205 | -$221,058 | -$432,146 |
| | Nez Perce | $1,308,224 | -$1,313,157 | -$2,635,316 |
| Oregon | Baker | $26,585 | -$26,321 | -$52,599 |
| | Gilliam | $222,908 | -$218,904 | -$423,281 |
| | Jefferson | $13,323 | -$13,323 | -$26,646 |
| | Morrow | $345,228 | -$354,299 | -$699,557 |
| | Sherman | $167,588 | -$155,831 | -$325,707 |
| | Umatilla | $616,089 | $70,226 | -$983,184 |
| | Union | $101,375 | -$101,597 | -$203,469 |
| | Wallowa | $34,020 | -$33,906 | -$269,512 |
| | Wasco | $95,245 | -$40,561 | -$151,006 |
| | Wheeler | $311 | -$311 | -$622 |
| Washington | Adams | $695,814 | -$1,925,464 | -$3,651,144 |
| | Asotin | $81,491 | -$81,491 | -$162,981 |
| | Benton | $167,633 | -$183,472 | -$339,792 |
| | Chelan | $22 | $0 | $0 |
| | Columbia | $709,137 | -$709,453 | -$1,421,173 |
| | Douglas | $23,311 | -$21,953 | -$21,605 |
| | Ferry | $0 | $0 | $0 |
| | Franklin | $891,948 | -$272,198 | -$900 |
| | Garfield | $365,907 | -$449,561 | -$852,836 |
| | Grant | $189,392 | -$731,639 | -$982,543 |
| | Kittitas | $1,720 | -$1,720 | -$3,439 |
| | Klickitat | $145,490 | -$357,610 | -$504,612 |
| | Lincoln | $0 | $0 | $0 |
| | Okanogan | $0 | $0 | $0 |
| | Spokane | $13,459 | -$507,367 | -$912,541 |
| | Stevens | $0 | $0 | $0 |
| | Walla Walla | $1,228,101 | -$1,225,179 | -$2,451,517 |
| | Whitman | $2,565,008 | -$1,807,591 | -$3,698,166 |
| | Yakima | $40,143 | -$40,143 | -$80,287 |

In terms of grain shipments, Nez Perce, Idaho accounted for the largest share of the savings or additional expenses in the scenario analysis. Its proximity to the river and west bound grain production means that it is more influenced by changes in river shipping costs than the other counties in Idaho.

Umatilla and Morrow counties were impacted the most by grain barge shipment costs in Oregon. These two counties accounted for 59% of the shipping cost savings in Scenario 1. Counties that benefit the most from reduced barge rates will at times take capacity/supply from other parts of the river. Due to these supply and capacity constraints and factoring in the costs of other modes, certain counties experienced higher shipping costs as trade flows through the regional transportation lanes change. This is most notable in the petroleum county tables where a more competitive river pulls supply that was formerly available for consumption in the greater Portland river, to be shipped inland via barge instead, increasing the transportation costs for counties in the Portland area. The total impacts when looking at the regional, PNW, level all had the positive or negative outcomes as expected but individual counties and states may win or lose for a specific commodity. This is important to note when looking at the petroleum results by county where we find that Oregon has transportation savings for scenario 1 as we expected. Washington has mixed impacts, with some counties positive and some negative and it is overall negative for Scenario 1 when isolating the impact from petroleum only.

*Table 278: Oregon's County Impacts on the PNW Economy from Petroleum Shipping (Value-Added Impacts)*

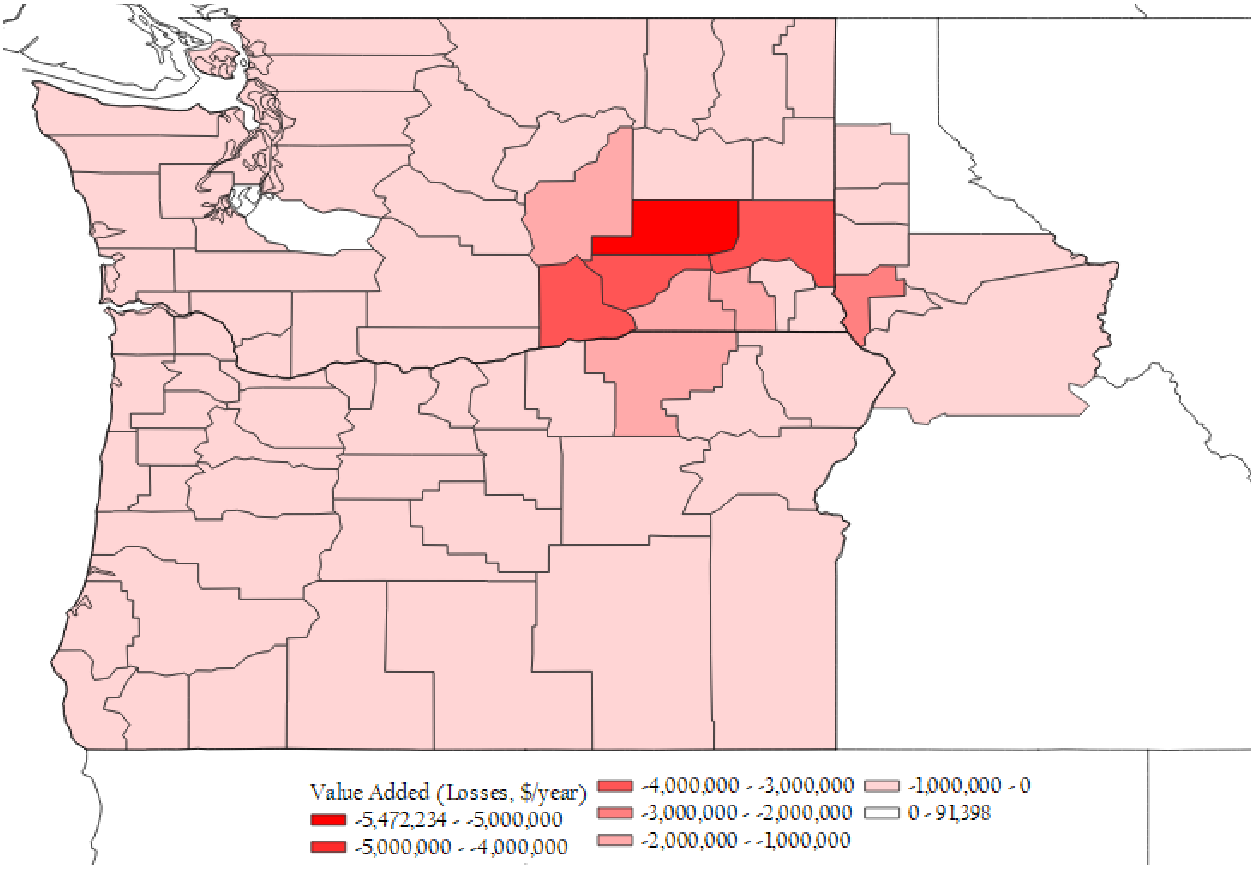
| | | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|
| Oregon | Baker | $48,247 | -$48,247 | -$96,493 |
| | Benton | $2,426,872 | $0 | $0 |
| | Clackamas | $205,243 | $0 | $0 |
| | Clatsop | $0 | $0 | $0 |
| | Columbia | $0 | $0 | $0 |
| | Coos | $1,382,582 | $0 | $0 |
| | Crook | $739,507 | $0 | $0 |
| | Curry | $7,406 | $0 | $0 |
| | Deschutes | $5,053,800 | $0 | $0 |
| | Douglas | $4,662,073 | $0 | $0 |
| | Gilliam | $41,599 | -$41,601 | -$83,200 |
| | Grant | -$17,074 | -$12,202 | -$112,576 |
| | Harney | $325,477 | $0 | $0 |
| | Hood River | $0 | $0 | $0 |
| | Jackson | $6,387,136 | $0 | $0 |
| | Jefferson | $34,773 | $0 | $0 |
| | Josephine | $609,417 | $0 | $0 |
| | Klamath | $2,211,367 | $0 | $0 |
| | Lake | $149,609 | $0 | $0 |
| | Lane | $9,390,375 | $0 | $0 |
| | Lincoln | $1,762,857 | $0 | $0 |
| | Linn | $5,046,706 | $0 | $0 |
| | Malheur | $0 | $0 | $0 |
| | Marion | $9,539,278 | $0 | $0 |
| | Morrow | $57,457 | -$57,455 | -$114,911 |
| | Multnomah | $3,083,660 | $0 | $0 |
| | Polk | $1,589,424 | $0 | $0 |
| | Sherman | $0 | $0 | $0 |
| | Tillamook | $224,858 | $0 | $0 |
| | Umatilla | $146,735 | -$146,736 | -$293,473 |
| | Union | $66,376 | -$66,376 | -$132,752 |
| | Wallowa | $9,235 | -$9,235 | -$18,469 |
| | Wasco | $0 | $0 | $0 |
| | Washington | $6,595,302 | $0 | $0 |
| | Wheeler | $46,786 | -$541 | -$1,083 |
| | Yamhill | $3,546,922 | $0 | $0 |

*Table 289: Washington's County Impacts on the PNW Economy from Petroleum Shipping (Value-Added Impacts)*

| | | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|
| Washington | Adams | -$226,295 | -$990,222 | -$1,821,090 |
| | Asotin | $0 | $0 | $0 |
| | Benton | $281,992 | -$3,276,349 | -$3,558,341 |
| | Chelan | $0 | $0 | $0 |
| | Clallam | $0 | -$977,353 | $0 |
| | Clark | $0 | $0 | $0 |
| | Columbia | $17,675 | $266,549 | $266,549 |
| | Cowlitz | $0 | $0 | $0 |
| | Douglas | -$756,856 | $0 | $0 |
| | Ferry | $179 | $0 | $0 |
| | Franklin | $170,397 | -$3,057,631 | -$3,228,028 |
| | Grant | -$301,660 | -$30,458 | -$173,757 |
| | Grays Harbor | $0 | $0 | $0 |
| | Island | $0 | $0 | $0 |
| | Jefferson | $39,812 | $0 | -$160,275 |
| | King | -$16,516,296 | $0 | $0 |
| | Kitsap | -$30,929 | $0 | $0 |
| | Kittitas | -$2,499,940 | $0 | $0 |
| | Klickitat | -$37,391 | -$25,457 | -$25,457 |
| | Lewis | -$23,650 | $0 | $0 |
| | Lincoln | $9,211 | $0 | $0 |
| | Mason | -$17,561 | $16,495 | -$29,448 |
| | Okanogan | $0 | $0 | $0 |
| | Pacific | $0 | $0 | $0 |
| | Pend Oreille | $0 | $0 | $0 |
| | Pierce | -$473,441 | $96,841 | $91,398 |
| | San Juan | $0 | $0 | $0 |
| | Skagit | $0 | $0 | $0 |
| | Skamania | $0 | $0 | $0 |
| | Snohomish | -$405,345 | $0 | $0 |
| | Spokane | $14,687 | $0 | $0 |
| | Stevens | $886 | $0 | $0 |
| | Thurston | $0 | $0 | $0 |
| | Wahkiakum | $0 | $0 | $0 |
| | Walla Walla | $88,048 | $893,655 | $865,188 |
| | Whatcom | $0 | $0 | $0 |
| | Whitman | $5,325 | $0 | $0 |
| | Yakima | -$1,465,480 | -$30,001 | -$60,002 |

In total, the Pacific Northwest is projected to lose $60.6 million/year in economic activity under the AOS 3 (12% increase in barge rates). The county-level Value Added impacts of AOS 3 are shown in Figure 44.

*Figure 44: Value Added Impacts of AOS 3 (12% increase in barge rates)*




## 10. CONCLUSIONS

Modern freight transportation systems operate in a multimodal ecosystem where cargo owners design supply chains to optimize cost and service. Across all transportation modes, labor and fuel are the two highest industry cost inputs required to deliver service. Trucks often perform the first and last mile handoff between producers or consumers and transportation networks. This is the most expensive mode but offers the most flexibility and is typically used sparingly in bulk transportation applications. Rail and barge have competed for market share for over 100 years, where rail typically concedes advantage to the waterway if the marine system is reliable and transparent when it comes to planned and unplanned outages. Cargo owners have traditionally managed risk by splitting freight between rail and barge networks in order to maintain options when networks fail.

This analysis documented freight costs and volumes of key commodities which currently use the Columbia Snake River Transportation network. Three investment scenarios for this important transportation system were developed which looked at level of infrastructure investment, transportation shipping service impacts on freight volumes and costs, and the number of direct and indirect jobs which would be impacted by waterway system performance.

### Factors which also influence investment

The 465-mile marine corridor supports 21 river ports, some of which are rail served. More than 17,000 land parcels, 113 grain elevators and dozens of small truckload carriers provide services to support marine shipments. Three significant ports have available capacity to grow and support additional marine development.

Tonnage from the Columbia Snake Systems is an economic engine for these communities.

The 2019 Washington State Rail Plan forecasted rail growth through 2040. Based on moderate economic assumptions, it projected an overburdened rail network which will require maintenance cost and investments to manage congestion. Not all producers have the volume to support a unit train network so barge options can provide service for smaller producers of specialty or customized orders.

Railroads are also facing unprecedented labor shortages and service exceptions due to network redesign known as precision scheduled railroading. This strategic move has created many service issues for which some of the largest rail users have taken complaints to the Surface Transportation Board for relief. The trucking industry is also facing driver shortages, contributing bottlenecks in the transportation network.

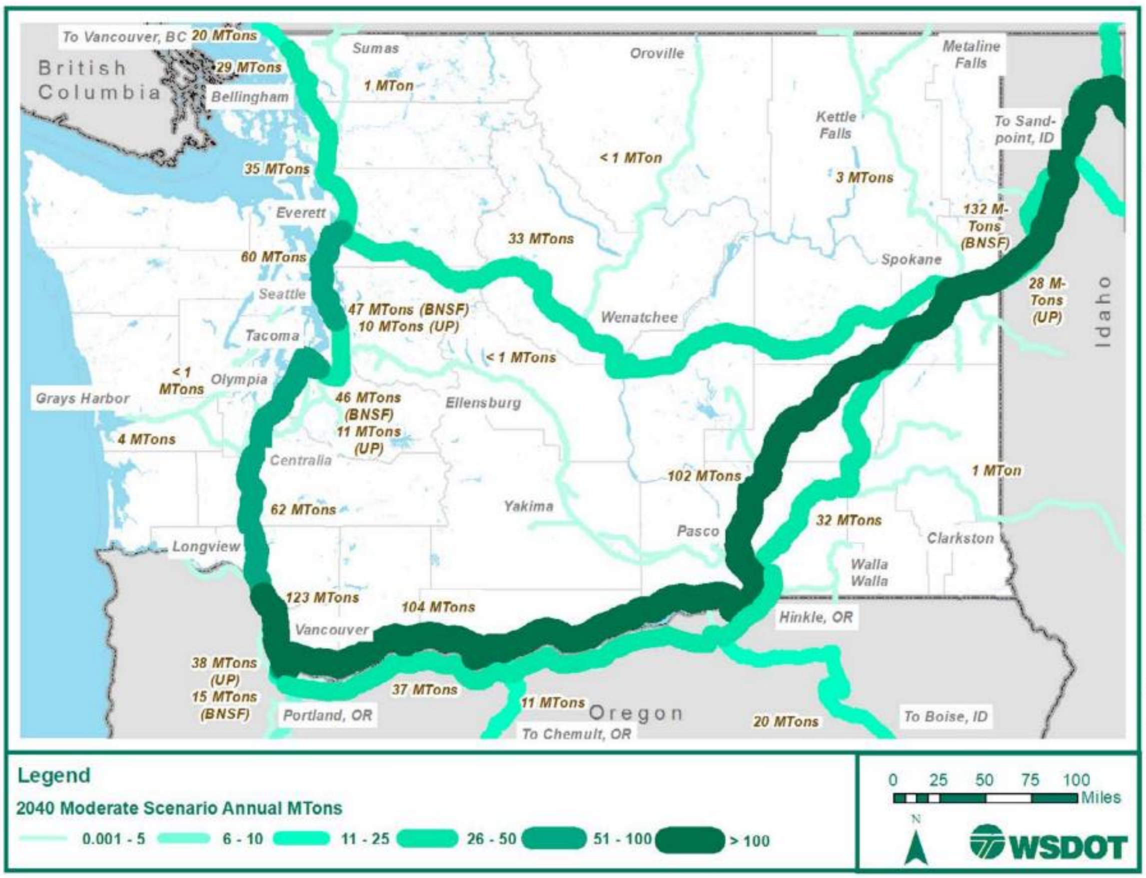



*Figure 45:11 2019 Washington State Rail Plan Freight Volumes*

## Climate Change and Environmental Sustainability

Resilience is becoming an increasingly significant consideration with record fires and floods and transportation disruptions in recent years. Investing in resilience and redundant systems is essential to keeping our global shipping routes reliable and connected to offshore markets which support our regional economies.

# REFERENCES


Agribusiness Consulting. (2019). Importance of Inland Waterways to U.S. Agriculture.

ATRI (2020). Analysis of the Operational Cost of Trucking.

Earth Economics. (2017). The Value of Natural Capital in the Columbia River Basin: A Comprehensive Analysis.

Edwards, W. (2015). Estimating Farm Machinery Costs. Ag Decision Maker.

ECONorthwest. (2019). Lower Snake River Dams Economic Tradeoffs of Removal.

EIA. (2019). State Energy Data System. (https://www.eia.gov/state/seds/seds-data-complete.php#Consumption)

FCS. (2020). National Transportation Impacts & Regional Economic Impacts Caused by Breaching Lower Snake River Dams.

Rocky Mountain Econometrics. (2015), Lower Snake River Dam Navigation Study.

USACE. (2020). Environmental Impact Statement: Columbia River System Operations.

USACE. (2002). Lower Snake River Juvenile Salmon Migration Feasibility Report and Environmental Impact Statement.

## APPENDIX

### A1 Transportation Optimization Model

To measure the economic impacts of Columbia-Snake River navigation, constrained transportation optimization models are developed to capture the choices that the region's shippers face. These models identify the shipment mode, route, and costs for each commodity and each shipper. The models are optimized by finding the set of commodity flows that minimizes total system-wide transportation costs.

The purpose of the transportation optimization model is to find the least cost set of routes that deliver commodities from their origin (farm, port, refinery) to their destination (port, farm, end-user), without exceeding system capacity constraints. To identify this set of routes (commodity-flows), the model is solved as a linear programming problem where total transportation costs, C, are written as function of volume transported, $v(o, d, m)$, from each origin, $o$, to each destination, $d$, by mode $m$, and transportation costs, $c(o, d, m)$ from each origin to each destination by mode:

$$C = \sum_{o,d,m} v(o, d, m) * c(o, d, m)$$

This is the region-wide total transportation cost function, that represents the sum of all volumes moved to satisfy supply and demand in the region, for each commodity. Then, total transportation costs (C) can be minimized by selecting the origin, destination, and mode of each commodity flow, subject to commodity supply and demand constraints:

$$\min_{v(o,d,m)} \sum_{o,d,m} v(o, d, m) * c(o, d, m)$$

subject to:

$$\sum_{d,m} v(o, d, m) \leq S(o),$$

$$\sum_{o,m} v(o, d, m) \geq D(d)$$

where $S(o)$ is equal to commodity supply available at origin $o$, and $D(d)$ is equal to commodity demand at destination $d$. Additional constraints are included in the linear optimization models to ensure transportation logistics are satisfied for each commodity and mode, including capacity constraints by mode and lane and capacity constraints at intermediary facilities (elevators, terminals).

The objective of each transportation optimization model is to minimize system-wide total transportation costs. Overall, an increase in barge efficiency (decrease in barge rates) results in a decrease in system-wide transportation costs. However, for some counties, an increase in barge efficiency (decrease in barge rates) may result in an increase in estimated county-level transportation costs. This is most notable in the petroleum commodity flows (Figure 38) where on a more efficient river, supply that was formerly available in the greater Portland region is shipped upriver to meet inland demand, at the cost of increasing delivered petroleum costs in the greater Portland area.