ECONOMIC IMPACTS OF CRUDE OIL TRANSPORT ON THE GRAYS HARBOR ECONOMY

August 2015

Resource Dimensions

Credits and Acknowledgments

This report has been prepared with the assistance of many people, to all of whom we extend sincere thanks. First, thank you to the volunteers of the Friends of Grays Harbor for their help in obtaining and compiling pertinent studies and publications.

We are indebted to the staff of the Quinault Indian Nation for their efforts in compiling certain data and maps, participation in expert interviews, and other support. We are grateful for their time and knowledge, which was essential to our understanding of the concepts and topics involved, and various analyses.

Finally, we are particularly appreciative of the endeavors of Arthur (R.D.) Grunbaum of the Friends of Grays Harbor. Without his insights and willingness to assist us in data collection this effort would have been very difficult to complete.

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Cover Credit:

Background, Beaches of Grays Harbor *(Resource Dimensions)*

Lower left inset, clockwise from top: Port of Grays Harbor, courtesy of KXRO (*photographer unknown*); Razor clams *(Washington Department of Fish and Wildlife)*; Fishing boats at Westport Marina *(Resource Dimensions)*.

This project was funded in part by the Rose Foundation (Oakland, CA) and through earlier work for the Quinault Indian Nation, which provided foundational data and analysis for this study.

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Table of Acronyms

AARG	Average Annual Rate of Growth
ANS	Alaska North Slope
ATB	Articulated tug-barge
BEA	Bureau of Economic Analysis, United States Department of Commerce
Bbl	Barrel
CBR	Crude-by-rail
DNR	Department of Natural Resources, Washington State
DSAYS	Discounted service acre years
DWT	Deadweight tonnage
ESD	Employment Security Department, Washington State
FTE	Full-time equivalent
FY	Fiscal year
GDP	Gross domestic product
GHRT	Grays Harbor Rail Terminal, LLC
GNOME	General NOAA Operational Modeling Environment
IMPLAN	IMpact analysis for PLANning
IO	Input-output
ITS	Imperium Terminal Services
NAICS	North American Industry Classification System
NOAA	National Oceanic and Atmospheric Administration
NWR	National Wildlife Refuge, Grays Harbor
OMA	Oil-mineral aggregate
PAH	Polycyclic aromatic hydrocarbon
PFMC	Pacific Fishery Management Council
PGH	Port of Grays Harbor
ppb	Parts per billion
ppm	Parts per million
QIN	Quinault Indian Nation
RTIA	Rail traffic impact analysis
T1	Terminal 1, Port of Grays Harbor
T3	Terminal 3, Port of Grays Harbor
TEEB	The Economics of Ecosystems and Biodiversity
USCB	United States Census Bureau
USDA-NASS	United States Department of Agriculture, National Agricultural Statistics Service
USFWS	United States Fish & Wildlife Service
VTIA	Vessel traffic impact analysis
WDFW	Washington Department of Fish & Wildlife
WTP	Willingness to pay

Executive Summary

INTRODUCTION

The Friends of Grays Harbor (FOGH) retained Resource Dimensions of Gig Harbor, Washington to conduct an independent study of the potential effects of three proposed projects at the Port of Grays Harbor (PGH) on the economic impacts of several key industries in Grays Harbor County, Washington. The three projects are the Westway Bulk Liquid Facility Project, the Imperium Bulk Liquid Facility Project, and the Grays Harbor Rail Terminal (GHRT) Bulk Liquid Logistics Terminal Facility Project.

This work included estimating potential costs, economic impacts, and changes in economic contributions due to a crude oil spill in or near the PGH.

Hypothetical crude oil spill scenarios were constructed to frame potential business activity changes. Economic impacts resulting from these scenarios were estimated for Non-Tribal commercial fisheries, commercial aquaculture and visitor-based businesses (businesses serving tourists and recreationists). The estimates developed do not include impacts to private property owners or governments. Similarly, given the complexities of ex-ante analysis on post-event changes in the labor market and the project scope impact estimates do not include jobs that may be created through post-spill response efforts.

The study also quantifies the value of economic contributions produced by select PGH nearshore natural systems to Grays Harbor County and the value of impacts on ecosystem services provisioning under the three hypothetical spill scenarios.

DATA COLLECTION AND ANALYSIS

Several assumptions were required to facilitate this study. Most importantly, the accuracy of our findings relies heavily on findings from other relevant studies, and our assumptions about their validity. Also of note, the impact scenarios used to estimate the economic impacts of a spill are not based on a real oil spill event. Instead, the economic models are framed using information from actual previous spills and relevant science. All monetary values are adjusted to 2014 dollars using gross domestic product (GDP) implicit price deflators.

Valuation methods used include economic impact analysis and benefit transfer. Economic impact analysis was used to assess business and activity changes in the regional economy attributable to externalities of the proposed projects. Economic input-output (IO) models developed using IMPLAN system databases were used to conduct the economic impact analysis. IO modeling was also used to assess the economic contributions of industries to the study region's economy (Grays Harbor County, Washington). The benefit transfer method was used to complement primary valuation research and estimate economic values for a select group of ecosystem services by transferring data from studies in other locations.

After screening for possible impacts to business activities from a crude oil spill, several industries were selected for assessment. These types of businesses include non-Tribal commercial fishing, commercial aquaculture, and visitor-related businesses (such as businesses that serve tourists and recreationists).

Data sources used to compile required information include literature and data provided by FOGH representatives, an independent literature review and data collection from publicly available resources.

Scenario Modeling: Potential Impacts of Oil Spills

Three oil spill scenarios were constructed from a Base Case scenario (normal business activities) using the best available science on oil types, characteristics, flow, fate, and transport (i.e. how a certain type of oil disperses from a spill). This information helped us select business activities most likely affected for each scenario.

Characteristics of the oil types most likely received and shipped by the proposed projects were assessed. There is no known publically available model for understanding oil flow, fate, or transport in or near Grays Harbor. Cumulative risk analyses for rail traffic or vessel traffic were also not available.

Applying results of a known spill to a modeled spill to project environmental impacts is problematic, as each involved Bunker C fuel oil, occurred/were modeled to occur off the Grays Harbor entrance, and involved far less oil than could be shipped by vessels calling on the proposed projects.

Four scenarios were constructed to estimate spill effects:

- Base Case Scenario, which assumes normal business activities (based on 2013 activities).
- Scenario 1: Derailment of or an accident involving a crude-by-rail (CBR) train between the Wishkah River crossing and Cow Point, causing a spill into the Chehalis River.
- Scenario 2: A marine vessel accident inside Grays Harbor in the navigable channel near Moon Island, causing a spill.
- Scenario 3: A marine vessel accident off the Grays Harbor entrance due to the bar crossing, causing a spill.

With no cumulative risk analyses and oil flow, fate, or transport model specific to Grays Harbor, assumptions were made regarding business activities affected, estimated economic impacts, and estimated changes in economic contributions post-spill.

Scenario 1, 2 and 3 Assumptions:

- Crude oil was the oil type selected based on project proponent documents and publicly available literature.
- Spill incidents occur in 2020, assuming regulatory and proposed construction and operations timelines.
- Adverse effects to certain business activities continue until 2022.[2]

[2] Environmental impacts of an oil spill can persist for many years. These scenarios, however, include three years of economic impacts of spilled oil, which is consistent with the duration of economic impacts observed after known oil spills.

- The type of oil spilled in each scenario is diluted bitumen crude oil. This oil type was selected because it exhibits characteristics similar to oils with well-known impacts outlined in previous studies.
- Spill volumes are 542,000 gallons in Scenario 1 and 11,000,000 gallons in Scenarios 2 and 3, similar to volumes of actual crude oil spills.
- Spilled oil spreads eastward into the Chehalis River and its tributaries, throughout all of Grays Harbor, and seaward north and south along the Pacific coast in hours.
- Response efforts do not completely remove oil before it reaches sensitive areas within Grays Harbor.
- Spilled oil emulsifies, disperses and settles on substrates, adhering to and causing smothering and mechanical injury to aquatic life.
- Some spilled oil is not cleaned and will persist in the environment.
- Spilled oil causes environmental damage that adversely affects business activities in many industries.
- The duration of impacts to Non-Tribal commercial fisheries, fisheries-based activities, commercial aquaculture and select visitor-based businesses begins in 2020, with reduced revenue occurring from 2020 through 2022.

To model post-spill economic impacts of fisheries-based activities, landings-related revenue was decreased by a factor of 33% for 2020, 2021 and 2022. To model post-spill economic impacts of select visitor-based businesses, visitor-related revenue was decreased by a factor of 10% for 2020, 2021 and 2022.

Inferences about oil flow and environmental impacts drawn from current literature were used to select business activities expected to be affected in Scenarios 1, 2 and 3. In Table ES-1, solid circles indicate business activities under each scenario assumed to be affected by externalities of spilled oil. The absence of a solid circle under each scenario indicates that the business activity is assumed to not be affected.

Table ES-1. Business Activities Affected, by Scenario

Business activity	Scenario 1	Scenario 2	Scenario 3
Non-Tribal commercial fishing			
Ocean salmon		●	●
River salmon and sturgeon	●	●	●
Dungeness crab	●	●	●
Groundfish			●
Pink shrimp			●
Albacore tuna			●
Spot shrimp			●
Sardine			●
Anchovy			●
Hagfish			●
Razor clam		●	●
Commercial aquaculture	●	●	●
Visitor-related businesses (tourism)	●	●	●
Sport fishing			
Ocean salmon		●	●
River salmon	●	●	●
Albacore tuna			●
Bottomfish	●	●	●
Halibut			●
Razor clam		●	●

Source: Resource Dimensions, 2015

Potential Impacts of Oil Transport and Spills on the Regional Economy

Non-Tribal Commercial Fisheries

Non-Tribal commercial fishers harvest several fisheries in river and marine waters. Fisheries landed in Grays Harbor County include: ocean salmon (Chinook and coho), river gillnet salmon (Chinook and coho), Dungeness crab, groundfish, pink shrimp, albacore tuna, spot shrimp, sardines, anchovy, and hagfish. Razor clams are harvested from Grays Harbor County beaches.

Weight and value data for Non-Tribal landings in Grays Harbor County are reported by the Pacific Fishery Management Council (PFMC) and the Washington Department of Fish and Wildlife (WDFW). The yearly average value for Non-Tribal commercial fisheries was $39,738,222 per year (Table ES-2).

Table ES-2. Yearly Average Values of Non-Tribal Commercial Fisheries (2004-2013)

Year	All Fisheries	
	Pounds	Value
2004	74,889,768	$ 21,730,775
2005	95,377,096	$ 38,113,433
2006	74,603,409	$ 25,627,998
2007	78,657,636	$ 31,503,538
2008	71,431,812	$ 41,806,976
2009	59,358,913	$ 30,247,019
2010	104,114,911	$ 39,105,912
2011	88,046,198	$ 55,869,687
2012	130,109,186	$ 54,195,748
2013	125,872,447	$ 59,181,139
Annual Average	90,246,138	$ 39,738,222

Source: Resource Dimensions, 2015

Commercial Aquaculture

The commercial aquaculture industry in Grays Harbor is comprised of six shellfish farms (i.e. farms that report sales of shellfish products) and two integrated shellfish farm/processors (IEc, 2014a). Commercial aquaculture in Grays Harbor County from 2004 to 2013 was comprised of mollusk (Pacific oyster and Manila clam) farming. From 2004 to 2013, annual average production of Pacific oysters in Grays Harbor County was 1,392,849 round pounds for an average value of $4,754,840. Annual average production of Manila clams in Grays Harbor County was 1,207 round pounds for an average value of $3,332. Expenditures per acre for shellfish farming were estimated to be $5,330.

Tourism and Recreation

Dean Runyan Associates (DRA) (2013) reported that overnight visitor trips to Grays Harbor County in 2012 totaled 1,501,000 person-trips (Table ES-3). DRA (2013) does not report an estimated number of day trips to Grays Harbor County.

Point 97 and the Surfrider Foundation recently conducted a study of coastal recreation in Washington. One component of this effort was a random online survey of state residents. Survey respondents indicated that 59.8% of trips to the coast were for recreation, and 23.9% of trips were for leisure and/or tourism. 13.4% of survey respondents reported that the length of their last trip to the Washington coast was a day trip (Point 97 and Surfrider Foundation, 2015).

Extrapolating from DRA (2013), it was estimated that there were 1,256,337 overnight trips and 168,349 day trips for a total of 1,424,686 trips to Grays Harbor County in 2013 for recreation, leisure and/or tourism (Table ES-3).

Table ES-3. Estimated Trips to Grays Harbor County for Recreation and Tourism (2012)

	Person Trips	Recreation Person Trips
Hotel, Motel	606,000	507,222
Private Home	567,000	474,579
Other Overnight	328,000	274,536
All Overnight	1,501,000	1,256,337
Day Trips		168,349
Total Trips		*1,424,686*

Sources: DRA, 2013; Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015

Note: 'Recreation Person Trips' includes trips for recreation, leisure and tourism.

Point 97 and Surfrider Foundation (2015) also asked survey respondents to estimate their trip expenditures (we summed categories). Average expenditures by category were multiplied by the estimated number of overnight trips to calculate estimated spending totals. Total expenditures by overnight visitors were estimated to exceed $146.8 million.

The same extrapolation was applied to spending by day trip visitors (the lodging/campsite fee expenditure category was excluded). Total expenditures by day trip visitors were estimated to be $15.3 million-plus.

Table ES-4 provides estimates for the total number of trips to Grays Harbor County for recreation, tourism and leisure and total trip expenditures. Trip expenditures were estimated to total over $162 million.

Table ES-4. Total Estimated Trips and Trip Expenditures

Visitor Type	Estimated Trips	Estimated Expenditures
Overnight visitors	1,256,337	$ 146,840,669
Day trip visitors	168,349	$ 15,306,305
Total	1,424,686	$ 162,146,974

Source: Resource Dimensions, 2015

Decreases in visitor spending are assumed to vary by scenario and municipality. To estimate potential post-spill changes in economic contributions resulting from disruptions to visitor patterns visitor-related revenue was decreased by a factor of 10% (the median of assumptions) for 2020, 2021 and 2022 (Ritchie, et al., 2013; Oxford Economics, 2010; Garza, et al., 2009).

Sport Fishing

A number of species are targeted by sport fishers, or anglers, in Grays Harbor, rivers and tributaries in nearshore areas, and at sea out of Westport. Recreational ocean salmon trolling, albacore tuna, bottomfish, and halibut angler-trips are reported as angler-trips departing from Westport. WDFW collects Grays Harbor recreational gillnetting trip data from private and charter boats in Westport at the

Johns River, 28th Street, Cosmopolis, Montesano, and Fuller Bridge boat launches. On average, there were 57,068 angler-trips per year from 2004-2013. Sport fishing for Dungeness crab was not considered because very little recreational crabbing occurs in the Grays Harbor area and data on recreational landings are not collected.

The United States Fish & Wildlife Service (USFWS) surveys national participation rates and trip and equipment expenditures on hunting, sport fishing and wildlife-associated recreation. The total number of freshwater and saltwater anglers in Washington was estimated at 938,000 in 2011, with 13,449,000 days of participation and 12,579,000 angler-trips (an average of 13.4 angler-trips per angler).

Estimated trip expenditures per angler-trip were multiplied by 57,068 to estimate total expenditures (categories were summed). Average expenditures for sport fishing in the Grays Harbor area were estimated to be $4.6 million annually.

Recreational Razor Clam Digging

WDFW manages razor clams on all coastal beaches in Washington for recreational use. Three of these beaches— Mocrocks, Copalis and Twin Harbors — are in Grays Harbor County. The average number of digger-trips for the four most recent seasons (2010-2011, 2011-2012, 2012-2013 and 2013-2014) total for these three beaches was 173,152 annually.

Results from an April 2008 survey conducted by University of Washington researchers were used to estimate trip expenditures per digging party by beach. The greatest expenditure categories, on average, were 'Gas and Oil' ($94.36), 'Hotel' ($91.51) and 'Restaurant' ($70.30) (2008 dollars).

Average trip expenditures per person were estimated to total $91.94 (2014 dollars). Trip expenditure estimates (summed over all categories) were multiplied by 173,152 to estimate total expenditures, on average over the four seasons, for digging on the three beaches. Total expenditures were estimated to average about $15.9 million annually.

Summary of Economic Contributions and Impacts

Economic impact tables, developed in IMPLAN, used business revenue and expenditure data (inputs) collected for selected Non-Tribal commercial fisheries-based and visitor-based businesses. Multiple output files were then created for industry and business, including data for 2014, base data for 2020, 2021, and 2022, and post-spill data for 2020, 2021 and 2022. IO models produce the following outputs: the number of full-time equivalent (FTE) direct, indirect and induced jobs created for the selected activities; direct, indirect and induced personal income generated from these jobs; business revenues; and local purchases made by these industries and businesses.

Economic Impacts of Select Industries and Businesses on Regional Economy

Table ES-5 indicates total economic impacts of industries selected for analysis. IMPLAN models generated the following economic impacts for the regional economy in 2013:

- 3,017.6 direct jobs generated by Non-Tribal commercial fisheries-based activities and visitor-based businesses (generally and collectively 'firms'). Purchases made by these entities supported an additional 456.8 induced jobs in the region.
- 276.2 indirect jobs were supported by $143.2 million of local purchases made by businesses supplying services to these firms.
- $101.9 million of direct wages and salaries were received by the 3,017.6 directly employed.
- Re-spending of this income created an additional $16.1 million of income and consumption expenditures in Washington, principally in Grays Harbor County. Those holding indirect jobs received $10.1 million in indirect income.
- Businesses providing services to these firms received $327.3 million of revenues.
- Firms in these industries paid $32.2 million in state and local taxes.

Table ES-5. Total Economic Impact of Non-Tribal Commercial Fisheries-based Activities and Visitor-Based Businesses ($2014)

		TOTAL IMPACT for Select Activities
Jobs		
Direct		3,017.6
Indirect		276.2
Induced		456.8
Total		**3,750.6**
Personal Income		
Direct	$	101,856,723
Indirect	$	10,071,314
Induced	$	16,153,506
Total	**$**	**128,081,543**
Business Revenue	**$**	**327,345,438**
Local Purchases	**$**	**143,175,789**
State and Local Taxes	**$**	**32,220,160**

Source: Resource Dimensions, 2015

Changes in Economic Impacts for Select Industries and Businesses In the Event of a Spill

To estimate the extent of changes in economic contributions under each scenario, we began with the Base Case scenario model for the period 2020 to 2022 for the select industries and businesses assessed. Sub-models were adjusted to estimate changes in the regional economy resulting from changes in activities expected under each scenario.

Base data for 2020, 2021 and 2022 was extrapolated from the 2014 data set. Post-spill data for 2020, 2021 and 2022, also extrapolated from the 2014 data set, were adjusted by the average three-year factors (0.33 for fisheries-based activities and 0.10 for visitor-based activities) to represent expected changes in business activities under each scenario.

The values estimated for 2020, 2021 and 2022 post-spill scenarios were subtracted from the values estimated for the 2020, 2021 and 2022 base data. The differences in these values represent the changes in economic contributions by business activities affected in each scenario.

The numbers of direct, indirect and induced jobs estimated from 2020 to 2022 are reported as averages. Personal income, business revenues and local purchases are reported as aggregates over 2020 to 2022.

Table ES-6 indicates the changes in economic contributions by Non-Tribal fisheries-based activities and visitor-based businesses to the regional economy from 2020 to 2022, by spill scenario:

- An average three-year decrease of 679.4 direct jobs in these activities in Scenario 1, 725.5 direct jobs in Scenario 2, and 892.7 direct jobs in Scenario 3. The majority of these direct job losses will be those employed in tourism and Non-Tribal commercial fishers.
- Purchases made by businesses supplying services to these businesses are estimated to decrease by $106.2 million in Scenario 1, $116.2 million in Scenario 2, and $138.5 million in Scenario 3.
- Direct wages and salaries over 2020 to 2022 are estimated to decline for the individuals still employed by these firms by $77.9 million in Scenario 1, $84.0 million in Scenario 2, and $101.1 million in Scenario 3.
- From 2020 to 2022, businesses providing services to these firms can expect to receive $235.0 million less in revenues in Scenario 1, $257.6 million less in Scenario 2, and $308.8 million less in Scenario 3.
- State and local taxes paid by individuals and firms in these industries was estimated to decrease by $20.9 million in Scenario 1, $23.6 million in Scenario 2, and $27.8 million in Scenario 3.

Table ES-6. Summary of Economic Contribution Losses for Non-Tribal Commercial Fisheries-based Activities and Select Businesses (2020-2022)

	Scenario 1 TOTAL	Scenario 2 TOTAL	Scenario 3 TOTAL
Jobs			
Direct	679.4	725.5	892.7
Indirect	59.8	65.7	78.6
Induced	107.3	115.5	140.1
Total	**846.5**	**906.7**	**1111.4**
Personal Income			
Direct	$ 77,867,051	$ 83,993,288	$ 101,088,733
Indirect	$ 8,141,370	$ 8,846,243	$ 10,947,373
Induced	$ 12,598,423	$ 13,579,978	$ 16,454,959
Total	**$ 98,606,844**	**$ 106,419,509**	**$ 128,491,065**
Business Revenue	**$ 234,988,579**	**$ 257,585,641**	**$ 308,811,611**
Local Purchases	**$ 106,226,452**	**$ 116,151,917**	**$ 138,462,625**
State and Local Taxes	**$ 20,929,803**	**$ 23,636,028**	**$ 27,762,640**

Source: Resource Dimensions, 2015

POTENTIAL IMPACTS OF AN OIL SPILL ON ECOSYSTEM SERVICE VALUES

Ecosystem services are outcomes of natural systems and processes that are beneficial to humans. Ecosystem services are often categorized into provision services (e.g. food, raw materials, and fresh water), regulating services (pest and flood control, carbon sequestration, and air quality), supporting services (habitat and biodiversity), and cultural services (recreation, tourism, spiritual, and aesthetic).

There are many valuation methods commonly used to quantify ecosystem services. For the scope of this study, the benefit transfer method was used. Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., per visitor day, per household, per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed.

Ecosystem Services in Grays Harbor County

Grays Harbor County ecosystems provide many services to residents and visitors. Estuaries, marine, wetlands, and rivers provide food. Marine areas provide raw materials. Forests, estuaries, rivers, marine areas, and wetlands contribute to the water supply. Forests and marine areas improve air quality. All land cover types provide aesthetic and amenity value. These services, among others, are an integral part of both natural and human systems.

Ecosystem services in Grays Harbor County are valued between $411.4 million and $3.3 billion (Table ES-7). The most valuable land cover type per acre is beaches, valued between $26,000 and $105,998 per acre. There are more acres of estuaries, however, and at the high end estuaries are the most valuable land cover type, providing $1.5 billion in services (acre/year). Forest and beaches provide the second and third highest total ecosystem service values, respectively.

Table ES-7. Summary of Ecosystem Services Values by Land Cover Type ($2015)

Land Cover	Acres	Low Total	High Total
Beaches	4,415	$115,575,797	$467,935,494
Estuaries	38,021	$89,888,138	$1,531,970,807
Forests	22,393	$122,516,434	$568,809,846
Grasslands	2,932	$22,632,506	$48,187,963
Rivers and Lakes	538	$949,249	$24,170,148
Marine	20,224	$17,456,724	$389,499,259
Shrub	5,635	$3,489,990	$11,270,000
Wetlands	8,886	$38,889,963	$304,016,389
Total	103,044	$411,398,801	$3,345,859,905

Source: Resource Dimensions, 2015

We estimate that the most valuable ecosystem service in Grays Harbor County is recreation and tourism, valued between $3,486 and $92,594 (acre/year) (Table ES-8). Soil formation and waste treatment are the second and third most valuable services, respectively (at the maximum).

Table ES-8. Summary of Ecosystem Services Values by Ecosystem Service Type ($2015/acre/year)

Service Provided	Min	Max
Provisioning		
Food	$1,164	$1,341
Raw Materials	$1	$1
Water Supply	$903	$21,391
Regulating		
Air Quality	$194	$194
Carbon Sequestration	$24	$590
Natural Hazards Mitigation	$3,702	$15,217
Pollination	$513	$884
Soil Formation	$162	$59,819
Soil Retention	$40	$3,490
Waste Treatment	$29,945	$56,592
Water Regulation	$759	$2,932
Societal/Cultural		
Aesthetic/Amenity	$7,110	$26,454
Recreation and Tourism	$3,486	$92,594
Supporting		
Habitat	$762	$6,426
Biodiversity/Genetic Resources	$593	$593

Source: Resource Dimensions, 2015

Ecosystem Services Damages by Scenario

Potential damages to ecosystem services caused by an oil spill range from $17 million at the low end of scenario 1 to $1.6 billion at the high end of scenario 2. Scenario 2, a spill in the navigable channel that spreads throughout Grays Harbor, causes the highest ecosystem services damages, from $113 million to $1.6 billion. The lack of empirical ecosystem services studies post-spill creates unavoidable uncertainty in our estimates and we present a wide range of values to reflect that uncertainty.

Scenario 1 causes the most severe damage to rivers and lakes (in acres damaged). Marine areas, forests, and estuaries have more highly valued ecosystem services, however, so total lost value is highest in those land cover types (Table ES-9). Scenario 2 most severely damages marine ecosystems, dramatically reducing productive acres. Estuaries are also seriously damaged and have more service value, therefore creating the highest total loss in value. Scenario 3 causes the most damage in marine ecosystems, both in acreage and total lost ecosystem services value.

Table ES-9. Summary of Ecosystem Services Damage by Scenario ($2015)

	Scenario 1		Scenario 2		Scenario 3	
Land Cover	**Low**	**High**	**Low**	**High**	**Low**	**High**
Beaches					$15,026,163	$60,836,914
Estuaries	$2,028,481	$34,571,574	$64,712,815	$1,102,905,741	$373,543	$6,366,327
Forests	$8,576,150	$39,816,689	$18,377,465	$85,321,477		
Grasslands			$2,715,901	$5,782,556	$115,787	$246,528
Rivers and Lakes	$758,693	$19,318,148	$29,995	$763,741		
Marine	$2,057,794	$45,914,074	$14,671,279	$327,349,630	$12,559,105	$280,222,222
Shrub	$139,600	$450,800	$1,235,029	$3,988,200		
Wetlands	$4,277,896	$33,441,803	$11,666,989	$91,204,917		
Total	$17,838,615	$173,513,088	$113,409,472	$1,617,316,260	$28,074,598	$347,671,991

Source: Resource Dimensions, 2015

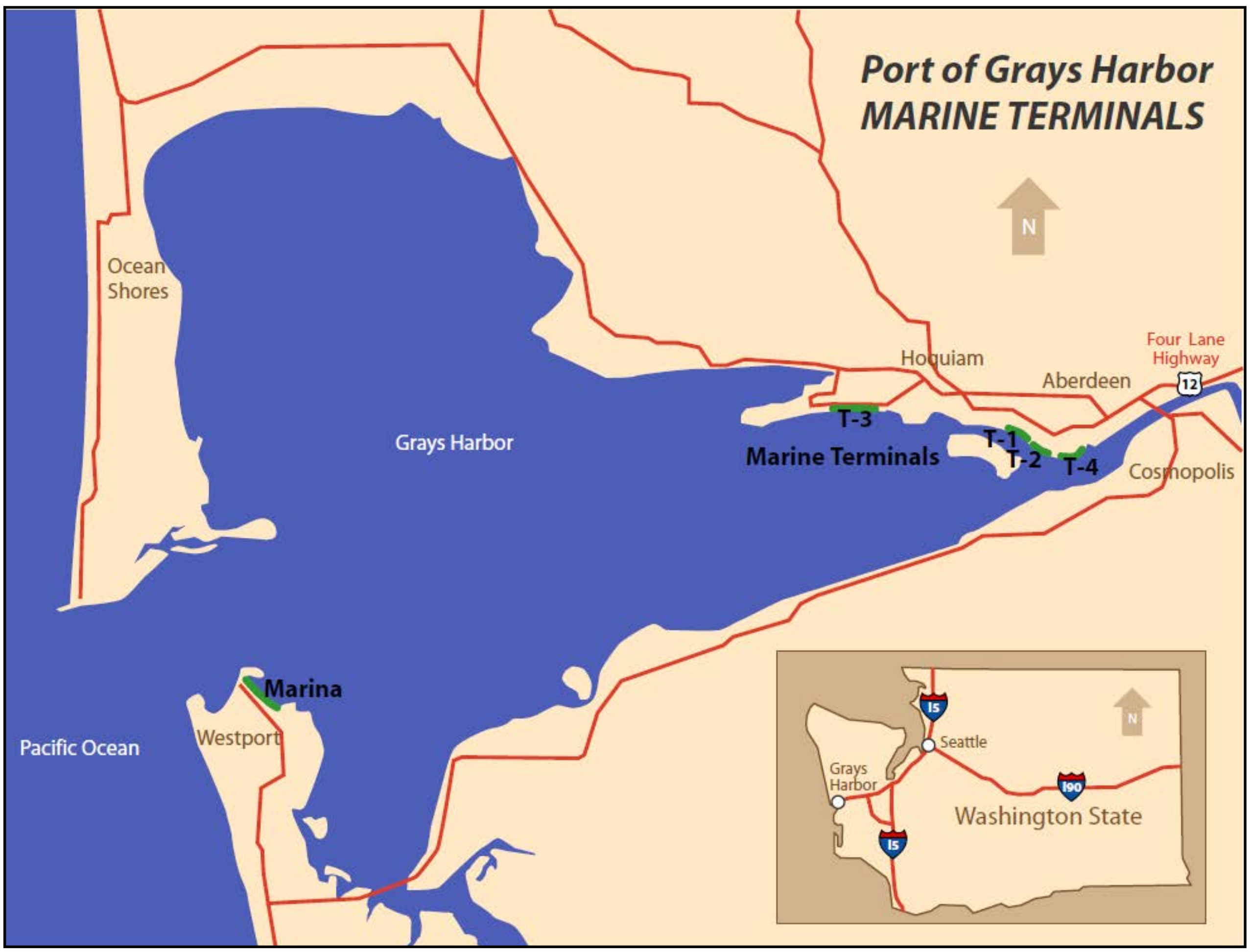
SECTION ONE: Introduction

1.1 BACKGROUND

The Port of Grays Harbor (PGH), located in Grays Harbor County, Washington, handles a diverse cargo mix. The highest volume of American-grown soybean meal in the United States is exported through PGH, and the Port receives the highest volume of seafood landings in Washington, primarily at its Westport Marina. Other products shipped through the PGH include automobiles, forest products, fuels, and other dry bulk and liquid materials (PGH, 2015).

PGH owns and operates the Westport Marina and has four terminals in the northeast corner of Grays Harbor, in the towns of Hoquiam and Aberdeen. Two current PGH tenants are proposing expansion projects at Terminal 1 (T1), and a third company is proposing constructing a new facility at Terminal 3 (T3) (Figure 1).

Figure 1. Port of Grays Harbor with Terminal Locations



Source: PGH, 2014

Project proponent Westway Terminal Company LLC, proposes to "*expand its existing bulk storage terminal to allow for the receipt of crude oil unit trains, storage of crude oil, and shipment of crude oil by ship or barge*" from T1 (City of Hoquiam and DOE, 2014c).

Project proponent Imperium Terminal Services, LLC, a wholly owned subsidiary of Imperium Renewables Inc., proposes expanding its existing bulk liquid storage terminal at T1 to facilitate the receipt, storage and shipment of biofuels, feedstocks for biofuel production, petroleum products, and renewable fuels (City of Hoquiam and DOE, 2014b). Project information documents note that bulk liquids may be shipped to and from this property by rail, trucks, ships or barges.

At T3, project proponent Grays Harbor Rail Terminal, LLC (GHRT) is proposing *"a bulk liquids rail logistics facility*". The new facility is anticipated to accommodate the receipt of 45,000 barrels (bbls) per day, on average, *"of various liquid bulk materials, specifically, various types of crude oil and condensates"*. These materials are proposed to be delivered to the proposed facility *"via unit trains in fully contained rail cars, unloaded into on-site storage tanks, and then loaded onto barges or other marine vessels"* (City of Hoquiam and DOE, 2014a).

1.2 Purpose and Limitations

The Friends of Grays Harbor (FOGH) retained Resource Dimensions of Gig Harbor, Washington to conduct an independent study of the potential effects of three proposed projects at the PGH on the economic impacts of several key industries in Grays Harbor County, Washington and on the contributions made by relevant PGH nearshore natural systems. This work included estimating the extent of potential costs and economic impacts due to a crude oil spill in or near Grays Harbor.

FOGH is a broad-based 100% volunteer tax exempt 501(c)(3) citizens group. Its mission is to "*foster and promote the economic, biological, and social uniqueness of Washington's estuaries and ocean coastal environments*". The goal of FOGH is to "*protect the natural environment, human health and safety in Grays Harbor and vicinity through science, advocacy, law, activism and empowerment*" (FOGH, 2014).

FOGH has many concerns regarding the proposed projects, including aspects of surface and marine transportation of commodities to and from the facilities, and operational impacts of the facilities (FOGH, 2014).

As with all socioeconomic research, study results have limitations that reflect trade-offs between project resources (time, funding, etc.) and study robustness and accuracy. Notwithstanding, the principal goals of the study have been met under a compressed timeframe.

It is important to note that the vast majority of the analyses herein rely on secondary data – data not collected and analyzed by the study authors. The study authors make no claims to the veracity of secondary data.

We quantify many of the economic contributions and losses that may be incurred due to the proposed projects. This report also details the potential magnitude of changes in economic contributions from the proposed projects and their associated operations, using the best available data. Assumptions were made to facilitate the analytical frameworks in this study. These are noted throughout to the extent practicable.

Lastly, we have not been able to incorporate all of the valid qualitative data that we gathered because of its magnitude and the complexity of analyzing such data. The most pertinent of this information is discussed; that such data was not incorporated does not undermine the quantitative analysis or results.

1.3 Overview: Proposed projects at the Port of Grays Harbor

1.3.1 Westway Bulk Liquid Facility Project

The Westway Bulk Liquid Facility Project — the expansion of an existing bulk liquid storage terminal — would be located on two adjacent parcels at T1 and would be built in two phases. Five new storage tanks to accommodate crude oils would be constructed, each having an individual capacity of 200,000 barrels (bbls) for a total storage capacity of 1,000,000 bbls. The annual maximum throughput of crude oil is anticipated to be 17,855,000 bbls (City of Hoquiam and DOE, 2014c).

An existing rail facility on the two parcels would be expanded from two short spurs, with 18 loading/unloading spots, to four longer spurs with 80 loading/unloading spots.

A new pipeline would also be constructed to connect the new tanks to T1 through an existing pipeline bridge. Work on the terminal dock is anticipated to include the addition of loading arms and components of a marine vapor combustion system. No in-water work would be performed.

Westway Terminal Company *"estimates that terminal operations would handle 458 unit trains a year (loaded and empty) or 1.25 trains per day [120 railcars]. The company estimates that the terminal operations would handle 99 to 119 barges a year (198 to 238 entry and departure transits)"* (City of Hoquiam and DOE, 2014c; City of Hoquiam, 2013).

1.3.2 Imperium Bulk Liquid Facility Project

The Imperium Bulk Liquid Facility Project — expansion of an existing bulk liquid storage terminal — would be located on a leased parcel at T1. A majority of the proposed project – new storage tanks and the bulk of rail facility improvements – would be in Hoquiam. A new office building and a portion of rail facility improvements would be in Aberdeen (City of Hoquiam and DOE, 2014b).

Imperium Terminal Services (ITS) proposes building up to nine new storage tanks, each with a capacity of 80,000 bbls (a projected new storage capacity of 720,000 bbls). The project proponent anticipates that the annual maximum throughput for the entire facility, including both existing storage capacity and proposed capacity, would be 30,000,000 bbls per year.

The new tanks would store bulk liquids including the following: *"biofuels, such as ethanol, biodiesel, and additional feedstocks for biofuel production such as used cooking oil/waste* *vegetable oil and animal fat; petroleum products including naptha, gasoline, vacuum gas oil, jet fuel, no. 2 fuel oil, no. 6 fuel and kerosene; crude oil; and renewable fuels such as renewable diesel and renewable jet fuel"* (City of Hoquiam and DOE, 2014b).

ITS proposes constructing about 6,100 feet of railroad track in multiple new rail spurs and expanding the existing rail yard.

Two new pipelines would be installed to connect the new tanks to T1 through an existing pipeline. ITS also proposes installing a marine vapor combustion unit and one or more new buildings. No in-water work would be performed.

ITS *"estimates that the terminal operations would handle a maximum of 730 unit trains a year (loaded and empty) or two (2) unit trains per day. The company estimates that the terminal operations would handle up to 200 ships or barges a year (400 entry and departure transits)"* (City of Hoquiam and DOE, 2014b).

1.3.3 Grays Harbor Rail Terminal Bulk Liquids Logistics Terminal Facility Project

The GHRT Bulk Liquids Rail Logistics Facility Project is proposed on one parcel at T3 in Hoquiam. GHRT anticipates that the facility will receive an average of 45,000 bbls per day of various liquid bulk materials via unit trains. Materials would be unloaded into on-site storage tanks then loaded onto barges or other marine vessels (City of Hoquiam and DOE, 2014a).

GHRT proposes four 20-car yard tracks and two 20-car off-loading or staging tracks for the facility (accommodating 120 rail cars), as well as a 'runaround' track necessary for repositioning. Six to eight above ground storage tanks are proposed for a storage capacity of 800,000 to 1,000,000 bbls. GHRT also proposes constructing up to four additional mooring dolphins off the existing concrete wharf (City of Hoquiam and DOE, 2014a).

GHRT notes that T3 is "*a deep water port capable of mooring Panamax class vessels with carrying capacity up to 350,000 barrels".* The project proponent anticipates a maximum of one unit train every two days delivering various liquid bulk materials. Marine vessel traffic is anticipated to include up to five vessels per month (*"up to 60 outbound vessel and barges per year are projected*") (HDR, 2014a).

1.4 TYPES OF CUMULATIVE ECONOMIC IMPACTS FROM PROPOSED PROJECTS

Rail and marine vessel traffic attributable to the proposed projects could cause direct and indirect changes in business activities for industries operating in the Grays Harbor area (such as in fisheries-based or visitor-based industries). Further, an oil spill, or chronic oil leakage from rail cars, the proposed facilities, or marine vessels could change business activities. These impacts are briefly detailed in this section.

1.4.1 Attributable to rail traffic

The three proposed projects at full build-out would increase loaded and unloaded crude-by-rail (CBR) unit trains by 1,371 annually, an average of 3.75 new CBR unit trains daily (Table 1).

Table 1. Rail Traffic Attributable to the Proposed Projects

Project	Unit trains per year (loaded and empty)	Unit trains per day (loaded and empty)
GHRT Bulk Liquids Logistics Terminal Facility	183	0.50
Imperium Bulk Liquid Facility	730	2.00
Westway Bulk Liquid Facility	458	1.25
Cumulative: GHRT and Imperium	913	2.50
Cumulative: GHRT and Westway	641	1.75
Cumulative: Imperium and Westway	1,188	3.25
Cumulative: All projects	1,371	3.75

Sources: City of Hoquiam and DOE, 2014b and 2014c; HDR Engineering, 2014a

Note: Table 1 describes the number of train trips by project, as reported by the project proponents. These figures do not reflect the specific volumes of oil projected to be moved by the project proponents, or the capacities of the unit trains anticipated to be used by the project proponents. For example, ITS has stated that the new project will receive loaded 100 car unit trains daily, and GHRT has stated that their new project would receive loaded 120 car unit trains every other day, on average. Adjusting for stated capacities, it is apparent that GHRT anticipates moving about half of the volume of oil that ITS anticipates to move.

On average, CBR unit trains are 100 cars long, and hold about 3,000,000 gallons of crude oil (DOE, 2015). The length of these unit trains varies (depending on car type and dimensions), as does their speed. However, any increase in rail traffic attributable to the proposed projects will cause direct and indirect economic impacts.

Among the most significant economic impacts of new CBR unit trains would be travel time delay and traffic blockage at specific intersections and crossings (Natural Resource Economics, 2014). Such delays could interrupt and impede individuals or firms conducting business activity near the proposed train route.

Damage to commercial and residential property could result from oil leaks, diesel emissions, vibration and noise from new rail traffic. Such damage, or the potential for such damage, could adversely affect property values. Likewise, new rail traffic could adversely affect property values if believed to limit access. The potential for accidents – including derailments, fires and explosions – would be heightened with new rail traffic, which could also adversely affect property values (Natural Resource Economics, 2014).

Further, due to some or all of the potential impacts described above, firms may forgo business opportunities and investments, resulting in less positive growth of jobs, income, other business activities, or tax revenues in the local and regional economies.

Other impacts of new rail traffic include: impacts to public safety (e.g., rail-related accidents involving pedestrians); an increased potential for vehicle/train accidents; potential delays of emergency services vehicles (e.g., fire, police, and ambulances); an increase in greenhouse gas emissions, and an increase in particulate emissions and associated health effects (Earthjustice, 2013; Natural Resource Economics, 2014).

1.4.2 Attributable to marine vessel traffic

The anticipated total annual entry (into PGH) and departure (out of PGH) of marine vessels attributable to the proposed projects yearly is 758, with all three proposed projects at full build-out. This is an average of 2.08 new tankers or barges daily (Table 2).[3]

Table 2. Marine Vessel Traffic Attributable to the Proposed Projects

Project	Entry and Departure Transits per year (maximum)	per day (maximum)
GHRT Bulk Liquids Logistics Terminal Facility	120	0.33
Imperium Bulk Liquid Facility	400	1.10
Westway Bulk Liquid Facility	238	0.65
Cumulative: GHRT and Imperium	520	1.43
Cumulative: GHRT and Westway	358	0.98
Cumulative: Imperium and Westway	638	1.75
Cumulative: All Projects	758	2.08

Sources: City of Hoquiam and DOE, 2014b and 2014c; HDR Engineering, 2014a

Each of the three project's information documents state that tankers or barges will be used to transport their products (City of Hoquiam and DOE, 2013; City of Hoquiam and DOE, 2014b; HDR Engineering, 2014a). The project information document for the GHRT project states that T3 "*is a deep water port capable of mooring Panamax class vessels with carrying capacity up to 350,000 barrels*". ITS explains that "*The largest vessel expected to be loaded at Terminal 1 is a Panamax class vessel (60,000 to 80,000* (deadweight tonnage) *DWT) and 300,000 to 350,000 bbls of cargo capacity. Ocean going barges will also be loaded with capacities of up to 150,000 bbls*" (Imperium Renewables, 2013).

Panamax tankers are tank vessels having dimensions up to a "*length of 750 feet, a draft of 41 feet, and a deadweight tonnage (DWT) of 60,000 to 80,000*" (DOE, 2015). Panamax class vessels are mid-sized cargo ships, the maximum size capable of passing through the lock chambers of the Panama Canal. To provide context, a Panamax class vessel is shown in Figure 2.

[3] Vessel traffic attributable to the proposed projects is in addition to existing vessel traffic. 2013 total entering transits in Grays Harbor by cargo/passenger ships, tankers and fishing vessels was 103 (DOE, 2015).

Figure 2. Panamax Class Vessel

Source: Imabari Shipbuilding, 2009

Articulated tug-barges (ATBs) can be used to transport crude oil products inland, near a coast, and at sea. ATBs are a tug-barge combination system (typically 100 to 150 feet long) with a notched stern, allowing a tug to be connected to the barge via a hinged connection to aid maneuvering (Figure 3).

Figure 3. Articulated Tug-Barge (ATB) Vessel

Source: Crowley Maritime Corporation, 2014

One bbl of oil is equivalent to 42 (U.S.) gallons. Thus, a Panamax vessel capable of carrying 350,000 bbls has a capacity of 14,700,000 gallons, and an ATB capable of carrying 150,000 bbls has a capacity of 6,300,000 gallons.

Increases in marine vessel traffic attributable to the proposed projects will cause direct and indirect impacts to the ecology of Grays Harbor and to business activities occurring in the region.

Traffic from tankers, barges and their escort tugs could disrupt the nearshore environment of Grays Harbor, which is habitat for many species, such as juvenile salmon that reside there during migration to sea. Increased turbidity and suspended sediments could negatively affect growth and survival of juvenile fish. Those fish residing in the near shore environment could be adversely impacted by noise, artificial light, and shading (from large vessels) attributable to the proposed projects (Earthjustice, 2013).

Marine vegetation such as eelgrass and macroalgae, important to many species for spawning, forage and refuge, may also be adversely affected by shading (Earthjustice, 2013).

Churning of the Grays Harbor estuary could occur from vessel propellers and wakes. As wave energy reaches shore, erosion (movement of sediment from the shoreline) or accretion (movement of sediment toward the shoreline) of the land could occur, thus altering the land surface and the habitat residing there. In shallow areas, propulsion systems of marine vessels can move sediment and create holes — an effect known as bottom scouring — that could negatively impact the benthic (sea floor) environment (Natural Resource Economics, 2014).

Ballast water discharged from ocean-going ships potentially carries invasive species, which over a long period could adversely affect ecological systems of Grays Harbor. Hull fouling is another potential source of invasive species.

Commercial and sport fishers fish in Grays Harbor and its rivers and tributaries, including in the waters near T1 and T3. These fishers would be directly impacted by increased marine vessel traffic from the proposed projects. Further, increased vessel traffic increases the risk of vessel collisions, groundings, cargo and fuel spills, and leaks during vessel fueling (Earthjustice, 2013).

Diminished revenues resulting from gear loss, damage, or the inability to actively fish are also possible. Vessel movements could damage nets in the water, or could prevent commercial fishers from setting nets altogether. For example, commercial fishers fish in waters around T1 and T3 where fish are known to congregate. Marine vessel movement attributable to the proposed projects is expected to be most intense in these areas, thus magnifying this conflict. Crab pot buoys can be destroyed by vessel wake. When a crab pot buoy is destroyed, crab fishers incur opportunity costs of fishing, forgo revenue from landed crabs, and incur the costs of replacing gear.

1.4.3 Attributable to an oil spill

Oil spills on land or in water from the proposed activities and associated traffic could potentially adversely affect the ecology of Grays Harbor and near shore waters and habitats.

Oil contamination can have devastating effects on freshwater and estuarine habitats and the species that reside there. Not only are the habitats within Grays Harbor at risk from the effects of a spill, so too are upwater habitats of the freshwater tributaries draining into Grays Harbor: "*The Chehalis, Humptulips, Wishkah, Johns, Elk and Hoquiam Rivers are tidally influenced by Grays Harbor. Water moves from Grays Harbor into these drainages and periodically creates a back water effect into its tributaries. Pollutants would make their way into freshwater systems and disperse in the same manner as saltwater*" (Earthjustice, 2013). Further, the proposed rail line closely parallels the Chehalis River, and crosses many fish-bearing streams in the Chehalis River Watershed, creating the potential for a spill directly into freshwater systems (Earthjustice, 2013).

The potential for polluted runoff from the proposed facilities during storm events also exists in the absence of appropriate mitigation (Earthjustice, 2013).

Oil contamination has been shown to cause adverse biological effects on plant and marine life. These effects can disrupt the entire food web of an area. Thus, the effects of oil contamination on all species – regardless of their commercial value – are of concern.

Spilled oil could also adversely affect business activities occurring in Grays Harbor, its tributaries, and adjacent marine waters. Many commercial fishers depend on fishing these waters. An oil spill could threaten their livelihoods if they were unable to fish due to an oil spill, or if fish buyers and processors stopped purchasing due to diminished market demand resulting from perceived or actual contamination of seafood. Commercial fishers might be unable to fish if their fishing areas are oiled, if they need to pass through oiled waters to reach their fishing areas, or if their ability to fish is impeded by spill response.

Revenue could decrease for businesses serving visitors to Grays Harbor County if visitors cancel trips to the area because of concerns that their trip experiences could be lessened. Sport fishers and birders could cancel their trips to the Grays Harbor area for the same reason, decreasing revenues to businesses serving these recreational users.

Finally, firms could forgo potential business opportunities due to risks associated with oil spills, resulting in less growth effect of jobs, income, other business activities, or tax revenues.

SECTION TWO: Scope and Approach

2.1 FRAMEWORK AND KEY ASSUMPTIONS

The remainder of this document is organized as follows:

Section 2, Scope and Approach

The economic valuation methods utilized in this study are presented. The analytical scope and various data collection methods are explained.

Section 3, Economic Setting

The economic setting – demographics, employment and the labor force, and the industries and occupations – of Grays Harbor County, Washington (the regional economy) is described.

Section 4, Scenario Modeling: Potential Impacts of Oil Spills

Characteristics of oil types anticipated to be accepted and shipped by the proposed projects are discussed. Hypothetical oil spill scenarios used in estimating economic impacts are explained.

Section 5, Potential Impacts of Oil Spills on the Grays Harbor County Economy

The economic impacts of relevant industries in Grays Harbor County are assessed. The changes in economic impacts and changes in economic contributions for these industries are evaluated by scenario.

Section 6, Ecosystem Service Valuation

The ecosystem service values provided by the nearshore environment of Grays Harbor County are assessed. The changes in these values are evaluated by scenario.

Key Assumptions

Several assumptions were required to facilitate this study. Most importantly, the accuracy of our findings relies heavily on findings from other relevant studies, and our assumptions of their validity.

Second, all monetary values were adjusted to 2014 dollars using the United States Department of Commerce, Bureau of Economic Analysis (BEA) published seasonally adjusted gross domestic product (GDP) implicit price deflators.[4]

Lastly, there has not been an oil spill in or near Grays Harbor of the magnitudes considered here. Therefore, it is necessary to rely on predicting the impacts such an event could cause.

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[4] The GDP deflator is an index number that represents the *average price* of all the goods and services produced in the economy. U.S. BEA Implicit Price Deflators for GDP, January 30, 2015. http://www.bea.gov

2.2 ECONOMIC VALUATION AND IMPACT METHODOLOGY

Three economic valuation methods were used to analyze each topic and industry. These methods were ***economic impact analysis***, ***economic contribution analysis*** and ***benefit transfer***. The specific uses for each valuation method, and the concepts inherent in each, are explained below.

2.2.1 Economic impact analysis

Economic impacts are those processes that track how spending changes attributable to an economic event – such as a business creation, modification or closure, or a natural or environmental change – move through an economy. An economic impact analysis studies the cumulative effects of those spending changes on a defined geographic study region (Day, 2012).

Five base impact models were developed to estimate the economic contributions and impacts of the Non-Tribal commercial fishing industry, commercial aquaculture, sport fishing and the visitor-based industry on the geographic study region of Grays Harbor County, Washington. From the base impact models, sub-models were constructed for the Non-Tribal fisheries and several groups of businesses with the visitor-based industry. In total, 15 sub-models were developed to evaluate the economic impacts and changes in contributions for the subject activities.

Economic input-output (IO) modeling can be used to estimate the impacts of business activity changes to a region's economy (an ***economic impact analysis***). The basic premise of the IO framework is that each industry sells its output to other industries and final consumers, and in turn purchases goods and services from other industries and primary factors of production. Thus, the economic performance of each industry can be determined by changes in both final demand and specific inter-industry relationships. IO tables assist in calculating overall changes in the flow of money in local and regional economies, including direct, indirect, and induced effects.

Direct effects occur when an industry spends on goods and services, wages, materials, and other related expenditures. These are typically referred to as direct costs of operation. **Indirect effects** occur when consequent purchases are made by suppliers of materials and services to sustain the direct expenditures. **Induced effects** occur when workers in the sectors stimulated by the direct and indirect expenditures spend additional income on consumer goods and services. **Total effect** is the sum of direct, indirect and induced effects.

For illustration, consider the example of a commercial fisher. To conduct the business activity of fishing, the fisher spends on materials at the local marine supply store. This transaction is a direct effect. To stock the materials, the store purchases from a supplier or directly from the manufacturer. These transactions are indirect effects. The store clerk receives wages from his/her labor, and in turn purchases groceries. This transaction is an induced effect.

In this analysis, the effects are those associated with the income and expenditures related to the Non-Tribal commercial fishing and aquaculture, and visitor-based industries activities. The outputs are shown as estimates of changes in employment, personal income, business output, and value added (gross regional product).

2.2.2 Economic impacts of the industries under study

Businesses that serve visitors and Non-Tribal commercial fishers contribute to the local and regional economies by generating business revenue that extends from local to national firms providing services for these sectors. Accordingly, these businesses provide employment and income to individuals. In understanding the linkages across the local and regional economies, note that a single number cannot summarize the impact of any sector; each sector generates several impacts that include employment impacts (jobs), personal income impacts, business revenue impacts, and tax impacts. These impacts are interrelated and non-additive.

Throughout the study, care has been taken to ensure a realistic assessment of the impacts generated by the business activities examined. The estimates developed do not include any costs or losses associated with the impacts of a potential spill to private property owners or governments. Similarly, given the complexities of ex-ante analysis on post-event changes in the labor market, impact estimates do not include jobs that may be created through post-spill response efforts.

These impact classifications are outlined below to aid in understanding the results of the impact analyses presented in Section 5.

Employment impacts (jobs) consist of three levels:

- **Direct Jobs** are those directly generated by fisheries-based activities, businesses that serve visitors, and related marine and seafood processing, transportation and other activities, estimated using modeled data and data collected through a literature review. Direct jobs generated by the commercial fishing fleet using Westport Marina include fishing crewmembers, boat/shipyard employees, and local fishing gear suppliers, for example. Other direct jobs supported by marina activity include those directly involved in managing the facility, and those supported by purchases made by boat owners including: boat equipment and supplies, repairs, local hotels, restaurants, retail stores and transportation firms.

  These jobs are directly generated, in that there would be an immediate dislocation of jobs if harvests and the marina activities serving commercial fishing were closed for a period of time, resulting in operations closing or leaving the area.

- **Indirect Jobs** are those created in the region and state due to goods and services purchased by firms (not individuals) directly dependent upon the business activities examined. These jobs are estimated through a combination of IMPLAN model data and data collected through a literature review. Jobs include those with maintenance and repair firms, parts and equipment suppliers, local office supply firms, etc.

- **Induced Jobs** are those created across the local economy because people directly employed in the business activities examined spend wages. Induced jobs are estimated from local, regional and statewide purchase data, and they include those held by residents of the region and state.

Personal income impact is the measure of employee wages and salaries (e.g. income from landings), not including benefits, received by individuals directly employed by fisheries-based activities, businesses that serve visitors, and related marine and seafood processing, transportation and other activities. The statewide re-spending effect of these earnings for purchases of goods and services is estimated in model iterations using the Washington State personal earnings multiplier, which reflects the percentage of purchases by individuals that are made within the state. Re-spending, in turn, generates induced employment impacts (additional jobs). Direct earnings are a measure of the local impact as those directly employed in the associated activities receive wages and salaries.

Business revenue impacts are created by those employed in fisheries-based activities, businesses that serve visitors, marine, transportation and other activities generating business revenue for firms that provide services. This revenue is circulated throughout the economy in several ways (e.g., to hire service providers, to purchase goods and other services, to pay facility rents, and to make tax payments). For the purpose of this study, we limit the interpretation of business revenue impacts to that which can be identified as staying within Washington (e.g., wages paid to Washington employees, for local purchases by individuals and businesses directly dependent on the relevant operations, and in contributions to state, local and federal taxes).

Tax impacts are tax payments (federal, state, and local) made by firms and individuals whose jobs are directly dependent upon and supported by (induced and indirect jobs) fisheries-based activities and related seafood processing activities, businesses that serve visitors, and related marine activity. Tax impacts include state and local taxes collected from all sources.

Value added figures represent the total value of the production of goods and services in the economy resulting from direct expenditures under analysis (valued at market prices).

2.2.2.1 IMPLAN model

The approach used joined that of an IO survey model, which involved obtaining data on the distribution of local sales and expenditures for each sector, with that of the IMPLAN system, which uses secondary data to construct estimates of local economic activity. IMPLAN is a computerized database and modeling system used for creating economic models and IO tables.[5] IMPLAN can be used to construct zip code, county or multi-county IO models for any region in the United States. The customized regional model developed for this study is derived from economic response coefficients of a national IO model and localized estimates of total

[5] IMPLAN was developed by researchers at the University of Minnesota working with the U.S. Forest Service in cooperation with the Federal Emergency Management Agency and the U.S. Department of the Interior, Bureau of Land Management to assist in land and resource management planning. In 1993, the founders incorporated as Minnesota IMPLAN Group, Inc. (MIG), and expanded to improve the original system. Today, software and data sets are available through IMPLAN Group LLC, Huntersville, NC.

gross outputs by sectors. The IMPLAN system adjusts national level data to fit the economic composition and estimated trade balance of a selected region.

The 2013 IMPLAN data set, County Data for Grays Harbor County, Washington, was used to develop all models and sub-models in IMPLAN version 3.0. To ensure consistency, 2013 is used as the base year for all analyses; dollar amounts are expressed in 2014 U.S. dollars.

2.2.2.2 Economic sectors used in IO models

Expenditures by commercial fishers typically include purchases of goods (gear, supplies, hardware, electronics), repair expenses (boats, nets, gear, engines), trip expenses (bait , fuel, groceries, ice), fixed expenses (moorage, licenses, insurance, accounting, etc.), labor expenses, and the owner's profit. Similarly, there are categories or classifications of expenditures made by each of the groups of visitor-based businesses selected for analysis. With guidance provided by IMPLAN, a bridge table (Appendix A) was created to translate North American Industry Classification System (NAICS) codes to IMPLAN industry codes to map the splits and aggregations used in the IO models' sectoring schemes.[6]

2.2.3 Economic contribution analysis

Regional economic contribution analysis for an industry, event or policy is commonly performed using IO models. IO models capture the complex interactions of consumers and producers of goods and services in the economy, such that goods produced by one sector become inputs of another, and the goods produced by that sector become inputs to yet other sectors. Thus, the change in demand for a good or service can generate a ripple effect throughout the local and regional economies. IO models are constructed to measure this effect.

In IO model terms, spending associated with one industry or sector of the economy can directly affect levels of activity in another industry or sector. In turn, directly affected industries can indirectly affect other industries or sectors. For example, visitors to Ocean Shores spend money on goods and services. Local businesses in turn purchase labor and supplies to meet the demand for those goods and services. The income and employment resulting from visitor purchases of goods and services from local businesses represent the direct effects of visitor spending within the economy.

Relevant to this study, the economic contribution of the Non-Tribal commercial fishing industry to the Grays Harbor County economy is the portion of the County's economy attributable to the total impact of the Non-Tribal commercial fishing industry. Thus, it is possible to examine the relative magnitude of the Non-Tribal commercial fishing industry in the study region.

IMPLAN uses backward linkages (through supply chains) to estimate the overall effects that an economic event has on a region's economy using inputs and implicit data. To determine the effect of increased or decreased production in an industry, IMPLAN assesses the industries that supply

[6] The NAICS was jointly developed by the United States, Canada and Mexico to provide comparability in statistics about business activities across North America.

the producing industry (e.g. commercial fishing), and the goods and services the producing industry requires for conducting business (Day, 2012). In a simple explanation, if a producing industry decreases demand for a good (e.g. fishing gear), the suppliers' sales of that good and their production of that good decrease in turn.

In this study, ***economic contribution analysis*** is used to estimate changes in the local and regional economies resulting from production impacts to Non-Tribal fisheries-based activities and visitor-based businesses associated with three hypothetical oil spill scenarios.

2.2.4 Ecosystem Services and Benefit transfer

Ecosystem services are outcomes of natural systems and processes that are beneficial to humans. The Economics of Ecosystems and Biodiversity (TEEB), a global research group studying the value of the natural environments, developed a widely used ecosystem services classification with the following four categories: provision (e.g. food, raw materials, and fresh water), regulating (pest and flood control, carbon sequestration, and air quality), supporting (habitat and biodiversity), and cultural (recreation, tourism, spiritual, and aesthetic). The TEEB classification system is used to identify ecosystem benefits in Grays Harbor County that could be affected by marine and rail traffic and a crude oil spill.

There are many valuation methods commonly used to quantify ecosystem services. For the scope of this study, the benefit transfer method was used. Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., per visitor day, per household, per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed. Economists define benefits for economic efficiency or benefit-cost analyses as the user's willingness to pay (WTP) in excess of current costs (e.g., net WTP) or consumer surplus. This is the benefit measure used by federal agencies for benefit-cost analysis and natural resource damage assessment (DOI, 1994; USEPA, 2000; U.S. Office of Management and Budget, 2000). See Section 6 for a more detailed discussion of both methods and results for ecosystem services in Grays Harbor and surrounding areas.

2.3 SCOPE OF ANALYSIS

Multiple types of businesses were selected for analysis after screening for potential impacts to business activities from rail and marine vessel traffic and an oil spill.

These businesses include: Non-Tribal commercial fishing, commercial aquaculture, and visitor-related businesses (such as businesses that serve tourists and recreationists).

Potential impacts were identified from project proponent documents and the legal record, and by examining studies performed in a similar context.

A literature review was conducted to obtain data on the types and characteristics of oils likely received and shipped by the proposed projects, actual and modeled oil spills in or near Grays

Harbor, effects of oil contamination on economically important local species, changes in visitor habits after oil spills, and on the revenues and expenditures of the business activities considered.

The potential revenue losses to the Non-Tribal fisheries-based (commercial fishing and commercial aquaculture) activities in the event of an oil spill were estimated. The total economic impacts; and impacts on personal income, employment and taxes generated by commercial fishing were derived using economic impact models. Potential revenue losses to visitor-based businesses from decreased patronage in the event of oil contaminated beaches, salt marshes and waters, or from the loss of visual amenities were estimated.

Section Three: Economic Setting

3.1 Demographics

Demographic trends for Grays Harbor County and Washington are briefly explored in this section. This data has significant bearing on the local and regional economies, and is included in the IMPLAN models – figuring in calculations made by the users and the system. Table 3 presents statistics in several demographic categories for Grays Harbor County and Washington.

The population density of Grays Harbor is about three times less than the rest of Washington. The median age of the Grays Harbor County population is slightly older than the median age of the state population. The average household size and the average family size of the Grays Harbor County population are both slightly lower than that of the state population.

The median household income, median family income and per capita income are lower in Grays Harbor County than in Washington.

The Grays Harbor County population reports a substantially higher housing vacancy rate than that reported for Washington (the vacancy rate of Grays Harbor County is more than double that of the state). The rate of seasonal, recreational, or occasional use of housing units in Grays Harbor County was reported to be more than triple that of Washington.

The rate of those 25 years an older with Bachelor's degrees and graduate or professional degrees is lower in Grays Harbor County than in the rest of Washington.

Table 3. Select Demographic Statistics, Grays Harbor County and Washington

Population Characteristics	Grays Harbor County	Washington
Population	72,797	6,724,540
Population density (per sq. mile)[1]	38.3	101.2
Percent male	51.3%	49.8%
Percent female	48.7%	50.2%
Median age (years)	41.9	37.3
Average household size	2.45	2.51
Average family size	2.94	3.06
Economic Characteristics[2] (2013 $)		
Median household income	$42,405	$59,478
Median family income	$52,948	$72,168
Per capita income	$21,828	$30,742
Housing Characteristics		
Occupied housing units	81.3%	90.8%
Owned-occupied	67.8%	63.9%
Renter-occupied	32.2%	36.1%
Vacant housing units	18.7%	9.2%
For seasonal, recreational or occasional use	9.6%	3.1%
Median home value[3]	$157,600	$262,100
Educational Attainment (Population 25 and older)[4]		
Less than 9th grade	5.6%	4.1%
9th to 12th grade, no diploma	9.0%	5.9%
High School graduate (includes equivalency)	31.6%	23.6%
Some college, no degree	29.2%	25.1%
Associate's degree	10.7%	9.5%
Bachelor's degree	9.8%	20.4%
Graduate or professional degree	4.2%	11.2%

Sources: USCB 2010a, 2010b, 2013a, 2013b, 2013c

[1] 2010 Census Summary File 1. Population, Housing Units, Area, and Density: 2010-State--County/County Equivalent.

[2] 2009-2013 American Community Survey, Selected Economic Characteristics (USCB, 2013a).

[3] 2009-2013 American Community Survey, Selected Housing Characteristics (USCB, 2013b).

[4] 2009-2013 American Community Survey, Selected Social Characteristics (USCB, 2013c).

The Washington State Employment Security Department (ESD) estimated that the population of Grays Harbor County will grow by about 4,200 from 2011 to 2040, shown in Table 4 (ESD, 2014). They estimated that the state population will grow by more than 2,000,000 over the same period.

Table 4. Historic and Projected Populations, Grays Harbor County and Washington

	1981	1991	2001	2011
Washington	4,229,281	5,021,335	5,970,329	6,767,900
Grays Harbor County	66,732	65,296	68,710	72,900
	2016	**2021**	**2031**	**2040**
Washington	7,124,447	7,514,897	8,250,339	8,820,691
Grays Harbor County	73,741	74,739	76,600	77,112

Source: ESD, 2014

Five-year population average annual rate of growth (AARG) increments are estimated to range from 0.2% to 0.3% for Grays Harbor County from 2011 through 2030, whereas AARGs for Washington range from 0.9% to 1.1% for the same time period, as projected by ESD (Table 5).

Table 5. Average Annual Population Growth Rates, Grays Harbor County and Washington

Period	Grays Harbor County	Washington
1991-2000	0.5%	1.9%
2001-2005	1.1%	1.3%
2006-2010	0.6%	1.3%
2011-2015*	0.2%	1.0%
2016-2020*	0.2%	1.1%
2021-2025*	0.3%	1.0%
2026-2030*	0.2%	0.9%

Source: ESD, 2014

3.2 EMPLOYMENT AND LABOR FORCE

The total Grays Harbor County civilian labor force ranged between 27,050 and 31,300 from 2008 to 2013, and the unemployment rate ranged between 11.0% and 13.6% over the same period (Table 6). Grays Harbor County's civilian labor force was reduced about 4,250 people from 2008 to 2013, and the unemployment rate declined about 2.2% over that time.

The AARG in the total labor force was 0.29% from 2003 to 2008, and the AARG of the employed labor force was -0.85% over the same period. From 2008 to 2013, the AARG of the total labor force was -2.97%, and the AARG of the employed labor force was -2.46%. Employment data is not reported at the sub-county level.

Table 6. Grays Harbor County Civilian Labor Force

Year/Time Period	Total	Employed	Unemployed*	Unemployment Rate
1993	27,730	23,900	3,470	12.7%
2003	30,840	28,280	2,560	8.3%
2008	31,300	27,180	4,120	13.2%
2009	30,830	26,630	4,200	13.6%
2010	29,750	25,830	3,920	13.2%
2011	28,650	25,050	3,600	12.6%
2012	27,470	24,220	3,250	11.8%
2013	27,050	24,080	2,970	11.0%
AARG, 1993-2003	1.15%	1.61%		
AARG, 2003-2008	0.29%	-0.85%		
AARG, 2008-2013	-2.97%	-2.46%		
AARG, 2003-2013	-1.34%	-1.66%		

Sources: ESD, 2014; Resource Dimensions, 2015

3.3 INDUSTRIES AND OCCUPATIONS

Grays Harbor County was reported by the United States Census Bureau (USCB) to have 1,690 business establishments in 2012. The retail trade sector had the highest share of business establishments (15.6%), followed by the accommodation and food services sector (13.8%) and the healthcare and social assistance sector (11.8%) (Table 7). Data, current as of June 26, 2014, is reported by the USCB using five-digit NAICS codes.

Table 7. Business Patterns of Grays Harbor County, by NAICS code

2012 NAICS code	Meaning of 2012 NAICS Code	Number of Establishments
00---	Total for all sectors	1,690
11---	Agriculture, forestry, fishing and hunting	75
22---	Utilities	3
23---	Construction	160
31-33---	Manufacturing	83
42---	Wholesale trade	52
44-45---	Retail trade	263
48-49---	Transportation and warehousing	76
51---	Information	20
52---	Finance and insurance	86
53---	Real estate and rental and leasing	84
54---	Professional, scientific and technical services	90
55---	Management of companies and enterprises	3
56---	Administrative and support and waste management	61
61---	Educational services	8
62---	Health care and social assistance	200
71---	Arts, entertainment and recreation	29
72---	Accomodation and food services	234
81---	Other services (except public administration)	159
99---	Establishments not classified	4

Source: USCB, 2014

Educational services and health care and social assistance industries employ the highest percentage of the workforce in Grays Harbor County (20.6%) (Table 8). A group of three industries — arts, entertainment, recreation, and accommodation and food services (12.2%), retail trade (11.0%), and manufacturing (10.8%) — employ the next higher percentages of the workforce.

Table 8. Workforce by Industry, Grays Harbor County

Industry	Estimate	Percent of workforce
Civilian employed population, 16 years and over	27,434	
Educational services, and health care and social assistance	5,658	20.6%
Arts, entertainment, and recreation, and accomodation and food services	3,359	12.2%
Retail trade	3,027	11.0%
Manufacturing	2,961	10.8%
Public administration	2,699	9.8%
Construction	1,965	7.2%
Transportation and warehousing, and utilities	1,622	5.9%
Agriculture, forestry, fishing, and hunting, and mining	1,405	5.1%
Professional, scientific, and management, and administrative and waste management services	1,382	5.0%
Other services, except public administration	1,162	4.2%
Finance and insurance, and real estate and rental and leasing	1,007	3.7%
Wholesale trade	694	2.5%
Information	493	1.8%

Source: USCB, 2013a

Of the civilian employed population (16 years and over), the highest rate of Grays Harbor County residents are employed in management, business, science and arts occupations (25.2%), followed by service occupations (23.5%) and sales and office occupations (22.1%) (Table 9).

Table 9. Workforce by Occupation, Grays Harbor County

Occupation	Estimate	Percent of Occupations
Civilian employed population, 16 years and over	27,434	
Management, business, science and arts occupations	6,915	25.2%
Service occupations	6,451	23.5%
Sales and office occupations	6,059	22.1%
Production, transportation and material moving occupations	4,346	15.8%
Natural resources, construction and maintenance occupations	3,663	13.4%

Source: USCB, 2013a

ESD projects occupational job growth for a ten-year period from current occupational data (2012). Occupational job growth is projected by regions based on state Workforce Development Councils. Grays Harbor County resides in the Pacific Mountain Region (Table 10), which also includes Lewis, Mason, Pacific, and Thurston Counties.

The highest occupational growth (by 2012-2017 AARG) is in construction and extraction (4.0%; 362 average annual openings), transportation and material moving (2.8%; 370 average annual openings) and healthcare support occupations (2.4%; 115 average annual openings). Healthcare support is projected to have the highest AARG, 2017-2022, at 2.0%, or 107 average annual openings.

Table 10. Recent and Projected Job Growth in Selected Occupations for the Pacific Mountain Region

Occupations	Estimated Employment			AARG		Average Annual Openings Due to Growth		Total Openings	
	2012	2017	2022	2012-17	2017-22	2012-17	2017-22	2012-17	2017-22
Total, All Occupations	189,737	206,152	216,431	1.7%	1.0%	3,267	2,035	7,972	6,880
Management	9,948	10,514	10,969	1.1%	0.9%	113	90	309	334
Community and Social Service	3,744	3,988	4,193	1.3%	1.0%	49	39	136	143
Education, Training, and Library	12,351	13,326	14,097	1.5%	1.1%	190	153	457	452
Healthcare Support	4,590	5,174	5,705	2.4%	2.0%	115	107	193	212
Food Preparation and Serving Related	14,419	15,913	16,560	2.0%	0.8%	298	129	976	610
Sales and Related	20,074	21,427	22,513	1.3%	1.0%	271	218	975	804
Office and Administrative Support	26,083	27,868	29,035	1.3%	0.8%	358	234	920	827
Farming, Fishing, and Forestry	5,978	6,285	6,296	1.0%	0.0%	63	1	201	135
Construction and Extraction	8,368	10,179	10,764	4.0%	1.1%	362	115	507	292
Installation, Maintenance, and Repair	7,357	7,953	8,288	1.6%	0.8%	120	62	283	259
Production	7,577	8,328	8,551	1.9%	0.5%	149	43	325	224
Transportation and Material Moving	12,548	14,396	15,011	2.8%	0.8%	370	121	657	454

Source: ESD, 2014

SECTION FOUR: Scenario Modeling: Potential Impacts of Oil Spills

As described in Section 1.3, project proponents state that they will receive and ship a variety of bulk liquids, including (and specifically in the case of the GHRT) crude oils. The Washington State Department of Ecology (DOE) recently stated that the transportations of oils "*into and through the state of Washington have primarily involved the transport by rail of two different types of crude oil – Bakken crude from North Dakota, and diluted bitumen from Alberta, Canada*" (DOE, 2015). Thus, it was assumed that these are the crude oil types most likely accepted and shipped by the proposed projects. Much of the information presented below on oil characteristics is sourced from the March 1, 2015, "*Washington State 2014 Marine & Rail Oil Transportation Study*" (DOE, 2015). <u>It should be emphasized that the study authors have not independently verified the information or conclusions within this publication, and thus cannot attest to its accuracy.</u>

Assumptions inherent in hypothetical oil spill scenarios in and near Grays Harbor are described in this section. These assumptions are required to estimate economic impacts and changes in economic contributions by affected business activities.

4.1 CRUDE OILS OVERVIEW

Crude oils are typically placed in one of three groups: light oils, medium oils and heavy oils. Light oils (including light crude oils) are considered moderately toxic, and are less likely to persist in the environment and adhere to surfaces and substrates than are medium and heavy oils (DOE, 2015). Light oils, however, are still capable of contaminating surfaces and subsurfaces and have potential for long-term contamination. Light oils leave a residue of up to one-third of the spill amount after a few days, and can generally be cleaned up with typical response methods and tools.

Medium oils (including medium crude oils) are considered moderately toxic, moderately persistent and moderately adherent (DOE, 2015). Typically, up to one-third of a medium oil spill will evaporate within 24 hours and contamination of surfaces and subsurfaces can be severe and long-term. It has been observed that cleanup of medium oil is most effective if conducted soon after the event. Medium oils can have severe adverse impacts to waterfowl and fur-bearing mammals.

Heavy oils (including heavy crude oils) are considered moderately toxic, highly persistent and highly adherent. Heavy oils tend to exhibit low volatility, weather slowly, and cause heavy contamination (DOE, 2015). Long-term contamination of surfaces and subsurfaces by spilled heavy oils is possible, and cleanup of heavy oils are difficult under all conditions. Heavy oils can have severe adverse impacts to waterfowl, fur-bearing mammals, and other organisms through smothering, ingestion, and mechanical injury.

Bakken crude oils exhibit characteristics most similar to light crude oils (DOE, 2015). Bakken crude oils are more volatile than most other domestic crude oils, and are more ignitable and flammable. These oils also have a low viscosity (meaning that it has a low resistance to flowing once set in motion), more similar to diesel or gasoline than to other crude oils.

Diluted bitumen crude oils, also known as 'dilbit' or Canadian 'tar sands oil', are a broad category of oils comprised of bitumen blends. These blends exhibit characteristics most similar to heavy crude oils (DOE, 2015). Diluted bitumen crude oils are produced by mixing bitumen (the highly viscous heavy crude oil extracted) with diluents of naptha-based oils (such as natural gas condensates) to a 70:30 bitumen:diluent ratio. Diluents assist in moving the mixture through pipelines. The diluent fraction will evaporate quickly after an oil spill; the heavier bitumen fraction will remain. Diluted bitumen crude oils have been found to exhibit similar corrosiveness, densities, and viscosities to conventional heavy crude oils (DOE, 2015).

4.2 Oil Characteristics

Spilled oil undergoes physical and chemical processes called 'weathering' in the environment. Weathering processes occur at different rates, which are functions of oil type, if the spill is on land or in water, and climatic and environmental conditions. Weathering processes include evaporation, emulsification, oxidation, spreading, dissolution, dispersion, sedimentation and biodegradation. These processes can cause spilled oil to become available for uptake by plants and animals, and affect toxicity and spill response.

Density is an important characteristic of oils. Diluted bitumen crude oils are denser than Bakken crude oils. When oil spills into water, its more volatile components evaporate, leaving less volatile, denser components. As oil density increases, it is more prone to sink. When sinking oil adheres to suspended sediments or debris in the water column an oil-mineral aggregate (OMA) is formed. If the OMA is denser than the water, it will sink. OMAs are more likely to occur when the spilled oil is in fine droplets, where there is a high concentration of sediments in the water column (for example in the surf zone of a beach or around a vessel loading zone), and where the water is highly turbulent. OMAs can remain suspended in the water column, mix with sediment and settle on the substrate, or diffuse through a substrate, and can be ingested by fish or shellfish (DOE, 2015).

Salinity and temperature also influences whether oil will float, become suspended in the water column, or sink. Saltwater and estuarine water are denser than freshwater. Thus the same oil can float in saltwater but sink in estuarine water. Oil density increases as temperature decreases.

Denser oils disperse more readily through the water column, and tend to spread faster on the water surface in the early stages of a spill than do less dense oils (DOE, 2015). Denser oils are also more likely than less dense oils to form stable emulsions in the water (DOE, 2015). Emulsified oils are more likely to persist in the environment, and are often much more viscous than the parent oil. Emulsions can present a range of challenges and complications in spill response, such as requiring collecting and storing a large volume of an oil/water mix.

Recently, Government of Canada researchers found that two diluted bitumen products float on saltwater "*even after evaporation and exposure to light and mixing with water*" (DOE, 2015). However, both products, when mixed with suspended sediments by high-energy wave action either sunk or were dispersed as floating tarballs. They also found that the effectiveness of chemical dispersants on these products was limited under normal conditions, and that dispersants were not effective when the products were mixed with sediments. However, DOE (2015) notes the behavior of oils is dynamic in real-world spills – some of the oil floats, some sinks, and some remains suspended in the water column (DOE, 2015).

Heavy and medium oils tend to be more adhesive (the degree to which oil remains after contact and draining) to surfaces, substrates and structures than are light oils. Oils exhibiting strong adhesiveness increase damage and cleanup costs, and limit the effectiveness of some on-water recovery methods (DOE, 2015).

More strongly adhesive oils can cause severe mechanical injuries to organisms. Mechanical injuries can be caused by coating, fouling or clogging "*of organisms and their appendages and apertures, such that movements and behaviors are mechanically inhibited*" (DOE, 2015).

The persistence of oil in the environment varies on many factors, including environmental conditions and other oil characteristics. Persistent oil fractions can adhere to and penetrate surfaces and substrates, causing serious ecological consequences. For example, highly persistent oil can adhere to feathers and fur and shoreline and wetland communities, causing hypothermia, smothering and mechanical injury, and mortality (DOE, 2015). Persistent oil can also "*interfere with the normal physical characteristics of substrates and sediments and make them inhabitable* [sic]*. Oil residues can also agglomerate with inorganic and organic particles or debris and become ingestible*" (DOE, 2015).

DOE considers heavy and medium oils to be highly persistent in the environment (with an anticipated time of persistence five to ten years or more), and light oils to be moderately persistent (with an anticipated time of persistence one month to one year).

Oil spilled on land or shorelines can spread, move downslope, evaporate or penetrate the substrate. Lands in the study area include shorelines inside Grays Harbor that are primarily marshes and sheltered tidal flats, and coastal shorelines consisting mainly of fine-grained sandy beaches (DOE, 2013a). Penetration rates of substrates are functions of temperature, porosity, saturation, land cover, oil viscosity and effective permeability. Diluted bitumen crude oils exhibit a high degree of penetration in sandy shores and estuarine sand sediments (DOE, 2015).

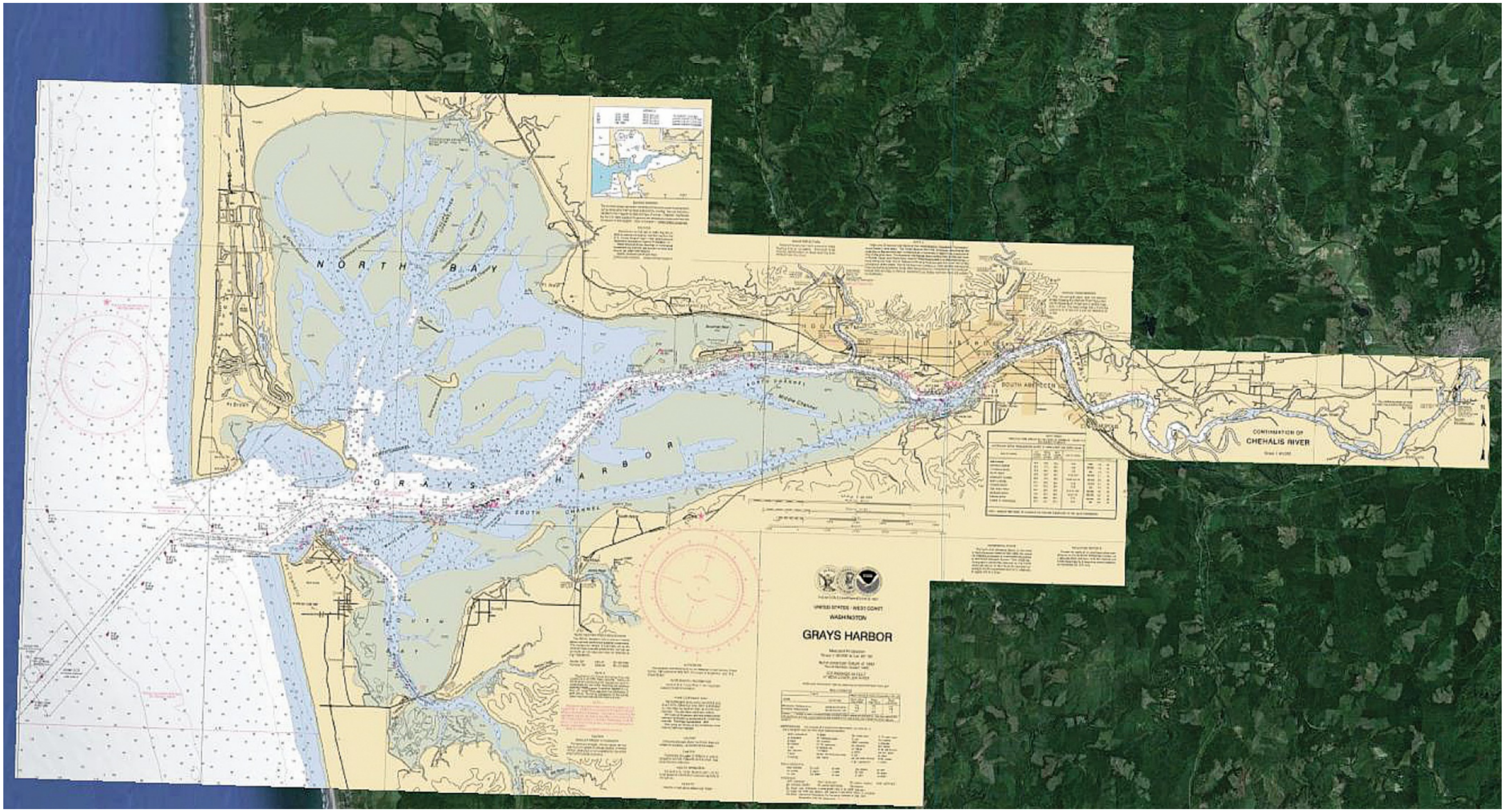
4.3 PHYSICAL CHARACTERISTICS OF GRAYS HARBOR

Grays Harbor is approximately 15 miles long, and at its widest, the Grays Harbor estuary is about 13 miles wide, narrowing to less than 100 yards wide in some places. The Chehalis, Wishkah, Hoquiam, Humptulips, Johns and Elk Rivers drain into Grays Harbor, as do numerous smaller rivers, creeks and streams. The entrance to Grays Harbor is about 2.5 miles wide (DOE, 2013a). Navigation of marine vessels in and out of Grays Harbor is challenging, as Grays Harbor "*has a complex navigation route due to a breaking bar at the entrance, a constrained channel and limited depth*" (DOE, 2015). At the bar "*inward-flowing ocean swells converge with outward flowing river currents*" (DOE, 2013a). This convergence, combined with sometimes strong and erratic currents and limited visibility, can be hazardous to vessel traffic. Further, two jetties (comprised of rocks placed by U.S. Army Corps of

Engineers) extend seaward from the Grays Harbor entrance for 0.2 miles (north jetty) and 0.9 miles (south jetty). Hazardous breakers can sometimes form near these jetties, especially during rough weather (DOE, 2015).

The predominant features of Grays Harbor are intertidal mud and sand flats that are formed as river-borne sediments and marine sediments deposit; water depths throughout the estuary are usually less than 20 feet (DOE, 2013a). The Grays Harbor navigable channel (the North Channel) has many shoals and flats, and it "*narrows to 0.6 miles wide with a number of turns where course changes are required*". See Figure 4 for the nautical chart of Grays Harbor. This dredged channel is 46 feet deep at the bar, 42 to 40 feet deep at the entrance, decreasing to 36 feet deep to Cow Point, and to 32 feet deep to Cosmopolis (DOE, 2015). The Middle and South Channels "*remain shoaled by erosion and sediment deposits*" and have not been dredged for navigation (DOE, 2013a).

Figure 4. Grays Harbor nautical chart



Source: Grays Harbor, NOAA Chart 18502, 2014. http://www.nauticalcharts.noaa.gov/csdl/seamlessraster.html

4.4 AVAILABLE RESEARCH ON OIL SPILLS IN GRAYS HARBOR

This study was conducted prior to an actual crude oil spill event in or near Grays Harbor attributable to the proposed projects. From real-world spills, it is known that the behavior of spilled oil in the environment is a function of the type and volume of oil spilled, climatic and environmental conditions, and geographic location. Spilled oil undergoes weathering processes once it is released into the environment. Spilled oil is also transported through the environment by physical forces, for example by wave action, wind, or tides (Grays Harbor empties twice per day at 2-4 knots). To understand the risk of crude oil spills resulting from the proposed projects, and the fate and transport of spilled oil in or near Grays Harbor, the study authors conducted a literature review for research on these topics specific to Grays Harbor.

Understanding the risk of a crude oil spill in Grays Harbor is predicated on understanding dynamic nature of Grays Harbor, the Pacific Coast, and associated marine vessel traffic systems. The risk of an oil spill from an individual marine vessel is a function of a complex set of internal and external variables. Finley (2013) explains "*Internal variables relate to the operation and maintenance of the vessel itself. External variables relate to the conditions and environment in which the vessel operates.*" Internal variables that lead to oil spills may result from "*poor training of personnel, errors in judgment or perception, lack of skill, corporate culture, inadequate safety procedures, poor equipment maintenance, or malfunctioning equipment*". External variables include "*environmental conditions such as weather conditions, visibility, sea state, currents and tides*" or interactions with other marine vessels in the vicinity that may cause an accident or grounding. Finley (2013) concludes "*By increasing the number of vessels in a system, the risk of a single vessel spilling oil will likely also increase as a result of the change in external variables, such as the presence of other vessels*".

Further, Finley (2013) explains "*Each vessel poses an individual risk that an oil spill could occur. More vessels operating means more chances of a spill. However, because the vessels are not operating independently in the system, this overall increased risk of a spill is not a simple additive increase based on the number of vessels. Rather, interactions between vessels in an increasingly complex system enhance the increased risk of a spill occurring in Grays Harbor. With each additional vessel operating in Grays Harbor, the risk or chance that an oil spill will occur in Grays Harbor goes up*".

As of August 2015, neither a vessel traffic impact analysis (VTIA) nor a rail traffic impact analysis (RTIA) had been conducted for the cumulative traffic attributable to the proposed projects. In the absence of these risk analyses, it is not possible to realistically gauge the risks of accidents involving marine vessels transporting crude oil or involving CBR unit trains.

As of August 2015, there are no publically available location files of Grays Harbor for the General NOAA Operational Modeling Environment (GNOME) tool. GNOME is used by NOAA to predict the possible trajectory a pollutant might follow in a body of water (i.e. the flow of oil). Though it is possible for users to create their own location files, NOAA forewarns that doing so requires regional physical oceanographic expertise, and thus is outside of the scope of this study.

DOE apparently received GNOME model location files for Grays Harbor prior to December 2013. These files will help DOE "*better understand the possible route, or trajectory, an oil spill might follow in Grays Harbor based on different input variables including the date and time of a spill, location, product types and quantity, and certain environmental conditions*" (DOE, 2013b). No results of this modeling have been publicly released as of August 2015.

Further, there is no publically available fate and transport model for spilled oil in or near Grays Harbor as of August 2015. Thus, it is not possible to realistically predict what happens to spilled oil once it is in water or on land in Grays Harbor. These would include the resources impacted, the severity and magnitudes of environmental impacts, and the duration of these impacts. For example, a fully loaded tanker can transport more oil than a fully loaded ATB; thus the tanker would pose a higher magnitude of environmental impact. Environmental impacts also depend to an extent on the type of oil transported. There may be more severe environmental impacts from an oil spill in one area of Grays Harbor than another area, due to the shipping channel, vessel traffic patterns or environmental conditions (Finley, 2013).

One publicly available study assessed the fate and transport of oil spilled outside the mouth of Grays Harbor. A spill of 25,000 bbls (1,050,000 gallons) of Bunker C fuel oil three miles off the entrance to Grays Harbor was modeled under several response scenarios. Modeling results showed that in the absence of response, spilled oil could spread through the majority of Grays Harbor within six hours post-spill, and could penetrate salt marsh habitat as soon as 12 hours post-spill (ASA, 2006). Though these findings are of limited utility for this study, given significant difference in characteristics between Bunker C fuel oil (a heavy oil) and Bakken and diluted bitumen crude oils, it suggests that oil spilled inside Grays Harbor could spread throughout and penetrate sensitive habitats in less time.

There is one known large oil spill near Grays Harbor, the *Nestucca* spill. In December 1988 the barge *Nestucca*, loaded with over 70,000 bbls of Bunker C fuel oil was being towed from Ferndale, Washington to Portland, Oregon by the tug *Ocean Service*. A stop was planned in Aberdeen, Washington. At 11:00 p.m. on December 22, 1988, the *Ocean Service* prepared to cross the Grays Harbor bar in rough conditions – reportedly "*wave heights of up to 14 feet with occasional 16-foot breaking swells, with winds of 10 knots out of the west*" (Yaroch, 1991). To cross the bar, the tug shortened the towline to the barge. The towline snapped and in an attempt to recover the free-floating barge the tug was lifted in a swell, collided with the barge, and opened a hole in the cargo tank. About 5,500 bbls (231,000 gallons) of Bunker C fuel oil was spilled before the hole could be temporarily patched about 24 hours later (Yaroch, 1991).

Due to high seas and strong currents no containment booms were used by responders. Most of the spilled oil washed ashore close to Ocean Shores, Washington, but the oil slick dispersed as far south as Oregon and as far north as Vancouver Island, British Columbia, washing oil ashore. The Washington coastline was oiled from Grays Harbor north to the Strait of Juan de Fuca; shorelines within Grays Harbor were also oiled (USFWS, 2004).

Spilled oil reached shore on the west coast of Vancouver Island in discontinuous patches on December 31, 1988. Small amounts of oil washed ashore from Victoria to Cape Scott, British

Columbia over the next three weeks. Most of the oil was comprised of weathered tarballs that usually covered less than five percent of the intertidal zone. Continuous covering of the intertidal zone occurred on a few beaches, typically in coatings 10 to 15 feet wide, 40 to 60 feet long and up to 1.5 feet thick (Owens, 1991). Harvest closures for crab and shellfish occurred and multiple commercial crabbing areas were closed for six months due to persistent contamination (Davis, 1989). Estimated migratory bird mortality from the *Nestucca* spill ranged from 52,000 to 78,000 seabirds (USFWS, 2004).

4.5 HYPOTHETICAL OIL SPILL SCENARIOS

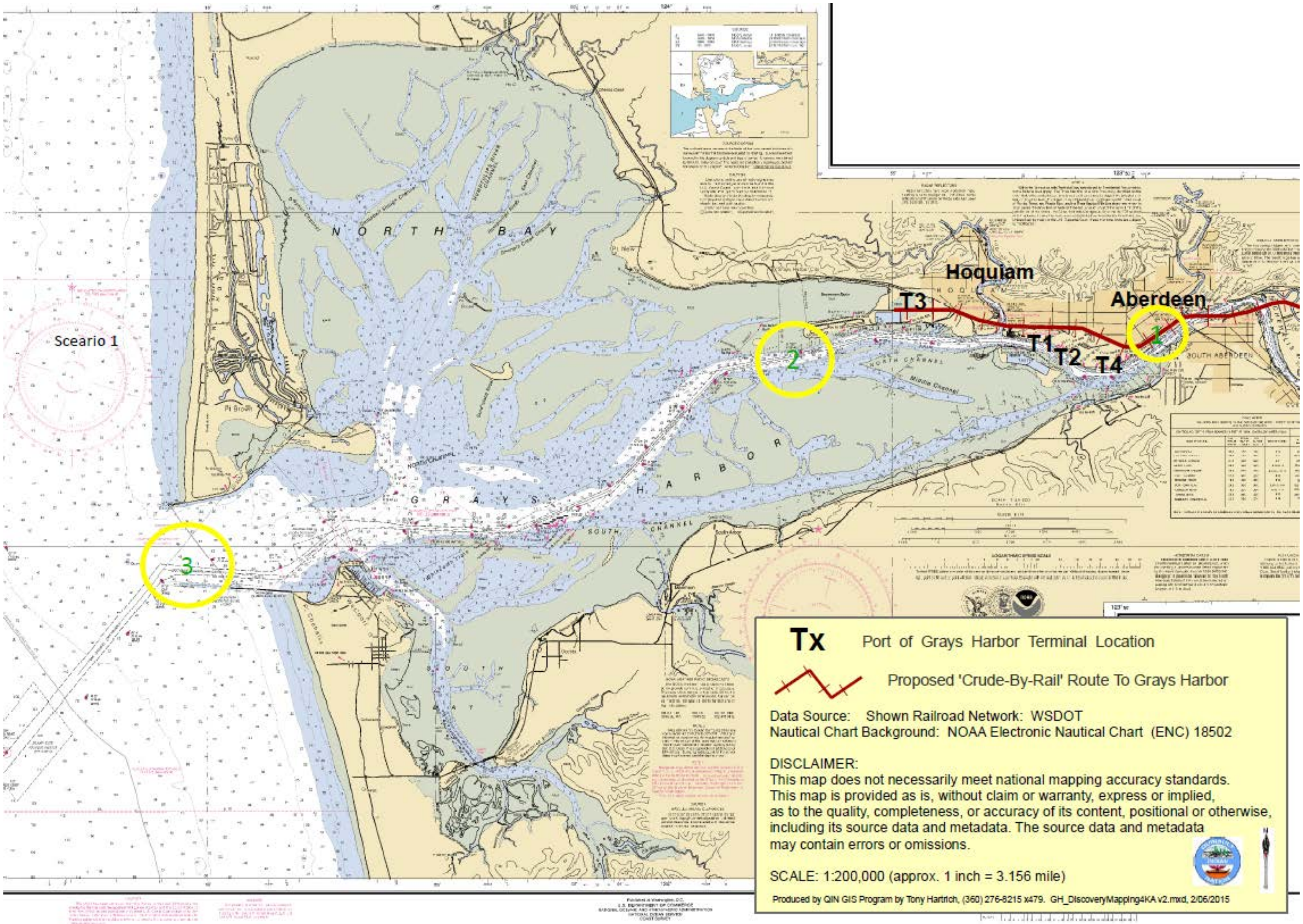
Applying the *Nestucca* spill and the ASA (2006) modeling results to project likely environmental impacts in the event of an oil spill is problematic, as these cases involved Bunker C fuel oil. They also occurred/were modeled to occur outside of the entrance of Grays Harbor, and involved much less oil than could be shipped by Panamax tankers or ATBs.

With no traffic risk analyses, oil flow model or fate and transport model specific to oil spills in Grays Harbor as of writing, assumptions were made regarding business activities affected, estimated economic impacts, and estimated changes in economic contributions post-spill. It was assumed that the type of oil spilled was a crude oil, based on project proponent documents and DOE (2015). To facilitate these estimations four scenarios were constructed:

- **Base Case:** Assumes status quo for typical activities, based on those in existence in 2013.
- **Scenario 1:** Derailment of or an accident involving a CBR unit train between the Wishkah River crossing and Cow Point, causing a spill into the Chehalis River.
- **Scenario 2**: A marine vessel accident inside Grays Harbor in the navigable channel near Moon Island, causing a spill.
- **Scenario 3:** A marine vessel accident off the Grays Harbor entrance due to the bar crossing, causing a spill.

The selected locations of Scenarios 1, 2 and 3 (Figure 5) are relatively close to the 'Potential Oil Spill Origin Points' used for response planning in the Grays Harbor Geographic Response Plan (DOE, 2013a). The Scenario 1 location was selected due to its proximity to the Chehalis River and to potential accidents with other traffic. The Scenario 2 location was selected because it is seaward of both T1 and T3, where loaded departing tankers and ATBs could conflict with other vessel traffic in the narrow navigable channel. The Scenario 3 location was selected because the Grays Harbor bar crossing is known to be highly dangerous in rough weather, and because of the potential for grounding on the jetties.

Figure 5. Oil spill scenario locations



Source: Quinault Department of Natural Resources Geographic Information System (GIS) Program, 2015

Scenario parameters are defined through a series of assumptions, explained below:

Year of hypothetical oil spill events

Scenarios 1, 2 and 3 are assumed to occur in 2020, the first year of full build-out and operation of all three projects.

Westway proposes two phases of project construction, with Phase 1 occurring from March 2016 to March 2017. The start date of Phase 2 is undefined, but it is anticipated that this phase will require ten months; apparently total construction is anticipated to require at least 24 months (Westway, 2014). ITS proposes to begin construction of project elements in several phases, with construction beginning in June 2013 and continuing until December 2014 (19 months) (Imperium Renewables, 2013)[7]. GHRT anticipates a construction phase of approximately 12 months (HDR Engineering, Inc., 2014a).

We assume all proposed projects progress through the regulatory process and are permitted in their current (August 2015) incarnations, that all construction requires at least two years, and that facility operations will ramp up to full capacity. Thus, 2020 was the year of incident assumed in each scenario.

Type of crude oil spilled

Much of the data on impacts of oil spills relied on in this study was collected from the *Exxon Valdez* oil spill. After grounding on March 24, 1989, the *Exxon Valdez* (*Exxon*) spilled approximately 258,000 bbls (10,836,000 gallons) of Alaska North Slope (ANS) crude oil into Prince William Sound, Alaska. It is estimated that about 20% of the spilled oil evaporated, and about 40% of the spilled oil coated the intertidal areas of Prince William Sound (Rice, et al., 2001).

Of the two crude oil types considered, diluted bitumen crude oils are characteristically more similar to ANS crude oil than are Bakken crude oils, in terms of volatility, persistence and potential for smothering and mechanical injury (DOE, 2015). The biological effects of spilled ANS crude oil are well-known and likely affected business activities, and hence economic impacts, can be readily projected. Thus, it was assumed that diluted bitumen crude oil was the type of oil spilled in Scenarios 1, 2 and 3.

Volume of oil spilled

Recent CBR unit train derailments have resulted in crude oil spills ranging from 4,550 gallons to 748,400 gallons (DOE, 2015). It was assumed that the volume of crude oil spilled in Scenario 1 is 542,000 gallons, or about five percent of the volume spilled by *Exxon*.

Panamax tankers have a capacity of 14,700,000 gallons. It was assumed that the volume of crude oil spilled in Scenarios 2 and 3 is 11,000,000 gallons. This volume is nearly equivalent to the volume of spilled by *Exxon*, and is about 75% of the capacity of a Panamax tanker.

[7] This time period has passed as of writing (August 2015).

Fate and transport of spilled oil

Diluted bitumen crude oils are not highly volatile; however, some fraction of the spill will evaporate. As discussed in Section 4.2, diluted bitumen crude oils tend to form stable emulsions and adhere strongly to hard surfaces, making cleanup difficult. Strongly adherent oils have exhibited a high capacity to cause smothering and mechanical injury.

Spilled oil was assumed to disperse rapidly in the water column and spread on the water surface. Fine droplets are assumed to form OMAs and settle in the water column or sink, especially where there is a high volume of suspended sediments such as around the PGH. Diluted bitumen crude oils are also thought to be highly persistent in the environment, possibly for up to ten years (DOE, 2015), and thus it was assumed that spilled oil would persist for this duration.

It was assumed that oil spilled in Scenarios 1, 2 and 3 spreads eastward through the intertidal zone, and throughout all of Grays Harbor in a matter of hours. It was assumed that oil spilled in Scenarios 2 and 3 spreads seaward north and south on the Pacific coastline of Washington in a matter of hours. Note that oil spread could vary considerably depending on tidal stage.

Spill response

Spill cleanup techniques for Grays Harbor include the use of containment booming, skimmers and vacuum trucks (DOE, 2013a). Chemical dispersion is also an option within one to two days after a spill.[8]

It is dubious whether the current (December 2013) response plan for oil spills in Grays Harbor would be adequate for large spills as in the scenarios, and whether sufficient resources and manpower would be available. Spill response capacity is limited in Grays Harbor, as the two primary spill response contractors have relatively small stockpiles of containment booms, vacuum trucks, storage tanks and other support equipment (O'Brien, 2013). These contractors would require additional response assets from offsite if a spill exceeded current capacities (O'Brien, 2013). These limitations could delay spill response, allowing oil to spread.

The use of containment booms and other response techniques on the Chehalis River are not likely to be effective due to swift currents and debris (O'Brien, 2013). Oil can disperse and affect shorelines quickly in this situation. Sediment and debris can also contribute to oil becoming suspended in the water column or sinking, impeding spill response. Further, currents, wind and tidal flows (acting on currents in Grays Harbor and at the terminus of the Chehalis River) can decrease the effectiveness of containment booming (Finley, 2013).

A significant spill (as in the scenarios), may require a large volume of contaminated water to be stored, as emulsions are oil/water mixtures and require a large storage capacity (DOE, 2015). It has been demonstrated that "*providing sufficient water storage capacity in Grays Harbor for recovered waste liquids from a significant oil spill has been problematic for response contractors and*

[8] The toxicities of chemical dispersants to plants and animals are not considered in this study, due to uncertainties as to the specific dispersants that might be used and the interactions of these dispersants with different oils.

cooperatives such as NRC, CCS, and WSMC in this area due to the limited availability" (O'Brien, 2013).

It was assumed that spilled oil would reach shorelines and the Grays Harbor estuary in a matter of hours. Chemical dispersants apparently have limited utility in dispersing diluted bitumen crude oils "*Under conditions simulating breaking waves, where chemical dispersants have proven effective with conventional crude oils, a commercial chemical dispersant (Corexit 9500) had quite limited effectiveness in dispersing diluted bitumen*" (DOE, 2013a).

Thus, it was assumed that due to limited spill response capability, climatic and environmental conditions, storage volume, and likely cleanup techniques in or near Grays Harbor, minimal containment and recovery of spilled oil was anticipated in Scenarios 1, 2 and 3.

4.6 Business activity changes after oil spills

Oil spilled in Scenarios 1, 2 and 3 was assumed to cause environmental externalities that in turn affect business activities in many industries. Known oil spills were researched to ascertain the severity and durations of effects to business activities post-spill.

4.6.1 Fisheries-based activities

Smothering and mechanical injury due to oil contamination can cause acute mortality to juvenile and adult fish and shellfish via exposure pathways including physical contact, respiration, and ingestion. It was assumed that acute mortality would result in decreased numbers of harvestable fish and shellfish.

Finfish are highly mobile and tend to swim away from unfavorable conditions. However, adult salmon returning through Grays Harbor to spawn were assumed to be at risk of acute mortality due to oil ingestion and mechanical injury in Scenarios 1, 2 and 3. Juvenile salmon entering or residing in the Grays Harbor estuary were also assumed to be at-risk of acute mortality due to oil ingestion and mechanical injury.

Juvenile and adult Dungeness crabs, less mobile than finfish, were assumed to be at-risk to acute mortality due to oil ingestion, smothering and mechanical injury. In Scenarios 1, 2 and 3 it was assumed likely that OMAs would settle in the water column and on the substrate, polluting the crabs' entire environment.

Mollusks, including razor clams, were assumed to be extremely vulnerable to spilled oil, and at-risk to acute mortality due to oil ingestion, smothering and mechanical injury. As with Dungeness crabs, the razor clams' entire environment was assumed to be polluted –harming organisms until cleaned.

Oil spills can cause harvest closures or render seafood harvests unmarketable and unsafe. Carcinogenic constituents (the chemical compounds of oils) released by weathering processes have been shown to rapidly collect in finfish and shellfish tissue (NOAA, 2002). Finfish can rid themselves of these toxins quickly due to high metabolisms. However, mollusks require a long time to cleanse themselves, perhaps weeks or months depending on the species and site-specific conditions. If levels of carcinogenic compounds in finfish and shellfish tissues are above safe levels for human consumption, harvests of these fisheries would be closed. Further, persistent exposure to carcinogenic compounds could close harvests for a long period.

Harvest closures after oil spills have ranged from months to years (Kingston, 1999; Gilroy, 2000; NOAA, 2002; Gohlke, 2011). For example, after *Exxon* salmon and herring harvests were closed for one season and advisories were published for four shellfish subsistence harvest areas. All fisheries were closed after the *Deepwater Horizon* spill (April 20, 2010) for at least one month, some for up to 12 months (Gohlke, 2011).

Decreased market demand for perceived unsafe seafood products could also limit landings and revenues in the months post-spill. Seafood can be unpalatable at very low levels of oil contamination, and consumer concerns regarding food safety can limit demand for potentially tainted seafood (Moller, et al., 1999). Significant brand damage to seafood was incurred after the 1993 *Braer* spill off Shetland, United Kingdom, and market demand for fish and shellfish plummeted, severely harming the local fishing industry (Goodlad, 1996). Consumer demand for Gulf of Mexico seafood products decreased sharply in the months after the *Deepwater Horizon* spill over concern about seafood safety, and the seafood supply chain was disrupted (CRS, 2011).

Weathered constituents of ANS crude oil have been shown to cause mortality to salmon embryos and decrease the marine survival rate of exposure survivors by 15% (Heintz, Short and Rice, 1999; Heintz, et al., 2000). See Appendix B for a more extensive discussion of effects of oil contamination on economically important finfish, such as salmon and sturgeon.

Embryos residing in rivers and tributaries draining into Grays Harbor or juveniles residing in the Grays Harbor estuary are assumed to be exposed to spilled oil in Scenarios 1, 2 and 3. Chinook and coho salmon exposed as embryos could be adversely affected up to six years post-exposure (the oldest salmon of a broodyear return to their birth places for spawning at six years) (Jorgensen, 2013). In other words, a portion of oiled embryos will be killed immediately, and survivors are less able to survive their time at sea and return to spawn. Ostensibly, there would be less fish to catch, and it was assumed that fisheries-based activities associated with fishing these populations would be diminished post-spill.

It was also assumed that a portion of Dungeness crab larvae and razor clam larvae exposed to spilled oil and oiled sediments would be killed immediately. Reproductive maturity for razor clams in the Pacific Northwest is typically two years, and reproductive maturity for Dungeness crabs is typically two or three years (USFWS, 1989; WDFW, 2008). As in the finfish fisheries, if razor clams and Dungeness crab are killed before they reproduce, or have smothering or mechanical injury, it was assumed that fewer clams and crabs would be available to harvest post-spill. See Appendix B for a more extensive discussion of effects of oil contamination on economically important shellfish, including crab, clams and oysters.

It would also be impractical to fish in oiled areas. Fishing vessels, nets and other gear could be fouled by oil, and fish contacting oiled nets would most likely be unmarketable (Jorgensen, 2013).

To facilitate estimations of economic impacts, it was assumed that the combined impacts of acute mortality, harvest closures, an inability to fish, and decreased demand would reduce landings-related revenue by 50% from baseline in Scenarios 1, 2 and 3 in the first 12 months post-spill.[9] It was assumed that these impacts continue, and combined with generational impacts of oil contamination, reduce landings-related revenue by 33% from baseline over 12 months to 24 months post-spill; 33% is also the median of the 12 months post-spill and 36 months post-spill reductions). Finally, it was assumed that generational impacts of oil contamination reduce landings-related revenue by 15% from baseline over the subsequent 12 months to 36 months post-spill).[10]

It was assumed that the duration of impacts to fisheries-based activities begin in 2020, with landings-related revenue reductions occurring until 2022. To model economic impacts and changes in economic contributions of fisheries-based businesses, landings-related revenue was decreased by a factor of 33% (the median of the assumptions) for 2020, 2021 and 2022.[11]

4.6.2 Visitor-based activities

Most of the research on impacts of oil spills to the visitor-based industry was conducted after the *Exxon* and *Deepwater Horizon* spills. In the case of *Exxon*, the visitor-based industry was relatively limited because it predominately served hunters and sport fishers, rather than beachgoers as in the Grays Harbor County. Data relative to the local visitor-based industry post-*Exxon* is mainly comprised of prospective survey results.

The *Deepwater Horizon* spill lasted 87 days, eventually discharging 20 times the volume of oil assumed in Scenarios 2 and 3. Researchers estimated that there was not a large drop in visitor-related spending because tourist spending was offset by business-related spending from spill responders (Tourism Economics, 2011). In Scenarios 1, 2 and 3 some tourist-related spending losses would be offset by spill response-related spending increases. It was assumed, however, that less tourist-related losses would be offset by spill spending than occurred after *Deepwater Horizon,* given differences in the nature and volumes of the events.

Scientific research has found that perceptions of risk can affect consumer patterns of demand (Crotts and Mazanec, 2013; Ritchie, et al., 2013; Ofiara and Brown, 1999). For example, even if a tourist would not be personally affected by an oil spill, their perception of the possibility could cause them to cancel or shorten their trip.

To estimate economic impacts from decreased visitation after *Deepwater Horizon*, Oxford Economics (2010) evaluated the duration of spill impacts on tourism after several oil spills, including *Exxon*, and concluded that the average range of time required for visitor spending to return to

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[9] A 50 percent reduction from baseline is a conservative value that reflects limitations in assuming timing of the fisheries, timing of the spill event, severity of acute mortality, duration of harvest closure(s), and uncertainties in consumer demand.
[10] In accordance with the 15% reduction in marine survival in oil-exposed fish explained previously.
[11] Note that environmental impacts of oil spills can persist for many years. However, the economic impacts of these scenarios are only covered for three years post-spill, consistent with impacts observed after known oil spills.

baseline was 12 to 28 months post-spill. For reference, visitor spending in the areas affected in *Exxon* required about 24 months to return to baseline.

Oxford Economics (2010) used low and high impact scenarios to estimate lost visitor revenue. The low impact scenario assumed a 12% decrease from baseline in the first 12 months post-spill, continuing to a 4% decrease from baseline 36 months post-spill. This trend was based on disruptions to visitor patterns lasting for 15 months post-spill. The high impact scenario assumed a 25% decrease from baseline in the first 12 months post-spill, continuing to an 8% decrease from baseline 36 months post-spill. This trend was based on disruptions to visitor patterns lasting for 36 months post-spill.

Ritchie, et al. (2013) reported significant decreases from baselines in vacation rentals on the U.S. Gulf Coast in the first six months after *Deepwater Horizon*. Decreases ranged from 7.5% in central west Florida to 29% in Alabama and Mississippi. Vacation rental revenue decreased by an average of 7.9% from baseline in the study area; Alabama and Mississippi – where beaches were heavily oiled – experienced a decrease in vacation rental revenue of 38.5% (Ritchie, et al., 2013).

Garza, et al. (2009) reported an estimated 15% decrease from baseline in uses of France's Atlantic Coast after the *Erika* (December 12, 1999) and *Amoco Cadiz* (March 16, 1978) oil spills.

There is little publicly available research regarding economic impacts of lost opportunities for sport fishing due to oil spills. Mills (1992) reported an estimated 15% decrease in angler-trips from 1988 to 1989 to the area oiled by the *Exxon* spill. No studies were identified that examined economic impacts of lost opportunities for recreational clam digging due to oil spills.

It was assumed that visitor-related revenues decreased 15% from baseline in Scenarios 1, 2 and 3 in the first 12 months post-spill. It was further assumed that visitor-related revenue decreased 10% from baseline over the next 12 months to 24 months post-spill, continuing to a decrease in visitor-related revenue of 5% from baseline over the next 12 months to 36 months post-spill. This mimics the trendlines used by Oxford Economics (2010), is in the middle of their impact scenario estimates, and lasts for a post-spill duration typically observed after known oil spills.

It was assumed that the duration of impacts to visitor-based activities begin in 2020, with visitor-related revenue reductions occurring until 2022. To model economic impacts and changes in economic contributions of visitor-based businesses (i.e. businesses that serve tourists and recreationists), visitor-related revenue was decreased by a factor of 10% (the median of the assumptions) for 2020, 2021 and 2022.

4.7 BUSINESS ACTIVITIES AFFECTED IN SPILL SCENARIOS

As previously discussed, assumptions regarding oil flow, environmental impacts and business activities affected by scenario are required to estimate changes in economic contributions from the affected industries and businesses.

Table 11 presents the results of these assumptions. Solid circles signify that the business activity was assumed likely to be affected in that scenario. For example, it is likely that Dungeness crab fishing is affected by environmental externalities resulting from the spilled oil in each scenario. The absence of a solid circle indicates that the business activity was assumed unlikely to be affected in that scenario. The business activities affected by scenario are explained in subsequent sections.

Table 11. Business Activities Affected by Scenario

Business Activity	Scenario 1	Scenario 2	Scenario 3
Non-Tribal commercial fishing			
Ocean salmon		●	●
River salmon and sturgeon	●	●	●
Dungeness crab	●	●	●
Groundfish			●
Pink shrimp			●
Albacore tuna			●
Spot shrimp			●
Sardine			●
Anchovy			●
Hagfish			●
Razor clam		●	●
Commercial aquaculture	●	●	●
Visitor-related businesses (tourism)	●	●	●
Sport fishing			
Ocean salmon		●	●
River salmon	●	●	●
Albacore tuna			●
Bottomfish	●	●	●
Halibut			●
Razor clam		●	●

Source: Resource Dimensions, 2015

4.7.1 Scenario 1 – Derailment / Accident involving a CBR unit train

As discussed previously, it was assumed that a portion of spilled oil would not be cleaned up and would spread throughout Grays Harbor in Scenario 1. Spilled oil was assumed to affect river gillnetting, Dungeness crab fishing and bottomfish fishing near the entrance to Grays Harbor, and resulting landings and expenditures. A decreased volume of landings would adversely affect the seafood processing industry, and a decrease in expenditures for fishing was assumed. The commercial aquaculture industry in Grays Harbor was also assumed to be adversely affected by spilled oil. Based on the limited knowledge of oil flow, spilled oil in Scenario 1 was assumed not to effect offshore fishing (commercial or sport), or razor clam digging.

It was assumed that tourists and recreationists would reduce visitation to the Grays Harbor area post-spill. Decreased visitation leading to decreased retail sales, etc., was assumed to adversely affect the visitor-based industry in Grays Harbor and those businesses dependent on visitor spending. It was assumed that these businesses would decrease spending accordingly. Due to their locations, Aberdeen, Hoquiam, Grays Harbor City, Markham, Ocosta, Bay City, Ocean Shores, and Westport would be adversely affected in Scenario 1. It was assumed that businesses such as restaurants, marinas, hotels, sporting goods stores, and tour guides would decrease spending accordingly.

4.7.2 Scenario 2 – Marine vessel accident inside Grays Harbor

A much larger volume of oil is assumed to be spilled in Scenario 2 than in Scenario 1, and the spill location was assumed to be further seaward. Oil not cleaned was assumed to disperse throughout Grays Harbor and flow seaward due to tidal drainage, eventually exiting Grays Harbor and migrating north and south along the Pacific coast.

Spilled oil was assumed to affect ocean salmon fishing, river gillnetting, and Dungeness crab fishing, and thus landings and expenditures. It was also assumed that razor clam digging in coastal beaches would be adversely affected. As in Scenario 1, a decreased volume of landings would adversely affect the seafood processing industry, and a decrease in expenditures for fishing was assumed. The commercial aquaculture industry in Grays Harbor was also assumed to be adversely affected by spilled oil. Spilled oil in Scenario 2 was assumed to not affect offshore fishing (commercial or sport).

It was assumed that all visitor-based businesses considered in this study would be adversely affected in scenario 2 due to decreased visitation. Businesses as such restaurants, tour guides, marinas, and hotels would be affected in Aberdeen, Hoquiam, Grays Harbor City, Markham, Ocosta, Bay City, Ocean Shores, Cohassett Beach, and Westport. These businesses would decrease spending accordingly.

4.7.3 Scenario 3 – Marine vessel accident off the Grays Harbor entrance

Based on the limited knowledge of oil flow, it was assumed that all fisheries-based activities and visitor-based activities considered in this study would be adversely affected by spilled oil in Scenario 3. It was assumed that these businesses would decrease spending accordingly. The only difference between Scenarios 2 and 3 is that offshore fishing activities are assumed to be adversely affected in Scenario 3.

SECTION FIVE: Potential Impacts of Oil Transport and Spills on the Regional Economy

5.1 NON-TRIBAL COMMERCIAL FISHING AND COMMERCIAL AQUACULTURE

Non-Tribal commercial fishers fish in multiple fisheries in the Grays Harbor area, including its rivers and tributaries and offshore, and land their catches in Grays Harbor. In addition to revenue generation from fishing, commercial fishers spend on goods and services in the regional economy required for their fishing operations. Commercial aquaculture operations in Grays Harbor also generate revenue and spend on goods and services in the regional economy. Estimated economic impacts and changes in economic contributions of Non-Tribal commercial fishing and commercial aquaculture-related activities are discussed in this section.

5.1.1 Non-Tribal Commercial Fishing

Weight and value data for Non-Tribal landings in Grays Harbor County are reported by the Pacific Fishery Management Council (PFMC) and the Washington Department of Fish and Wildlife (WDFW). Fisheries landed in Grays Harbor County include: ocean salmon (Chinook and coho), river gillnet salmon (Chinook and coho), Dungeness crab, groundfish, pink shrimp, albacore tuna, spot shrimp, sardines, anchovy, hagfish, and razor clams (IEc, 2014b). Total pounds landed and landed value (2014 dollars) for each fishery from 2004 to 2013 are reported in Table 12. The yearly average value of landings in Grays Harbor for all fisheries was estimated to be $39,738,222.

Table 12. Non-Tribal Commercial Fisheries, Harvests and Values

	Ocean Salmon			Gillnet Salmon			Dungeness Crab			Groundfish (Non-Whiting)		
Year	Pounds		Value	Pounds		Value	Pounds		Value	Pounds		Value
2004	321,912	$	675,939	57,948	$	58,544	3,874,459	$	8,617,025	1,594,004	$	1,606,154
2005	423,053	$	891,352	36,995	$	46,798	13,511,827	$	22,629,161	2,053,487	$	1,722,262
2006	77,560	$	296,525	10,940	$	17,776	7,553,104	$	13,840,385	841,339	$	752,544
2007	148,350	$	614,933	26,365	$	50,806	7,010,382	$	17,497,017	2,062,067	$	1,124,566
2008	108,163	$	436,775	104,411	$	189,657	7,172,254	$	20,479,121	2,444,852	$	1,598,712
2009	246,197	$	837,638	25,230	$	42,129	4,560,595	$	11,754,163	3,425,925	$	1,804,649
2010	472,933	$	2,341,189	69,080	$	131,843	6,307,509	$	16,558,463	2,562,981	$	1,260,842
2011	231,257	$	856,751	67,625	$	146,132	9,093,337	$	28,928,782	687,954	$	956,372
2012	203,226	$	939,517	120,652	$	233,697	4,207,929	$	16,383,516	982,102	$	1,144,586
2013	346,437	$	1,790,267	54,536	$	119,471	8,767,773	$	24,947,003	1,177,294	$	691,358
Annual Average	257,909	$	968,089	57,378	$	103,685	7,205,917	$	18,163,464	1,783,201	$	1,266,205

	Groundfish (Whiting)			Pink Shrimp			Albacore Tuna			Spot Shrimp		
Year	Pounds		Value	Pounds		Value	Pounds		Value	Pounds		Value
2004	49,836,319	$	2,024,302	3,807,105	$	1,688,043	7,069,861	$	6,248,311	112,971.00	$	240,268
2005	58,662,712	$	3,563,563	4,066,801	$	1,924,902	6,223,764	$	6,646,167	44,096.00	$	70,517
2006	49,248,798	$	3,271,526	5,205,497	$	1,906,790	5,942,954	$	5,114,954	10,742.00	$	28,874
2007	50,993,354	$	4,115,707	2,610,804	$	1,343,886	6,482,801	$	5,871,431	25,284.00	$	105,185
2008	35,667,617	$	3,601,888	4,817,481	$	2,749,620	8,630,155	$	10,846,528	26,393.00	$	90,365
2009	17,533,743	$	1,136,733	5,833,861	$	1,884,020	9,225,981	$	9,847,094	95,370.00	$	285,172
2010	52,782,827	$	3,427,833	8,292,405	$	2,892,190	7,372,062	$	7,959,994	142,513.00	$	748,897
2011	43,659,941	$	4,979,147	8,361,711	$	4,209,823	7,856,179	$	12,079,968	98,499.00	$	386,010
2012	36,813,930	$	5,568,064	8,116,412	$	3,948,387	12,040,818	$	17,497,050	36,715.00	$	189,675
2013	42,041,014	$	5,436,671	12,517,208	$	5,320,620	11,462,199	$	14,838,479	46,237.00	$	102,257
Annual Average	43,724,026	$	3,712,543	6,362,929	$	2,786,828	8,230,677	$	9,694,998	63,882	$	224,722

Table 12. Non-Tribal Commercial Fisheries, Harvests and Values (continued)

	Sardines		Anchovy		Hagfish		Razor Clam	
Year	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
2004	7,737,990	$ 482,952	470,500	$ 77,118	-	$ -	6,699	$ 12,119
2005	9,989,837	$ 570,343	361,000	$ 41,785	-	$ -	3,524	$ 6,583
2006	5,211,114	$ 221,047	350,000	$ 39,698	107,117	$ 62,585	44,244	$ 75,294
2007	8,665,711	$ 450,189	327,260	$ 33,247	242,485	$ 189,472	62,773	$ 107,099
2008	11,342,157	$ 1,091,511	225,820	$ 27,125	830,765	$ 579,200	61,744	$ 116,474
2009	15,478,436	$ 1,510,162	1,680,927	$ 80,041	1,188,243	$ 953,311	64,405	$ 111,907
2010	24,536,263	$ 2,505,641	147,010	$ 12,720	1,424,867	$ 1,258,004	4,461	$ 8,296
2011	16,297,984	$ 2,054,415	334,891	$ 26,084	1,348,456	$ 1,229,576	8,364	$ 16,627
2012	65,544,441	$ 6,458,449	369,088	$ 27,961	1,660,768	$ 1,776,966	13,105	$ 27,880
2013	48,033,500	$ 4,561,582	193,190	$ 16,607	1,218,618	$ 1,320,427	14,441	$ 36,397
Annual Average	21,283,743	$ 1,990,629	445,969	$ 38,239	802,132	$ 736,954	28,376	$ 51,868

Sources: PFMC, 2014; IEc, 2014b; Resource Dimensions, 2015

WDFW reports only the numbers of Chinook and coho caught per year (not weights or values of landings) in the Non-Tribal commercial gillnet fishery in Grays Harbor (IEc, 2014b). Average weights of fish landed by Quinault Indian Nation (QIN) Treaty commercial fishers in the Tribal commercial gillnet fishery and the average prices per pound paid by Quinault Pride Seafood and independent buyers were used to estimate weights and values of landings (Resource Dimensions, 2015) (Table 13).

Table 13. QIN Gillnet Fisheries, Average Weights and Prices

	QIN Gillnet Fishery: Chinook Average		QIN Gillnet Fishery: Coho Average	
Year	**Weight (lbs.)**	**Price**	**Weight (lbs.)**	**Price**
2004	18.83	$ 1.48	10.42	$ 0.79
2005	19.02	$ 1.18	9.69	$ 1.05
2006	19.87	$ 1.69	10.89	$ 1.28
2007	19.51	$ 2.22	9.68	$ 1.43
2008	20.01	$ 2.62	11.57	$ 1.51
2009	16.35	$ 1.68	10.20	$ 1.07
2010	17.78	$ 2.49	10.65	$ 1.34
2011	15.49	$ 2.49	9.58	$ 1.69
2012	17.39	$ 2.29	9.00	$ 1.76
2013	15.32	$ 2.54	8.96	$ 2.15

Source: QDFi Database, 2015

The numbers of Chinook and coho salmon caught in Non-Tribal river gillnet fisheries for each year were multiplied by the average QIN weights to estimate total weights. These figures were multiplied by QIN-reported prices to estimate total values in current year dollars. Estimated total values were then converted to 2014 dollars (Table 14).

Table 14. Non-Tribal Gillnet Fisheries, Weights and Estimated Values

	Chinook Gillnet Fishery Estimated		Coho Gillnet Fishery Estimated		Gillnet Salmon Fisheries Total	
Year	Weight (lbs.)	Value	Weight (lbs.)	Value	Weight (lbs.)	Value
2004	3,445.47	$ 6,199.03	54,502.96	$ 52,344.73	57,948.42	$ 58,543.76
2005	7,209.08	$ 9,971.89	29,785.99	$ 36,826.21	36,995.07	$ 46,798.10
2006	3,874.26	$ 7,482.38	7,065.39	$ 10,293.59	10,939.65	$ 17,775.97
2007	10,026.42	$ 24,788.38	16,338.22	$ 26,017.55	26,364.63	$ 50,805.93
2008	14,348.01	$ 40,956.76	90,063.37	$ 148,700.16	104,411.38	$ 189,656.92
2009	19,508.78	$ 35,533.96	5,720.85	$ 6,594.97	25,229.63	$ 42,128.93
2010	26,582.71	$ 70,784.50	42,497.66	$ 61,058.25	69,080.37	$ 131,842.75
2011	32,853.52	$ 85,687.55	34,771.79	$ 60,444.73	67,625.31	$ 146,132.28
2012	27,451.04	$ 64,660.30	93,200.92	$ 169,036.71	120,651.96	$ 233,697.01
2013	1,301.85	$ 3,351.01	53,234.47	$ 116,119.91	54,536.32	$ 119,470.92

Sources: IEc, 2014b; Resource Dimensions, 2015

5.1.2 Commercial Aquaculture

The commercial aquaculture industry in Grays Harbor is comprised of six shellfish farms (i.e. farms that report sales of shellfish products) and two integrated shellfish farm/processors (IEc, 2014a). The United States Department of Agriculture, National Agricultural Statistics Service (USDA-NASS) reported eight operations in Grays Harbor County with sales and distribution, having a total value of $5,559,000 (USDA-NASS, 2014).

In 2013, commercial aquaculture operations in Grays Harbor County reported Pacific oyster sales of $5,187,446 (2014 dollars) on 1,565,904 round pounds, and Manila clam sales of $8,037 on 2,950 round pounds (2014 dollars) (IEc, 2014a).

From 2004 to 2013, annual average production of Pacific oysters and Manila clams in Grays Harbor County was 1,392,849 round pounds and 1,207 round pounds, respectively. Average values over this time period for Pacific oysters and Manila clams were $4,754,840 and $3,332 (2014 dollars), respectively (Table 15) (IEc, 2014a.)

Table 15. Commercial Aquaculture Production, Grays Harbor County

	Pacific Oyster		Manila Clams	
Year	Round Pounds	Value ($2014)	Round Pounds	Value ($2014)
2004	1,378,664	$ 5,362,290	83	$ 300
2005	1,339,464	$ 4,498,958	-	$ -
2006	1,428,407	$ 4,795,239	-	$ -
2007	1,470,898	$ 4,722,114	-	$ -
2008	1,045,443	$ 3,519,614	-	$ -
2009	1,123,869	$ 3,886,081	-	$ -
2010	1,030,586	$ 3,533,584	-	$ -
2011	1,804,434	$ 6,134,273	-	$ -
2012	1,740,822	$ 5,908,801	9,034	$ 24,983
2013	1,565,904	$ 5,187,446	2,950	$ 8,037
Average	1,392,849	$ 4,754,840	1,207	$ 3,332

Source: IEc, 2014a

Data from a survey conducted of commercial shellfish growers in Washington in 2010 was used to estimate expenditures and employment for commercial aquaculture. Average spending per farmed acre for shellfish farming in Washington was $4,988 (2010 dollars) (Northern Economics, 2013). Table 16 presents estimated spending per farmed acre by expenditure category.

Table 16. Commercial Aquaculture Expenditures

	Pacific Oyster		Manila Clams	
Year	Round Pounds	Value ($2014)	Round Pounds	Value ($2014)
2004	1,378,664	$ 5,362,290	83	$ 300
2005	1,339,464	$ 4,498,958	-	$ -
2006	1,428,407	$ 4,795,239	-	$ -
2007	1,470,898	$ 4,722,114	-	$ -
2008	1,045,443	$ 3,519,614	-	$ -
2009	1,123,869	$ 3,886,081	-	$ -
2010	1,030,586	$ 3,533,584	-	$ -
2011	1,804,434	$ 6,134,273	-	$ -
2012	1,740,822	$ 5,908,801	9,034	$ 24,983
2013	1,565,904	$ 5,187,446	2,950	$ 8,037
Average	1,392,849	$ 4,754,840	1,207	$ 3,332

Sources: Northern Economics, 2013; Resource Dimensions, 2015

5.1.3 Economic Impacts of Non-Tribal Commercial Fishing and Commercial Aquaculture-related Activities on Grays Harbor County, 2013

Non-Tribal commercial fishing and commercial aquaculture-related activities generated the following economic impacts for the regional economy in 2013 (Table 17):

- 925.4 direct jobs generated by these activities. Purchases made by individuals and firms in these industries supported an additional 132.6 induced jobs in the region.
- 41.6 indirect jobs were supported by $37.2 million of local purchases made by businesses supplying services to these industries.
- $29.9 million of direct wages and salaries were received by the 925.4 directly employed by Non-Tribal commercial fishing and commercial aquaculture-related activities. Re-spending of this income created an additional $5.0 million of income and consumption expenditures in Washington, principally in Grays Harbor County. Those holding indirect jobs received $2.1 million in indirect income.
- Businesses providing services to firms in these industries received $81.5 million of revenues.
- Firms in the Non-Tribal commercial fishing and commercial aquaculture industries paid $4.2 million in state and local taxes.

Table 17. Summary of Economic Impacts Generated by Non-Tribal Commercial Fishing- and Commercial Aquaculture-related Activities, 2013 ($2014)

Grays Harbor County	Commercial Fishing	Commercial Aquaculture	Total
Jobs			
Direct	731.9	193.5	925
Indirect	36.3	5.3	42
Induced	96.1	36.5	133
Total	**864.3**	**235.3**	**1099.6**
Personal Income			
Direct	$ 21,271,291	$ 8,611,764	$ 29,883,055
Indirect	$ 1,892,549	$ 195,800	$ 2,088,349
Induced	$ 3,639,303	$ 1,383,843	$ 5,023,146
Total	**$ 26,803,143**	**$ 10,191,407**	**$ 36,994,550**
Business Revenue	$ 63,630,263	$ 17,902,405	**$ 81,532,668**
Local Purchases	$ 26,041,492	$ 11,149,221	**$ 37,190,713**
State and Local Taxes	$ 3,470,959	$ 702,048	**$ 4,173,007**

Source: Resource Dimensions, 2015

5.1.4 Projected Economic Impacts of Non-Tribal Commercial Fishing and Commercial Aquaculture-related Activities on Grays Harbor County, 2020 – 2022

To evaluate the economic impacts under each of the three scenarios detailed in Section 4.5, we begin with the Base Case Scenario, which is built upon the original IMPLAN sub-model and assumes no changes from activities in 2013 (i.e., growth, expansion, decline, etc.), for Non-Tribal commercial fishing- and commercial aquaculture-related activities (Table 18).

Table 18 indicates the Base Case Scenario economic impacts projected for the regional economy over the three-year period 2020 to 2022 (reported in $2014 dollars):

- An average of 995.8 direct jobs generated by Non-Tribal commercial fishing- and commercial aquaculture-related activities.[12] Purchases made by these individuals and firms supporting an additional average of 160.2 induced jobs in the region.
- An average of 59.0 indirect jobs supporting a total of some $134.7 million in local purchases made by businesses supplying services to these activities.

[12] Note that job growth is not specific to commercial fishing and commercial aquaculture, but also jobs directly associated with these industries.

- Nearly $108.2 million of direct wages and salaries would be received by an annual average of 995.8 directly employed by these activities. Re-spending of this income would create an additional $18.8 million of income and consumption expenditures in Washington, principally in Grays Harbor County. Those holding indirect jobs would receive some $11.3 million in indirect income.

- Businesses providing services to individuals and firms in these industries would receive some $277.3 million of revenues.

- Individuals and firms in these industries would pay some $14.8 million in state and local taxes.

Table 18. Summary of Economic Impacts Generated by Non-Tribal Commercial Fishing- and Commercial Aquaculture-related Activities, 2020-2022

Grays Harbor County	Commercial Fishing	Commercial Aquaculture	Total
Jobs			
Direct	791.4	204.4	996
Indirect	52.6	6.4	59
Induced	116.7	43.5	160
Total	**960.7**	**254.3**	**1215**
Personal Income			
Direct	$ 76,456,296	$ 31,758,361	$ 108,214,657
Indirect	$ 10,544,050	$ 722,068	$ 11,266,118
Induced	$ 13,660,352	$ 5,103,319	$ 18,763,671
Total	**$ 100,660,697**	**$ 37,583,748**	**$ 138,244,446**
Business Revenue	$ 217,965,197	$ 59,328,092	**$ 277,293,289**
Local Purchases	$ 93,602,029	$ 41,115,968	**$ 134,717,997**
State and Local Taxes	$ 12,162,689	$ 2,589,004	**$ 14,751,693**

Source: Resource Dimensions, 2015

5.1.5 Scenario-based Changes in Economic Impacts Generated by Non-Tribal Commercial Fishing- and Commercial Aquaculture-related Activities on Grays Harbor County, 2020 – 2022

To estimate the changes in economic contributions under each scenario, we begin with Base Case Scenario models for the period 2020 to 2022 for Non-Tribal commercial fishing- and commercial aquaculture-related activities and accordingly adjust each to estimate changes in regional economy impacts resulting from activity levels expected under each scenario (Section 4.5). Tables 19, 20 and 21 show the economic impacts, as changes in contributions to the regional economy, for 2020 to 2022 by scenario.

Scenario 1: Table 19 indicates the changes in economic contributions by these activities to the regional economy for 2020 to 2022, estimated in Scenario 1:

- An average three-year decrease of 299.7 direct jobs in these industries; over 72% of these direct job losses will be by Non-Tribal commercial fishers. Resulting purchases made by the remaining 696.1 individuals would support an average of 110.6 induced jobs in the region (a loss of 49.6 induced jobs).
- An average three-year decrease of 17.0 indirect jobs resulting in an estimated $42.3 million decrease in purchases made by businesses supplying services to these activities.
- A three-year total decline of $33.8 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 696.1 directly employed by Non-Tribal commercial fisheries and commercial aquaculture-centered activities. Re-spending of remaining income will create an estimated additional $13.0 million of income and consumption expenditures in Washington, principally in Grays Harbor County (a $5.8 million decrease for the period as shown in Table 19). A three-year total decrease of 17.0 indirect jobs and some $3.2 million in related income from the Base Case Scenario was estimated.
- Businesses providing services to Non-Tribal commercial fisheries and commercial aquaculture-based activities can expect to receive $83.8 million less in revenues.
- A decrease of $4.4 million in state and local taxes paid by individuals and firms in these industries.

Table 19. Scenario 1: Summary of Changes in Economic Contributions by Non-Tribal Commercial Fishing and Commercial Aquaculture-related Activities, 2020-2022

Grays Harbor County	Commercial Fishing	Commercial Aquaculture	Total
Jobs			
Direct	216.5	83.2	300
Indirect	14.4	2.6	17
Induced	31.9	17.7	50
Total	**262.8**	**103.5**	**366.3**
Personal Income			
Direct	$ 20,915,610	$ 12,928,829	$ 33,844,439
Indirect	$ 2,884,448	$ 293,954	$ 3,178,402
Induced	$ 3,736,948	$ 2,077,561	$ 5,814,510
Total	**$ 27,537,006**	**$ 15,300,344**	**$ 42,837,350**
Business Revenue	$ 59,626,918	$ 24,152,467	**$ 83,779,385**
Local Purchases	$ 25,605,925	$ 16,738,310	**$ 42,344,235**
State and Local Taxes	$ 3,327,248	$ 1,053,983	**$ 4,381,231**

Source: Resource Dimensions, 2015

Scenario 2: Table 20 indicates the changes in economic contributions by Non-Tribal commercial fishing and commercial aquaculture-related activities to the regional economy for 2020 to 2022, estimated in Scenario 2:

- An average three-year decrease of 300.3 direct jobs in these activities; over 72% of these direct job losses will be by Non-Tribal commercial fishers. Resulting purchases made by the remaining 695.5 individuals would support an average of 110.5 induced jobs in the region (a loss of 49.7 induced jobs).
- An average three-year decrease of 17.1 indirect jobs resulting in an estimated $42.4 million decrease in purchases made by businesses supplying services to these activities.
- A three-year total decline of $33.9 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 695.5 directly employed by these activities. Re-spending of remaining income will create an estimated additional $12.9 million of income and consumption expenditures in Washington, principally in Grays Harbor County (a $5.8 million decrease for the period as shown in Table 20). A three-year total decrease of 17.1 indirect jobs and some $3.2 million in related income from the Base Case Scenario was estimated.

- Over the period 2020-2022, businesses providing services to these activities can expect to receive $84.0 million less in revenues.

- A decrease of $4.4 million in state and local taxes paid by individuals and firms.

Table 20. Scenario 2: Summary of Changes in Economic Contributions by Non-Tribal Commercial Fishing and Commercial Aquaculture-related Activities, 2020-2022

Grays Harbor County	Commercial Fishing	Commercial Aquaculture	Total
Jobs			
Direct	217.1	83.2	300
Indirect	14.5	2.6	17
Induced	32	17.7	50
Total	**263.6**	**103.5**	**367.1**
Personal Income			
Direct	$ 20,978,049	$ 12,928,829	$ 33,906,878
Indirect	$ 2,893,072	$ 293,954	$ 3,187,026
Induced	$ 3,748,122	$ 2,077,561	$ 5,825,683
Total	**$ 27,619,243**	**$ 15,300,344**	**$ 42,919,587**
Business Revenue	$ 59,805,207	$ 24,152,467	**$ 83,957,674**
Local Purchases	$ 25,682,488	$ 16,738,310	**$ 42,420,799**
State and Local Taxes	$ 3,337,195	$ 1,053,983	**$ 4,391,178**

Source: Resource Dimensions, 2015

Scenario 3: Table 21 presents the changes in economic contributions by Non-Tribal commercial fishing and commercial aquaculture-related activities to the regional economy for 2020 to 2022, estimated in Scenario 3:

- An average three-year decrease of 405.4 direct jobs in Non-Tribal commercial fishing- and commercial aquaculture-related activities; over 79% of these direct job losses will be by Non-Tribal commercial fishers. Resulting purchases made by the remaining 590.4 individuals would support an average of 95 induced jobs in the region (a loss of 65.2 induced jobs).

- An average three-year decrease of 24.0 indirect jobs resulting in an estimated $54.8 million decrease in purchases made by businesses supplying services to these activities.

- A three-year total decline of $44.1 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 590.4 directly employed by these activities. Re-spending of remaining income will create an estimated additional $11.1 million of income and consumption expenditures in Washington, principally in Grays Harbor County (a $7.6 million decrease for the period as shown in Table 21). A three-year total decrease of 24.0

indirect jobs and some $4.6 million in related income from the Base Case Scenario was estimated.

- Over the period 2020-2022, businesses providing services to these activities can expect to receive $112.9 million less in revenues.
- A decrease of $6.0 million in state and local taxes paid by individuals and firms in these industries was estimated.

Table 21. Scenario 3: Summary of Changes in Economic Contributions by Non-Tribal Commercial Fishing and Commercial Aquaculture-related Activities, 2020-2022

Grays Harbor County	Commercial Fishing	Commercial Aquaculture	Total
Jobs			
Direct	322.2	83.2	405
Indirect	21.4	2.6	24
Induced	47.5	17.7	65
Total	**391.1**	**103.5**	**494.6**
Personal Income			
Direct	$ 31,125,358	$ 12,928,829	$ 44,054,187
Indirect	$ 4,292,483	$ 293,954	$ 4,586,437
Induced	$ 5,561,129	$ 2,077,561	$ 7,638,691
Total	**$ 40,978,970**	**$ 15,300,344**	**$ 56,279,314**
Business Revenue	$ 88,733,634	$ 24,152,467	**$ 112,886,101**
Local Purchases	$ 38,105,386	$ 16,738,310	**$ 54,843,696**
State and Local Taxes	$ 4,951,432	$ 1,053,983	**$ 6,005,415**

Source: Resource Dimensions, 2015

5.2 Tourism and Recreation

This subsection discusses the economic impacts of tourism and recreation in Grays Harbor County, and the changes in economic contributions of the visitor-based industry under Scenarios 1, 2 and 3. The economic contributions of sport fishing and recreational razor clam digging are highlighted.

5.2.1 Tourism and recreation trips and trip expenditures

Dean Runyan Associates of Portland, Oregon annually analyzes the economic impacts of visitor spending for Washington at the state and county levels. 2012 is the most recent year that Dean Runyan Associates reported data on visitation, visitor spending and economic impacts of this spending at the county level.

DRA (2013) indicates that overnight visitor trips to Grays Harbor County in 2012 totaled 1,501,000 person-trips (Table 22). DRA (2013) does not report an estimated number of day trips to Grays Harbor County.

Point 97 and the Surfrider Foundation recently conducted a study of coastal recreation in Washington for the Washington State Department of Natural Resources (DNR). One component of this study was a random online survey of state residents. The study authors reported that survey results were statistically valid; however, white and female populations of the resident population were over-represented, while the Hispanic population was under-represented versus the 2010 United States Census.

Survey respondents indicated that 59.8% of trips were for recreation, and 23.9% of trips were for leisure and/or tourism (a combined 83.7%) (Point 97 and Surfrider Foundation, 2015). Further, 13.4% of survey respondents reported that the length of their last trip to the Washington coast was a day trip (Point 97 and Surfrider Foundation, 2015).

Extrapolating from DRA (2013), it was estimated that 1,256,337 of overnight trips to Grays Harbor County in 2013 were for recreation, leisure and/or tourism (Table 22). In addition, it was estimated that there were 168,349 day trips to Grays Harbor County in 2012 for the same purpose(s) for 1,424,686 total trips.

Table 22. Estimated Trips to Grays Harbor County for Recreation and Tourism

	Person Trips	Recreation Person Trips
Hotel, Motel	606,000	507,222
Private Home	567,000	474,579
Other Overnight	328,000	274,536
All Overnight	1,501,000	1,256,337
Day Trips		168,349
Total Trips		*1,424,686*

Sources: DRA, 2013; Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015

Note: 'Recreation Person Trips' includes trips for recreation, leisure and tourism.

Point 97 and Surfrider Foundation (2015) also asked survey respondents to estimate their trip expenditures. The leading expenditure categories were lodging/campsite fee (an average per person of $25.96), car fuel ($24.02) and food and beverages at a restaurant or bar ($23.95). Average expenditures by category were multiplied by the estimated number of overnight trips (1,256,337) to derive estimated spending totals by category. Total expenditures by overnight visitors were estimated to exceed $146.8 million (Table 23) (Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015).

Table 23. Estimated Trip Expenditures for Overnight Visitors to Grays Harbor County

Expenditure category	Estimated total expenditures
Lodging/Campsite Fee	$ 32,614,509
Car fuel	$ 30,177,215
Food and beverages at a restaurant or bar	$ 30,089,271
Food and beverages from a store	$ 17,953,056
Shopping and souvenirs (t-shirts, posters, gifts, etc.)	$ 12,400,046
Airline flight	$ 3,052,899
Charter fee (whale watching, etc.)	$ 2,638,308
Bus/Ferry/Train ticket	$ 2,273,970
Park entrance, museum, aquarium or other entrance fee	$ 1,897,069
Other	$ 1,884,506
Sundries (sunscreen, surf wax, motion sickness, pills, batteries, camera data cards, etc.)	$ 1,871,942
Lessons, clinics, camps	$ 1,821,689
Car rental	$ 1,608,111
Boat rental	$ 1,344,281
Parking	$ 1,319,154
Boat fuel	$ 1,042,760
Bait and tackle	$ 891,999
Equipment rental (surfboard, bike, kayak, stand-up paddle, etc.)	$ 841,746
One-day fishing license fee	$ 716,112
Dive equipment rental and airfills	$ 402,028
Boat ramp fees	$ 326,648
Total	$ 146,840,669

Sources: Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015

The same extrapolation was applied to calculate spending by day trip visitors, except the lodging/campsite fee expenditure category was not included. Average expenditures by category were multiplied by the estimated number of day trips (168,349) to derive estimated spending totals by category. Total expenditures by day trip visitors were estimated to exceed $15.3 million (Table 24) (Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015).

Table 24. Estimated Trip Expenditures for Day Trip Visitors to Grays Harbor County

Expenditure Category	Estimated Total Expenditures
Car fuel	$ 4,043,743
Food and beverages at a restaurant or bar	$ 4,031,959
Food and beverages from a store	$ 2,405,707
Shopping and souvenirs (t-shirts, posters, gifts, etc.)	$ 1,661,605
Airline flight	$ 409,088
Charter fee (whale watching, etc.)	$ 353,533
Bus/Ferry/Train ticket	$ 304,712
Park entrance, museum, aquarium or other entrance fee	$ 254,207
Other	$ 252,524
Sundries (sunscreen, surf wax, motion sickness, pills, batteries, camera data cards, etc.)	$ 250,840
Lessons, clinics, camps	$ 244,106
Car rental	$ 215,487
Boat rental	$ 180,133
Parking	$ 176,766
Boat fuel	$ 139,730
Bait and tackle	$ 119,528
Equipment rental (surfboard, bike, kayak, stand-up paddle, etc.)	$ 112,794
One-day fishing license fee	$ 95,959
Dive equipment rental and airfills	$ 53,872
Boat ramp fees	$ 43,771
Total	$ 15,306,291

Sources: Point 97 and Surfrider Foundation, 2015; Resource Dimensions, 2015

Table 25 provides estimates for the total number of trips to Grays Harbor County for recreation, tourism and leisure and estimated total trip expenditures. Trip expenditures were estimated to exceed $162 million.

Table 25. Total Estimated Trips and Trip Expenditures

Visitor Type	Estimated Trips	Estimated Trip Expenditures
Overnight visitors	1,256,337	$ 146,840,669
Day trip visitors	168,349	$ 15,306,305
Total	1,424,686	$ 162,146,974

Source: Resource Dimensions, 2015

Decreases in visitor spending are assumed to vary by scenario and municipality. Industries including retail services, the arts, entertainment, recreation services and hospitality are most closely associated with visitor spending on tourism and recreation. Table 26 presents the percentages of total workforces employed in the visitor industry.To estimate potential post-spill changes in economic contributions resulting from disruptions to visitor patterns visitor-related revenue was decreased by a factor of 10% (the median of assumptions) for 2020, 2021 and 2022 (Ritchie, et al., 2013; Oxford Economics, 2010; Garza, et al., 2009).

Table 26. Workforce by Industry, Grays Harbor County and Municipalities

Geography	Workforce	Retail trade, arts, entertainment, and recreation, and accomodation and food services (% of workforce)	Percent of Grays Harbor County's workforce
Grays Harbor County	26,548	23.4%	23.5%
Aberdeen	6,326	25.6%	6.1%
Cosmopolis	659	22.8%	0.6%
Hoquiam	3,208	23.7%	2.7%
Ocean Shores	1,876	34.4%	2.4%
Westport	652	18.7%	0.5%

Source: USCB, 2013a

Note: Workforce is defined as the civilian employed population 16 year and over.

5.2.2 Sport fishing

A number of species are targeted by sport fishers, or anglers, in Grays Harbor, and its rivers and tributaries, in nearshore areas and at sea out of Westport. To estimate the yearly average total expenditures on sport fishing in these areas, yearly average angler-trips and yearly average expenditures on sport fishing were calculated.

Yearly (over the ten-year period 2004 to 2013), and average angler-trips by fishery are presented in Table 27. Recreational ocean salmon trolling, albacore tuna, bottomfish, and halibut angler-trips are reported as angler-trips embarking from Westport. WDFW collects Grays Harbor recreational gillnetting trip data from private and charter boats in Westport; at the Johns River, 28th Street Landing, Cosmopolis Boat Launches (in Grays Harbor); and at Montesano Fuller Bridge Boat Launches (on the Chehalis River). Yearly average angler-trips totaled 57,068 for these sport fisheries.

Sport fishing for Dungeness crab was not considered. WDFW notes that very little recreational crabbing occurs off the Washington coast. Further, data on sport fishing trips or sport landings for Dungeness crab on the Washington coast are not collected (IEc, 2014b, p. 44).

Table 27. Yearly and Average Angler-Trips by Sport Fishery, 2004-2013

Year	*Ocean Salmon Total	*Coastal River Salmon Total	Albacore Tuna	Bottomfish	Halibut
2004	38,189	7,673		16,500	3,992
2005	35,170	3,383		17,300	3,243
2006	24,541	4,760		19,500	2,478
2007	25,916	2,418		17,700	2,285
2008	18,731	2,244		17,200	2,408
2009	37,831	3,830	1,563	15,200	2,645
2010	38,428	2,047	2,455	13,500	2,240
2011	33,545	2,556	1,783	16,300	2,556
2012	33,545	4,380		18,000	2,627
2013	35,889	424		17,300	2,868
Average	32,179	3,372	1,934	16,850	2,734
Total					*57,068*

Sources: IEc, 2014b; PFMC, 2014; WDFW, 2013a

**Denotes total comprised of Chinook and Coho for Ocean Salmon and Coastal River Salmon.*

The United States Fish & Wildlife Service (USFWS) conducts national surveys for participation rates and trip and equipment expenditures on hunting, sport fishing and wildlife-associated recreation. Results are parsed by state, for state residents and non-residents. The most recent survey was conducted in 2011; results were revised and re-released in January 2014.

The number of anglers in Washington, sport fishing in freshwater and saltwater, was an estimated 938,000 in 2011, totaling 13,449,000 days of participation and 12,579,000 angler-trips. This yields an average of 13.4 angler-trips per angler in 2011 (USFWS, 2014).

Total yearly trip and equipment expenditures by category were divided by 13.4 to derive estimated trip expenditures. These values were multiplied by 57,068 to estimate total expenditures by category. Average expenditures for sport fishing in the Grays Harbor area were estimated to be nearly $4.6 million yearly (2014 dollars) (Table 28).

Table 28. Yearly Average Expenditures, Grays Harbor Area Sport Fisheries

Expenditure category	Average expenditure per angler-trip	Average yearly trip expenditures
Total trip and equipment expenditures for fishing	*$ 80.48*	***$ 4,592,824***
Trip related expenditures		
Food and Lodging, Total		
Food	$ 10.86	$ 619,827
Lodging	$ 2.58	$ 147,142
Transportation	$ 13.75	$ 784,813
Boating costs	$ 9.14	$ 521,704
Other trip costs	$ 8.13	$ 463,741
Equipment	$ 36.02	$ 2,055,640

Sources: USFWS, 2014; Resource Dimensions, 2015

5.2.3 Recreational razor clam digging

WDFW manages razor clams on all coastal beaches in Washington for recreational use. Three of these beaches, Mocrocks, Copalis and Twin Harbors, lie in Grays Harbor County.

WDFW collects data on the total number of razor clams harvested for each beach, the number of recreational razor clam digger-trips, and the number of total digging days allowed. Total digger-trips for four seasons were publicly available: 2010-2011, 2011-2012, 2012-2013 and 2013-2014.

Total digger-trips for Mocrocks, Copalis and Twin Harbors beaches for these four seasons are presented in Table 29. Note that the 2013-2014 season saw the highest number of digger-trips and razor clams harvested for the fishery since 1982. The average total for the three beaches for these seasons was 173,152 (WDFW, 2011, 2012, 2013b and 2014).

Table 29. Total Recreational Razor Clam Digger-Trips

Beach	2010-2011	2011-2012	2012-2013	2013-2014
Mocrocks	37,749	44,002	51,783	74,736
Copalis	50,533	26,212	95,700	75,198
Twin Harbors	66,566	40,632	106,278	119,872
Total	*154,848*	*110,846*	*253,761*	*269,806*
Average	173,152			

Sources: WDFW, 2011, 2012, 2013b and 2014

An April 2008 survey conducted by University of Washington researchers was used to estimate expenditures on recreational razor clam digging. On the three beaches, diggers spent an average of 1.85 nights on digging-trips, traveled 236 miles (round trip), and had an average of 3.99 people per party and 3.60 diggers per party (Dyson and Huppert, 2010) (Table 30).

Table 30. Recreational Razor Clam Digging Party Statistics

Beach	No. Nights Spent	Miles Traveled (round-trip)	Diggers per Party	People per Party
Mocrocks	1.06	232	3.71	4.09
Copalis	1.44	254	3.98	4.42
Twin Harbors	3.06	222	3.10	3.46
Average	1.85	236	3.60	3.99

Source: Dyson and Huppert, 2010

Trip expenditures per digging party were estimated by beach. The greatest expenditure categories, were 'Gas and Oil' ($94.36), 'Hotel' ($91.51) and 'Restaurant' ($70.30) ($2008) (Dyson and Huppert, 2010) (Table 31).

Table 31. Average Trip Expenditures for Recreational Razor Clam Digging

Expenditure Category	Mocrocks	Copalis	Twin Harbors	Average
Hotel	$ 85.67	$ 115.77	$ 73.10	$ 91.51
Camping	$ 9.36	$ 6.19	$ 18.18	$ 11.24
Restaurant	$ 57.42	$ 78.44	$ 75.04	$ 70.30
Groceries	$ 29.71	$ 38.37	$ 65.50	$ 44.53
Gas and Oil	$ 64.49	$ 107.15	$ 111.43	$ 94.36
Ferry Tolls	$ 1.18	$ 0.23	$ 0.66	$ 0.69
Other Transport	$ 1.16	$ 0.96	$ 0.80	$ 0.97
All Other	$ 14.79	$ 28.75	$ 25.21	$ 22.92

Source: Dyson and Huppert, 2010

Average trip expenditures per person were an estimated $91.94. Trip expenditure category estimates were multiplied by 173,152 to estimate total expenditures by category, on average over the four seasons, for digging on the three beaches. Total expenditures were estimated to exceed $15.9 million yearly (Table 32).

Table 32. Average Expenditures Per Person Per Trip and Total Expenditures

Expenditure Category	Average Expenditures Per Person Per Trip ($2008)	($2014)	Total expenditures
Hotel	$ 22.94	$ 25.01	$ 4,330,523.18
Camping	$ 2.82	$ 3.07	$ 531,575.62
Restaurant	$ 17.62	$ 19.21	$ 3,326,243.52
Groceries	$ 11.16	$ 12.16	$ 2,105,524.27
Gas and Oil	$ 23.65	$ 25.78	$ 4,463,849.97
Ferry Tolls	$ 0.17	$ 0.19	$ 32,898.82
Other Transport	$ 0.24	$ 0.26	$ 45,019.43
All Other	$ 5.74	$ 6.26	$ 1,083,929.43
Total	$ 84.34	$ 91.94	$ 15,919,564.23

Sources: Dyson and Huppert, 2010; Resource Dimensions, 2015

5.2.4 Economic Impacts of Tourism and Recreation Activities on Grays Harbor County, 2013

As Table 33 indicates, tourism and recreation activities generated the following economic impacts for the regional economy in 2013:

- 2,092.2 direct jobs generated by these activities. Purchases made by individuals and firms in these industries supported an additional 324.2 induced jobs in the region.
- 234.6 indirect jobs were supported by $106.0 million of local purchases made by businesses supplying services to these industries.
- $72.0 million of direct wages and salaries were received by the 2,092.2 directly employed by tourism and recreation activities. Re-spending of this income created an additional $11.1 million of income and consumption expenditures in Washington, principally in Grays Harbor County. Those holding indirect jobs received $8.0 million in indirect income.
- Businesses providing services to firms in these industries received $245.8 million of revenues.
- Firms in the tourism and recreation industries paid $28.0 million in state and local taxes.

Table 33. Summary of Economic Impacts Generated by Tourism and Recreation Activities, 2013 ($2014)

	Tourism	Sport Fishing	Recreational Razor Clam Digging	Total
Jobs				
Direct	1,915.7	47.9	128.6	2,092.2
Indirect	215.0	5.0	14.6	234.6
Induced	292.1	7.4	24.7	324.2
Total	**2,422.8**	**60.3**	**167.9**	**2651**
Personal Income				
Direct	$ 65,166,476	$ 1,917,500	$ 4,889,692	$ 71,973,668
Indirect	$ 7,297,575	$ 178,306	$ 507,084	$ 7,982,965
Induced	$ 10,029,521	$ 256,051	$ 844,788	$ 11,130,360
Total	**$ 82,493,572**	**$ 2,351,857**	**$ 6,241,564**	**$ 91,086,993**
Business Revenue	$ 223,676,897	$ 5,754,149	$ 16,381,724	**$ 245,812,770**
Local Purchases	$ 95,989,749	$ 2,424,984	$ 7,570,343	**$ 105,985,076**
State and Local Taxes	$ 25,325,067	$ 673,797	$ 2,048,289	**$ 28,047,153**

Source: Resource Dimensions, 2015

5.2.5 Projected Economic Impacts of Tourism and Recreation on Grays Harbor County, 2020-2022

To evaluate the economic impacts under each of the three scenarios detailed in Section 4.5, we begin with the Base Case Scenario, which is built upon the original IMPLAN sub-model and assumes no changes from activities in 2013 (i.e., growth, expansion, decline, etc.), for tourism and recreation activities.

Table 34 indicates the Base Case Scenario economic impacts projected for the regional economy over the three-year period 2020 to 2022 (reported in $2014 dollars):

- An average of 2,115.6 direct jobs generated by tourism and recreation activities. Purchases made by these individuals and firms supporting an additional average of 327.8 induced jobs in the region.

- An average of 237.4 indirect jobs supporting a total of some $367.2 million in local purchases made by businesses supplying services to these activities.

- More than $249.3 million of direct wages and salaries would be received by an annual average of 2,115.6 directly employed by these activities. Re-spending of this income would create an additional $38.6 million of income and consumption expenditures in Washington, principally in Grays Harbor County. Those holding indirect jobs would receive some $27.7 million in indirect income.

- Businesses providing services to individuals and firms in these industries would receive some $853.0 million of revenues.
- Individuals and firms in these industries would pay some $97.2 million in state and local taxes.

Table 34. Summary of Economic Impacts Generated by Tourism and Recreation Activities, 2020-2022

	Tourism	Sport Fishing	Recreational Razor Clam Digging	Total
Jobs				
Direct	1,937.40	48.4	129.8	2,115.6
Indirect	217.5	5.1	14.8	237.4
Induced	295.4	7.5	24.9	327.8
Total	**2450.3**	**61.0**	**169.5**	**2680.8**
Personal Income				
Direct	$ 225,776,273	$ 6,634,462	$ 16,918,105	$ 249,328,840
Indirect	$ 25,283,235	$ 616,929	$ 1,754,486	$ 27,654,650
Induced	$ 34,748,355	$ 885,923	$ 2,922,927	$ 38,557,205
Total	**$ 285,807,863**	**$ 8,137,314**	**$ 21,595,518**	**$ 315,540,695**
Business Revenue	$ 775,815,865	$ 19,816,029	$ 57,410,271	**$ 853,042,165**
Local Purchases	$ 332,566,822	$ 8,390,331	$ 26,193,034	**$ 367,150,187**
State and Local Taxes	$ 87,741,420	$ 2,331,305	$ 7,086,983	**$ 97,159,708**

Source: Resource Dimensions, 2015

5.2.6 Scenario-based Changes in Economic Impacts Generated by Tourism and Recreation Activities on Grays Harbor County, 2020 – 2022

To estimate the changes in economic contributions under each scenario, we begin with Base Case Scenario models for the period 2020 to 2022 for tourism and recreation activities and accordingly adjust each to estimate changes in local and regional economy impacts resulting from activity levels expected under each scenario (Section 4.5). Tables 35, 36 and 37 show the economic impacts, as changes in contributions to the regional economy for 2020 to 2022 by scenario.

Scenario 1: Table 35 indicates the changes in economic contributions by these activities to the regional economy for 2020 to 2022:

- An average three-year decrease of 379.9 direct jobs in these industries.. Resulting purchases made by the remaining 1,735.9 individuals would support an average of 270.1 induced jobs in the region (a loss of 57.7 induced jobs).

- An average three-year decrease of 42.8 indirect jobs resulting in an estimated $63.9 million decrease in purchases made by businesses supplying services to these activities.

- A three-year total decline of $44.0 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 1,735.9 directly employed by tourism and recreation activities. Re-spending of remaining income will create an estimated additional $31.8 million of income and consumption expenditures in Washington, principally in Grays Harbor County (a $6.8 million decrease for the period as shown in Table 35). A three-year total decrease of 42.8 indirect jobs and some $5.0 million in related income from the Base Case Scenario was estimated.

- Over the period 2020-2022, businesses providing services to individuals and firms in these industries can expect to receive $151.2 million less in revenues.

- A decrease of $16.6 million in state and local taxes paid by firms in these industries was estimated.

Table 35. Scenario 1: Summary of Changes in Economic Contributions by Tourism and Recreation Activities, 2020-2022

	Tourism	Sport Fishing	Recreational Razor Clam Digging	TOTAL
Jobs				
Direct	357.1	9.1	13.5	379.7
Indirect	40.2	1.0	1.6	42.8
Induced	53.6	1.5	2.6	57.7
Total	**450.9**	**11.6**	**17.7**	**480.2**
Personal Income				
Direct	$ 40,983,656	$ 1,273,548	$ 1,765,408	$ 44,022,612
Indirect	$ 4,661,115	$ 119,196	$ 182,657	$ 4,962,968
Induced	$ 6,308,599	$ 170,305	$ 305,010	$ 6,783,914
Total	**$ 51,953,370**	**$ 1,563,049**	**$ 2,253,075**	**$ 55,769,494**
Business Revenue	$ 141,443,255	$ 3,821,936	$ 5,944,003	**$ 151,209,194**
Local Purchases	$ 59,571,232	$ 1,603,665	$ 2,707,320	**$ 63,882,217**
State and Local Taxes	$ 15,362,745	$ 451,516	$ 734,311	**$ 16,548,572**

Source: Resource Dimensions, 2015

Scenario 2: Table 36 indicates the changes in economic contributions by tourism and recreation activities to the regional economy for 2020 to 2022:

- An average three-year decrease of 425.2 direct jobs in these industries. Resulting purchases made by the remaining 1,690.4 individuals would support an average of 262.0 induced jobs in the region (a loss of 65.8 induced jobs).

- An average three-year decrease of 48.6 indirect jobs resulting in an estimated $73.7 million decrease in purchases made by businesses supplying services to these activities.

- A three-year total decline of $50.1 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 1,690.4 directly employed by tourism and recreation activities. Re-spending of remaining income will create an estimated additional $30.8 million of income and consumption expenditures in Washington, principally in Grays Harbor County (a $7.8 million decrease for the period as shown in Table 36). A three-year total decrease of 48.6 indirect jobs and some $5.7 million in related income from the Base Case Scenario was estimated.

- Over the period 2020-2022, businesses providing services to individuals and firms in these industries can expect to receive $173.6 million less in revenues.

- A decrease of $19.2 million in state and local taxes paid by firms in these industries.

Table 36. Scenario 2: Summary of Changes in Economic Contributions by Tourism and Recreation Activities, 2020-2022

	Tourism	Sport Fishing	Recreational Razor Clam Digging	Total
Jobs				
Direct	389	10.3	25.9	425.2
Indirect	44.5	1.1	3.0	48.6
Induced	59.3	1.6	4.9	65.8
Total	**492.8**	**13.0**	**33.8**	**539.6**
Personal Income				
Direct	$ 45,300,751	$ 1,415,660	$ 3,369,999	$ 50,086,410
Indirect	$ 5,177,112	$ 132,006	$ 350,099	$ 5,659,217
Induced	$ 6,982,871	$ 189,094	$ 582,330	$ 7,754,295
Total	**$ 57,460,734**	**$ 1,736,760**	**$ 4,302,428**	**$ 63,499,922**
Business Revenue	$ 157,955,270	$ 4,233,615	$ 11,439,082	**$ 173,627,967**
Local Purchases	$ 66,726,510	$ 1,788,192	$ 5,216,417	**$ 73,731,119**
State and Local Taxes	$ 17,333,075	$ 498,084	$ 1,413,691	**$ 19,244,850**

Source: Resource Dimensions, 2015

Scenario 3: Table 37 presents the changes in economic contributions by tourism and recreation activities to the regional economy for 2020 to 2022:

- An average three-year decrease of 487.3 direct jobs in these industries.. Resulting purchases made by the remaining 1,628.3 individuals would support an average of 252.9 induced jobs in the region (a loss of 74.9 induced jobs).
- An average three-year decrease of 54.6 indirect jobs resulting in an estimated $83.6 million decrease in purchases made by businesses supplying services to these activities.
- A three-year total decline of $57.0 million in direct wages and salaries from Base Case Scenario 2020-2022 was estimated for the 1,491.3 directly employed by tourism and recreation activities. Re-spending of remaining income will create an estimated additional $29.7 million of income and consumption expenditures in Washington, principally in Grays Harbor County (an $8.8 million decrease for the period as shown in Table 37). A three-year total decrease of 54.6 indirect jobs and some $8.8 million in related income from the Base Case Scenario was estimated.
- Over the period 2020-2022, businesses providing services to individuals and firms in these industries can expect to receive $195.9 million less in revenues.
- A decrease of $21.8 million in state and local taxes paid by firms in these industries.

Table 37. Scenario 3: Summary of Changes in Economic Contributions by Tourism and Recreation Activities, 2020-2022

	Tourism	Sport Fishing	Recreational Razor Clam Digging	Total
Jobs				
Direct	446.1	11.3	29.9	487.3
Indirect	50	1.2	3.4	54.6
Induced	67.4	1.8	5.7	74.9
Total	**563.5**	**14.3**	**39.0**	**616.8**
Personal Income				
Direct	$ 51,577,959	$ 1,564,870	$ 3,891,717	$ 57,034,546
Indirect	$ 5,810,088	$ 144,791	$ 406,057	$ 6,360,936
Induced	$ 7,934,521	$ 208,961	$ 672,787	$ 8,816,269
Total	**$ 65,322,568**	**$ 1,918,622**	**$ 4,970,561**	**$ 72,211,751**
Business Revenue	$ 177,999,406	$ 4,680,361	$ 13,245,743	**$ 195,925,510**
Local Purchases	$ 75,584,778	$ 1,993,453	$ 6,040,698	**$ 83,618,929**
State and Local Taxes	$ 19,566,707	$ 550,519	$ 1,639,999	**$ 21,757,225**

Source: Resource Dimensions, 2015

SECTION SIX: Potential Impacts of an Oil Spill on Ecosystem Service Values

6.1 INTRODUCTION

The marine, estuarine and nearshore environments of the Grays Harbor area provides economic benefits to Grays Harbor County through a multitude of ecosystem services – the products and services produced by the environment.

Ecosystem services provided by natural processes, aesthetic values and non-consumptive resource use can impact the fiscal health of a community through reducing costs (Caudill and Henderson 2004; Newcome, et al 2005). This section provides an abridged look at the value of ecological services and resulting economic benefits produced by the marine, estuarine and nearshore environment of the Grays Harbor area.

The stream of economic benefits that flow to and through Grays Harbor County and its communities near these environments include use benefits derived from goods and services delivered by the Pacific Ocean, the Chehalis River, the Grays Harbor estuary, and coastal beaches. Use benefits or values are both direct and indirect. Direct use benefits include things like lodging, charter boat fees, food, equipment purchases and rentals, fuel, local arts, gifts, etc.

Indirect use benefits are functional in nature. Examples include goods and services such as water supply, fish and wildlife habitat, flood control, water filtration, nutrient cycling, erosion control, air purification, the provision of wildlife viewing, photography and recreational opportunities, cultural resources, viewsheds, and amenity values.

These conditions or processes produce benefits that have economic utility or satisfy an economic want. At times, the conversion of benefits into goods is clear and linkages are valued through market trading. Frequently, however, the connections are not explicit in how we currently measure costs and benefits. This examination seeks to shed light on these connections by accounting for several services or goods not traded directly in markets, like those associated with wetland functions.

A benefit transfer approach, meta-analyses function transfer, explained in Section 6.4.2, is used to estimate certain economic values associated with the habitats in Grays Harbor County by adapting estimates available from studies completed in a similar context.

6.2 OBJECTIVES

Increasingly, governments are aware that decisions about economic sustainability and resource management that overlook values produced by ecosystems, an indispensable complement to the human-created economy, may have lasting economic consequences. When ecological services are lost through inadequate planning, taxpayers and governments incur significant costs to replace these services. Some services can be only partially replaced, and some cannot be replaced by investment.

Interference with or degradation of ecosystem services can result in a decline in water quality, air quality, soil stability, and biodiversity that decreases quality of life in our communities. With our improved grasp on humanity's profound dependence on ecological services, economists have worked to develop and improve ways to measure complex ecosystem service values. The objective of ecosystem economics is to quantify and value the ecological and economic benefits of services protected or restored, and to use this information to improve land use and resource management decision-making. The overall goal of this section is to raise awareness of the economic value of ecosystem services provided by the marine, estuarine and nearshore environments of the Grays Harbor area to Grays Harbor County, and more broadly to Washington State.

6.3 Ecosystem Service Valuation

Studies conducted on the value of ecological services produced by nature indicate services worth billions of dollars annually. Yet, as with this study, these analyses examine a finite set of services, limited to those upon which comprehensive valuation has been performed. While the estimated **$411 million to $3.3 billion in annual economic value** (Table 40) generated by the study area may seem high, given the limitations of the study and the fact that many values produced by ecological services are difficult to express in dollar figures, the true value of services is most certainly underestimated. Further, services not yet identified and their value to future generations is not included in our analysis.

When thoughtfully managed, natural systems produce substantial economic value that provide in perpetuity to future generations. When natural systems are destroyed the services they performed are lost and communities must pay to replace them (Evans and EcoNorthwest, 2004).

When the quality of natural storm protection, salmon productivity or water quality and supply services decline, for example, residents are taxed to pay for levees, storm water systems, hatcheries and filtration plants. Communities incur real costs to replace services that were previously provided freely. Additionally, replacement services are often less capable than the ecosystem services they replace.

To understand the real economic costs of damaged natural systems in policy and decision-making, governments are increasingly considering ecosystems as economic assets. The values we can name are greater than those for which we can establish prices or costs, so ecosystem service values are markers for the minimum value of the true social value of the services provided – thus enabling us to replace the default value of $0.00 historically used in policy and decision-making frameworks (e.g., cost-benefit analysis, programmatic master planning).

On valuing ecosystem services

An ecosystem service is a "service flux," that is, its efficiency is measured as output per unit of time. Intact, healthy ecosystems are self-organizing; they provide valuable services in perpetuity at no cost. The delivery of ecosystem services depends on maintaining a particular structure or arrangement of ecosystem constituents. Yields of ecological service fluxes such as pollination and water filtration are distinct from resource flow such as timber extraction. For example, a single-species timber plantation might yield resource-flows (wood) for extraction, but a timber plantation would not provide the same service-fluxes as an intact natural forest ecosystem. Specifically, service fluxes such as flood mitigation, decomposition of wastes, renewal of soil, pollination, pest control, translocation of nutrients, and provision of habitat are not yielded by a timber plantation to the same degree as by a natural forest ecosystem. When it comes to generation of ecological services, the elements of the ecosystem, and their relationship to each other, matter.

To describe ongoing fluxes of ecosystem services, scientists and economists often describe the service-flux in terms of the dollar value it generates per unit of area over a given time period. It is also important to note that value is not fixed in time. The values of many ecological services are increasing as they become increasingly scarce (Boumans et al., 2002).

6.4 METHOD

Benefit transfer provides the most feasible method to assess the economic contributions generated by ecosystem services provided to Grays Harbor County, given constraints on the study. Only a limited set of ecosystem services could be reasonable valued for this project. The ecosystem services for which values are estimated are the following:

- terrestrial habitat (total economic value is recreational use and passive use value);
- wetlands (habitat, flood control, nature-based recreation: angling, hunting, bird watching, aesthetic enjoyment/amenity, erosion control , water supply, and the regulation of water quality); and
- aquatic habitat (nonuse values only).

These values are presented in Section 6.5.2. The benefit transfer approach used is outlined below.

6.4.1 Determination of Lands Area by Ecosystem Classification

The geographic information system (GIS) ArcGIS was used to map the study area and calculate acreage by ecosystem classification. To create the area of analysis, a polygon layer for Grays Harbor was built from the DNR hydrolayer clipped at the outer edge of the jetties, the US 101/SR 105 bridge over the Chehalis River, and the point where the double line banks of rivers end at a single arc. This coverage was buffered out one mile, and used to clip all other coverages.

To calculate the base acreage of riverine inputs, the DNR hydrolayer for Grays Harbor was filtered by stream type to narrow selection to larger freshwater inputs, and the acreage calculated based on an average width of 25 feet.

The DNR ShoreZone Inventory, a comprehensive field survey of nearshore habitats conducted from 1994 to 2000, was used to determine areas of nearshore habitat. This area was clipped from the DNR hydrolayer polygon coverage of Grays Harbor to generate the total acreage of marine area within the harbor. The acreage of ocean marine habitat was calculated from a point 200 feet west of the hydrolayer shoreline to the edge of the one mile buffer for 0.25 mile north and south of the mouth of the harbor. Beach acreage was calculated as the remaining 200 feet for the same mileage.

Land cover estimates were derived from the Washington State Land Use 2010 coverage. This map was produced from digital county tax parcel layers and intended as a general spatial analysis for the purpose of identifying land use patterns across large areas. Parcels in this layer were grouped into three classifications: timber, agriculture and open space, with commercial, residential, and industrial lands excluded. Classification of parcels as timber, shrub, or grassland were made based upon reference to 2015 aerial photos (Google Earth).

Freshwater wetlands were classified from National Wetland Inventory maps of Grays Harbor.

Table 38. GIS coverages used in the analysis.

Coverage	Source	Habitat	Location
National Wetland Inventory	USFWS	Wetlands	http://www.fws.gov/wetlands/Data/Data-Download.html
Grays Harbor County Hydrography	WDNR	Marine, Rivers, Beaches	https://fortress.wa.gov/dnr/adminsa/DataWeb/dmmatrix.html
Washington Shore Zone Inventory	WDNR	Estuarine	https://fortress.wa.gov/dnr/adminsa/DataWeb/dmmatrix.html
Washington Landuse 2010	WSDOE	Forests, Shrub, Grasslands	http://www.ecy.wa.gov/services/gis/data/data.htm#l

Source: Resource Dimensions, 2015

Acreages for each of the three spill scenarios were calculated from baseline acreages using masks. For each scenario, a polygon was generated using the spill point of origin and extending out to all areas assumed to be inundated by oil. The resultant area was used to erase each baseline coverage to determine the number of acres of habitat remaining. In turn, the projected loss of value of services provided by injured land cover type was used to determine the potential change in ecosystem service values for each scenario.

6.4.2 Valuation approach

Over the past four decades, several economic methods have been developed to estimate the value of environmental goods and services not traded directly in markets (Borrisova-Kidder, 2006). These approaches to non-market valuation have developed principally within two branches of traditional economics – environmental and natural resource economics.

Generally, the methods can be broken into three primary categories – direct market valuation approaches (e.g., market price, avoided and replacement cost, production function), the use of individuals' actual behavior related to environmental services (revealed preference) and information collected in consumer surveys on hypothetical behavior related to environmental services (stated preference). Revealed preference methods include those as travel cost and hedonic pricing. Popular stated preference approaches include contingent valuation, choice modeling or choice experiments, and group valuation.

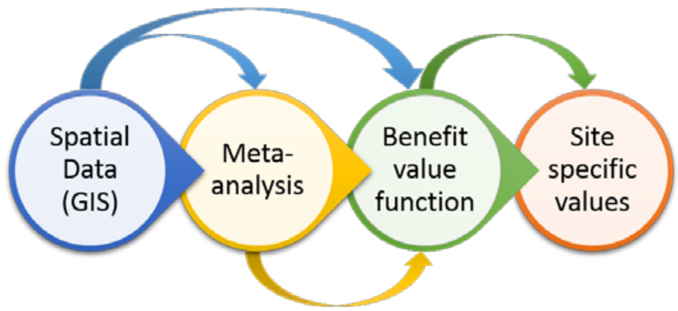
These valuation methods have been used to estimate values for virtually all ecosystem services for most forms of terrestrial, wetland, and aquatic habitats. This study employs a meta-analyses function “benefit transfer” approach (values are transferred using a value function derived from the results of existing studies).

Benefit transfer involves applying a monetary benefit value per unit estimate (e.g., per visitor day, per household, per acre) from an existing study site to an unstudied area for which a per unit benefit value is needed. Economists define benefits for economic efficiency or benefit-cost analyses as the user’s willingness to pay (WTP) in excess of current costs (e.g., net WTP) or consumer surplus. This is the benefit measure used by federal agencies for benefit-cost analysis and natural resource damage assessment (U.S. Department of Interior, 1994; USEPA, 2000; U.S. Office of Management and Budget, 2000).

Meta-analyses function transfer provides a relatively accurate approach to estimating benefit transfer by enabling controls for important differences in context and site variables. This method produces lower transfer errors than unit value and value function transfer. Also, this approach is well-suited to valuing diverse policy sites because the value function can be applied to a database containing site-specific information on habitat and relevant socioeconomic characteristics.

Primary elements of a meta-analysis benefit function transfer are shown in Figure 6. The meta-analysis itself consists of a review of the available literature on the value of the ecosystem service of interest. Meta-analysis data is then used to estimate a value function that relates the service value to the characteristics of the ecosystem service. Characteristics might include the type and size of the land covers present, ecosystem functions, proximity to similar ecosystems, and the number of people that benefit (population). In this study, we use GIS to obtain information on some of these characteristics and to develop the acreages for relevant PGH near-shore land covers. Lastly, the characteristics of the policy site are plugged into the value function to estimate the value of the ecosystem services produced by the region of study.

Figure 6. Components of meta-analyses benefit function transfer



Resource Dimensions, 2015.

This study uses a number of meta-analysis value functions for different land covers and ecosystem services. These are introduced at the point that they are used in later in this section.

To evaluate the reliability of our value estimates, 95% prediction intervals are calculated for each value. The prediction interval provides an estimated range of values likely to include the unknown true ecosystem service value. The range is calculated from the meta-analysis sample data and the variation in predicted values. Thus, if we were to repeat the procedure continually, 95 times out of 100 the prediction interval would contain the unknown true service value. The prediction interval spectrum therefore gives an indication of how certain we are about the predicted value. A wider interval indicates higher uncertainty.

For the purposes of this study, all ecosystem service values presented are obtained using the above benefit transfer protocol.

6.4.3 Economic benefits

Generally, economic benefits are defined as what a user (e.g., visitor, recreationist, household) would pay to ensure continued access to a particular resource (good/service), or for an enhancement in the resource (e.g., increased catch of a chosen species). In this study, economic benefits would be what users would pay for continued access to Grays Harbor fisheries and recreation opportunities. Since actual visitor expenditures have already been paid for gas, supplies, accommodations, bait, etc., these dollars cannot be used as a measure of benefit, to do so would result in an inaccurate double counting method.

Quantifying the economic values of ecosystem services allows us to put a dollar value on possible ecosystem damages caused by an oil spill.

6.4.4 Units of analysis for benefit transfer

To use benefit transfer, a per unit benefit value must be selected from a list of current studies or a table of average values, which is then applied to the proposed policy site or activity for which values are needed. For this study we have elected to use a per acre standard measure.

6.4.5 Limitations

Within the limits of the study, available and reliable data and related literature, we examine and express the value of ecosystem services in monetary units as a tool to provide better insight into the economic benefits of nature's goods and services.

The expression of the value of ecosystem services in monetary terms does not suggest that these values should be used as a foundation to establish prices and or that they should be treated as commodities that can be traded in the marketplace. Most ecosystem services are public goods. Monetizing their value provides an estimate of their benefits to society—benefits that would be lost if they were destroyed or gained if they were restored.

6.4.6 Data: Literature review and meta-analyses

To update values for wetlands, terrestrial and aquatic land covers, threatened and endangered species, fishing, hunting and miscellaneous passive uses (generally referred to as viewing), we began with Resource Dimensions 2013 database. Our database was checked for regional appropriateness and completeness; reconciled and new studies acquired through literature search were added to ensure the most current values for the PGH nearshore region.

6.5 GRAYS HARBOR COUNTY ECOSYSTEM SERVICES

Grays Harbor County contains a diverse mix of natural ecosystems that provide services for residents and visitors. The following section describes ecosystem services present in Grays Harbor County *that are analyzed in this study* (Table 39). Data availability precludes analyzing all ecosystem services on all land types.

6.5.1 Ecosystem Services

Ecosystem services are categorized into four main types: provisioning, regulating, societal/cultural, and supporting (TEEB, 2010). Provisioning resources provide sustenance, raw materials such as fuel or timber, and fresh water. Regulating services balance and control ecosystems with outcomes such as improving air quality, moderating extreme events, forming soil, and sequestering carbon. Societal/cultural services are those with historic, cultural, or spiritual value. Supporting services keep ecosystems vibrant and sustaining and include habitat and biodiversity.

Provisioning

Provisioning services analyzed in this study include food, raw materials, and water supply. The predominant **Food** ecosystem service in Grays Harbor County is produced by fisheries in aquatic habitats including beaches, estuaries, rivers, and marine areas. Razor clams, steelhead, salmon, bass, and trout are example species. Wetland environments also support fisheries. **Raw Material** production, principally biomass, occurs in wetlands. Estuaries, rivers, and marine areas contribute to the **Fresh Water Supply**. Rivers flowing through Grays Harbor County drain almost 3,500 mi^2, which is twice the size of Rhode Island (GHC, 2001;

Gendaszek, 2011). Wetlands play an even more important role in providing fresh water. They feed downstream water supplies and recharge groundwater in subsurface aquifers and shallow subsurface flows, the latter of which helps keep water in streams in dry years (GHC, 2001). Wetlands also protect the fresh water supply by mediating saltwater intrusion (Boyd, 2010). Estuaries also recharge aquifers (Pendleton, 2008). Subsurface aquifer recharge is critical because most of the county's water supply comes from precipitation rather than river inflow (GHCC, 1992).

Regulating

Regulating studies analyzed are air quality, natural hazards mitigation, carbon sequestration and storage, pollination, soil formation and retention, waste treatment, and water regulation. **Air Quality** is improved by both forests and marine ecosystems. Forests improve air quality by taking in carbon dioxide, releasing clean oxygen, and trapping particulate matter (Krieger, 2001). Marine ecosystems improve air quality by filtering pollutants and carbon dioxide, and releasing clean oxygen from phytoplankton (Daily, 1997; CODH, 2013). **Natural Hazards Mitigation**, such as flood and storm water control, is provided by forests, grasslands, wetlands, beaches, and estuaries. Forests and grasslands absorb and slow rainfall; wetlands act like a sponge, reducing peak discharge by slowing and storing rainfall; and beaches and estuaries protect inland areas from storm surge (GHC, 2001). Wetlands also reduce storm damage because their structure increases friction, which decreases wind speed, wave height, storm surge height, and slows storm-driven currents (CODH, 2013). **Carbon Sequestration and Storage** is an important function of grasslands and estuaries. Grasslands and estuaries sequester carbon in soils as organic matter (Daily, 1997). For example, a conservative estimate of the carbon sequestration capability of the Snohomish Estuary in the Puget Sound is 2.55 million tons over the next 100 years (RAE, 2014). Bee **Pollination is** a terrestrial service of forests, shrublands, and grasslands. These land cover types provide plants to pollinate and habitat for bees (Costanza et al., 1997). The county has at least 133 plants important to pollinators (WNPS, 2015; The Xerces Society, 2013a, 2013b). **Soil Formation and Retention** occurs primarily on grasslands, in estuaries, and on beaches. Grasslands and estuaries control erosion, capture sediments, and accumulate organic matter, and beach dunes retain sediments (Barbier et al., 2011; Daily, 1997; Oades, 1988). Forests, grasslands, wetlands, estuaries, and beaches provide **Waste Treatment** services by degrading pollutants and cycling nutrients (MES, 2015). **Water Regulation** refers to maintaining natural hydrologic flows throughout the biosphere (de Groot et al., 2002). All land types contribute to water regulation, but we focus on river services. Rivers and their riparian areas are an integral part of ensuring water flow for irrigation, industry, and residential water use.

Societal/Cultural

Societal/Cultural services analyzed are aesthetic/amenity, recreation, and tourism. All land covers types in Grays Harbor County have intrinsic **Aesthetic and/or Amenity** value.

Aesthetic or amenity value is a passive use benefit (visual enjoyment) that people derive from experiencing nature and feeling a sense of wellbeing. Grays Harbor County boasts seven major bodies of water, one of only two temperate rainforests in the U.S., and 50 miles of beaches (GHT, 2015). **Recreation** and **Tourism**, as discussed in previous sections, are important pieces of the county economy. People come to the region specifically to experience recreation opportunities such as sport fishing, beach combing, and bird watching, which are all attributable to unique natural attributes of the county. The county advertises nine different recreation opportunities tied to ecosystem services (GHT, 2015).

Supporting

Supporting services analyzed in this study are habitat and biodiversity. WDFW identifies 14 distinct priority **Habitat** types that support over 300 species of fish, shellfish, birds, mammals, amphibians, and reptiles, and at least 19 federally threatened and endangered species (WDFW, 2008; DOE, 2013a). Of the 300 species mentioned above, over half are listed as WDFW priority species — those that "require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. Priority species include State Endangered, Threatened, Sensitive, and Candidate species; animal aggregations considered vulnerable; and species of recreational, commercial, or tribal importance that are vulnerable." The habitats are comprised of 541 native vascular plants (WNPS, 2015). We analyze six habitat types that provide essential habitat and are vital for conserving **Biodiversity**.

Table 39. Ecosystem services and habitats assessed (indicated ●)

Ecosystem Services	Habitat							
	Terrestrial			Aquatic				Wetlands
	Forests	Shrub	Grasslands	Beaches	Estuaries	Rivers	Marine	
Provisioning								
Food					●	●	●	●
Raw Materials (e.g. timber)							●	
Water Supply	●				●	●	●	●
Regulating								
Air Quality	●						●	
Natural Hazards Mitigation	●		●	●	●			●
Carbon Sequestration and Storage	●				●			
Pollination	●	●	●					
Soil Formation				●	●		●	
Soil Retention			●					
Waste Treatment	●		●	●	●			●
Water Regulation						●		
Societal/Cultural								
Aesthetic/Amenity	●	●	●	●	●	●		●
Recreation and Tourism	●	●		●	●	●		●
Cultural/Spiritual								
Supporting								
Habitat	●	●			●	●	●	
Biodiversity/Genetic Resources		●						
Total Acres	22,393	5,635	2,932	8,886	4,415	38,021	538	20,224

Source: Resource Dimensions, 2015

6.5.2 Ecosystem Services Valuation

We estimate that the total value of ecosystem services in Grays Harbor County's nearshore environment is between $411 million and $3.3 billion (acre/year) (Table 40.)[13] Carbon storage adds another $45 million to $279 million (acre/year) (Table 41). Beaches provide the most valuable services, between $26,000 and $105,988 (acre/year). There are more acres of estuaries, however, and at the high end estuaries are the most valuable land cover type, providing $1.5 billion in services (acre/year).

Table 40. Base Valuation for Port of Grays Harbor region nearshore ecosystem services by land cover ($/Acre/Year) ($2015)

Land Cover	Acres	Low	High	Low Total	High Total
Beaches	4,415	$26,178	$105,988	$115,575,797	$467,935,494
Estuaries	38,021	$2,364	$40,293	$89,888,138	$1,531,970,807
Forests	22,393	$5,471	$25,401	$122,516,434	$568,809,846
Grasslands	2,932	$7,719	$16,435	$22,632,506	$48,187,963
Rivers and Lakes	538	$1,764	$44,926	$949,249	$24,170,148
Marine	20,224	$863	$19,259	$17,456,724	$389,499,259
Shrub	5,635	$619	$2,000	$3,489,990	$11,270,000
Wetlands	8,886	$4,377	$34,213	$38,889,963	$304,016,389
Total	103,044			$411,398,801	$3,345,859,905

Source: Resource Dimensions, 2015

Table 41. Base Valuation Carbon Storage for Select Land Covers ($/acre)

Land Cover	Acres	Low	High	Low Total	High Total
Estuaries	38,021	$1,166	$7,184	$44,318,216	$273,145,720
Grasslands	2,932	$255	$2,212	$748,082	$6,485,391
Total	40,953			$45,066,298	$279,631,111

Source: Resource Dimensions, 2015

Please see Appendix C for a table of studies used to calculate ecosystem services values and Appendix D for ecosystem service values by individual service and land cover type.

6.6 Environmental Impacts caused by Oil Spill

Wetland and aquatic ecosystems are assumed to be the primary ecosystems affected by the oil spill scenarios presented in Section 4. While there is suggestion that oil spilled in waterways can have long-term consequences to terrestrial ecosystems as oil flows though the food chain, such analysis is beyond the scope of this report. The sections below outline ecosystems likely affected by an oil spill

[13] Nearshore is defined as the land and marine area between the shoreline and the beginning of the offshore zone. We use a one-mile zone, both inland and from the shoreline, in determining the baseline for land covers used in this study.

and our estimation of associated decreases in ecosystem services values. The National Research Council commissioned a report on using an ecosystem services approach to analyzed effects of the *Deepwater Horizon* spill. They developed a comprehensive framework but did not apply it to the spill. The lack of empirical ecosystem services studies post-spill creates unavoidable uncertainty in our estimates and we present a wide range of values to reflect that uncertainty.

6.6.1 Ecosystems likely affected by an oil spill

Ecosystem response to an oil spill is not static or uniform. Ecosystem characteristics, such as health, composition, size, and resiliency determine severity and duration of damages. Like our analysis of the economic impacts of a spill, we base our assessment of possible *ex-ante* ecosystem effects post-spill on best available science and literature. We present a range of possible damages to ecosystem services that reflect the intractable number of controlling variables and resulting uncertainty.

Wetlands

Freshly spilled oil causes more environmental damage than older, weathered oils (Mendelssohn et al., 2012). The proximity of the impact scenarios in this study to potentially affected ecosystems increases the likelihood that fresh oil will reach relevant land cover types. Visible coating by fresh oil may immediately decrease societal and cultural ecosystem services.

Spilled oil can immediately impact wetlands' foundation and structure by causing necrosis and plant mortality on contact (Mendelssohn et al., 2012). Some wetland vegetation can survive initial coating, but die when oil penetrates the soil and coats roots and rhizomes. Oil-soaked roots prevent nutrient uptake and re-sprouting. The loss of root systems also increases erosion potential, which can turn wetland area into open water. This directly reduces biomass and can impact a wetland's ability to filter water, mitigate natural hazards, and provide habitat and biodiversity (CODH, 2013).

Spilled oil also impacts sub-surface wetland ecosystems. Spilled oil can cause mortality or avoidance in benthic (on and in the bottom of a body of water) microalgae and invertebrates (Mendelssohn et al., 2012). These species are an important part of the food chain, and perform vital ecosystem functions such as aerating sediments, decomposition, and nutrient transfer. This directly decreases wetlands' ability to transfer waste. If high mortality occurs, opportunistic species can proliferate and change species composition with long-lasting ripple effects in the broader ecosystem (Mendelssohn et al., 2012).

Wetland fisheries are also susceptible to oil damage. Oil can cause mortality and increased vulnerability in eggs, larvae, and early life-stage populations in wetland nursery habitat and breeding grounds (Mendelssohn et al., 2012). Many fish species can avoid damaged habitat but experience population declines if forced to occupy sub-optimal habitats. These damages can decrease wetlands' ability to provide food.

Estuaries

Estuaries, especially salt marshes (an ecosystem found within estuaries), are one of the most sensitive intertidal habitats to spilled oil (USEPA, 1993; Lewis and Pryor, 2013). Estuaries are one of the most productive ecosystems in the world, and some toxic byproducts of spilled oil degradation are more soluble in freshwater than in saltwater, making estuarine damage potentially more severe (Fodrie et al., 2014; Mendelssohn et al., 2012). Visible oiling of salt marsh vegetation may immediately reduce aesthetic, recreation, and tourism ecosystem services.

Salt marshes can be immediately affected by spilled oil. Oil can cause rapid mortality in plant species, both in aboveground plant cover and belowground roots and rhizomes. Plant mortality exposes soil to wave and tidal action that erodes marsh area (Silliman et al., 2012). Loss of marsh sediment is likely a long-term impact. The *Deepwater Horizon* spill caused the most severe salt marsh damage in the seaward 10 meters (Silliman et al., 2012). Erosion in heavily oiled areas occurred at over twice the rate than reference sites. Erosion and loss of marsh habitat may decrease estuaries' ability to provide clean water, mitigate hazards, sequester carbon, and treat waste.

Multiple studies show recovery of salt marsh plants after oil exposure as roots and rhizomes regenerate. Recovery time and success varies by ecosystem (Lewis and Pryor, 2013). Hoff (1995) surveyed the recovery times of salt marshes after exposure to spilled oil, and found that vegetation recovery takes anywhere from a few weeks to 20 years after contamination. Recovery times depend on factors, including climate, physical location, severity of contamination, type of spilled oil, and response method. Heavily oiled marshes in colder climates can take many years to recover (Hoff, 1995). Lack of reestablishment from one oiling event lasted at least one to three years (Hampson and Moul, 1978; de la Cruz, Hackney and Rajanna, 1981).

A February 1991 spill of ANS crude oil from a Texaco pipeline in Fidalgo Bay, Washington provides a comparable example for Grays Harbor. Salt marsh plants in Fidalgo Bay required three to four years to recover. The spill involved moderate to heavy oiling of a medium crude oil. The spill caused damage to salt marshes and eelgrass habitats, injuring spawning herring, surf smelt, crab, and clams (WDFW, 2004). The pipeline spilled 550 bbls of oil into Fidalgo Bay, which is approximately 0.005% of the amount of oil assumed in these scenarios. The oil coated 2.63 acres of salt marsh in the bay.

Oil contamination in salt marshes effects not only surface vegetation, but also invertebrate, mussel, and fish species that depend on the vegetation for nursery habitat (Silliman et al., 2012). The *Deepwater Horizon* spill caused mortality in estuarine snails and mussels. After the *Exxon Valdez* spill, herring and pink salmon embryos had genetic damage, deformities, smaller hatches, and mortality (Fodrie et al., 2014) (See Section 4 and Appendix B for a more detailed discussion of impacts on fisheries). Oil contamination can also change phytoplankton composition and reduce biomass (Glide and Pinckney, 2012).

Oil can also collect in estuarine benthic environments. This can cause long-term stress on species that feed in the benthic zone (Fodrie et al., 2014). Diluted bitumen crude oils are known to penetrate estuarine benthic zones (DOE, 2015). Damages to habitat and dependent species may affect the ecosystem service provision of food, recreation, habitat, and biodiversity.

Beaches

Oil spilled on beaches causes some of the most visible damages of oil spill events. Fresh oil can cover beaches with oil mats, and tar balls can wash ashore years later (Hayworth et al., 2011). Recreation, tourism, and aesthetic/amenity values are assumed to be heavily impacted by oil spilled on beaches (as discussed in Section 4). Food provision is also assumed to be affected, primarily razor clam digging.

Beaches in Grays Harbor are primarily fine-grained sandy beaches (DOE, 2013a). This means that there are smaller interstitial spaces than coarse-grained beaches, so it is harder for oil to penetrate the sandy surface (Gundlach and Hayes, 1978). It may be possible to mechanically scrape surface oil. Wave action, seasonal erosion, and tidal energy, however, can transfer oil deep into the sand (Haysworth et al., 2011). A 2004 study of oil persistence in Prince William Sound found 55,600 kg of biologically available oil on beaches — 12 years after the *Exxon Valdez* spill (Short et al., 2004).

Oil can cause immediate mortality to mollusks, infauna, and meiofauna (both very small invertebrates that live in interstitial spaces). Oil can suffocate these species or disrupt oxygen flow by clogging interstitial spaces (McLaughlin and Brown, 2006). If native meiofauna suffers oil damage, fauna structures can be disrupted by opportunistic species (McLaughlin and Brown, 2006). Beach meiofauna may play an important role in nutrient cycling and processing organic matter.

Rivers

Oil spilled in rivers can affect riparian, in-stream and flood plain habitats. Oil can cause mortality in lichens, mosses and other flora, which provide habitat and food sources for insects and invertebrates (Hutchinson, 1989). Oil can also cause mortality in insects and invertebrates. As in sandy beach ecosystems, death of native plant species and proliferation of opportunistic species can change ecosystem plant structures (Trett et al., 1989). Oil can cause immediate mortality to fish species. Of particular concern in the Chehalis River are possible injury to salmon migration routes, spawning areas, and juvenile rearing habitat (DOE, 2013a).

The 2010 *Enbridge* oil spill discharged at least 20,000 bbls of dilbit into the Kalamazoo River (USFWS, 2015). The oil type and volume of oil spilled are similar to Scenario 1, which makes it a good example of possible river ecosystem effects. The USFWS led a team of experts to review environmental damages from the spill. They released a damage assessment and restoration plan in May 2015; the following environmental damages examples are from that report.

Oil from an underground pipeline rupture seeped into a wetland area near a tributary of the Kalamazoo River in Michigan. The oil made its way into the tributary and into the Kalamazoo River. The oil initially floated on river surfaces, but as it mixed with sediment, sank and collected in the benthic environment. Aquatic and floodplain habitats were also oiled. Habitat damage was quantified by discounted service acre years (DSAYS), which represent acres affected, percent loss of ecosystem services, and duration of injury, discounted to present value. Estimates projected 5,790 lost DSAYS to in-stream habitats (loss of ecosystem services was between 50% and 90%).

Mortality in fish, birds, mammals, amphibians, and benthic invertebrates was observed immediately post-spill. Studies conducted two years after the spill found fewer unionids (freshwater mussels) downstream of the oil spill than upstream. Toxicity studies revealed ongoing threats to benthic fauna and invertebrates. These damages indicate possible losses to food provision and water supply ecosystem services.

The spill immediately closed 39 miles of river. Portions of the river were closed to angling, shoreline use, and park use as long as four years post-spill. Swimming fish consumption advisories were in place two years post-spill. Researchers are still estimating damages to aesthetic/amenity, recreation, and tourism services.

Marine

As discussed in Section 4 and Appendix B, oil spills in the marine environment can seriously injure fisheries and societal ecosystem services. Please see aforementioned sections for further discussion. Oil spills can cause damages throughout the marine environment, some of which are discussed below.

Marine invertebrates suffer mortality from suffocation and toxicity immediately post-spill. Species impacted can include sea urchins, limpets, sand clams, cockles, and amphipods (Blackburn et al., 2014). Oil that settles to the ocean floor can cause cellular, growth, and reproductive damage to invertebrates long after a spill event. Plankton can also suffer both direct injury and future ability to grow and reproduce (Abrianno et al., 2011). Abrianno et al. (2011) also point out that plankton community structures can be affected as zooplankton dies and phytoplankton experiences decreased predation.

Microbes vital to nutrient cycling in marine environments can shift to hydrocarbon consumption after an oil spill (CODH, 2013). Nutrient cycling is then disrupted because hydrocarbons do not contain nutrients found in the organisms usually consumed by microbes. Microbial consumption of hydrocarbons can also decrease oxygen in the water column, indicating possible impacts to air quality ecosystem services of marine ecosystems.

Kelp, seagrass, and other marine flora can be injured by oil spills (Chang et al., 2014). Underwater vehicle surveys indicated that ocean floor biota was injured after the *Deepwater Horizon* spill (CODH, 2013). Injures to ocean fauna and invertebrate species mentioned above indicate reductions in ecosystems' ability to provide habitat and biodiversity.

6.6.2 Impact scenarios

Scenario 1, a spill into the Chehalis River, results in ecosystem services values reduction of $17.8 million to $173.5 million. Ecosystem values are reduced from the base case of $411.4 million to $3.35 billion to $393.5 million to $3.17 billion (Table 42). The most severely impacted land cover type is rivers and lakes (in acres). The most total ecosystem services value is lost in marine areas (more acres and higher value per acre).

Table 42. Scenario 1: Change in Value of Grays Harbor region nearshore ecosystem services, by land cover ($/Acre/Year)

Land Cover	Acres	Low	High	Low Total	High Total
Beaches	4,415	$26,178	$105,988	$115,575,797	$467,935,494
Estuaries	37,163	$2,364	$40,293	$87,859,656	$1,497,399,233
Forests	20,825	$5,471	$25,401	$113,940,284	$528,993,156
Grasslands	2,932	$7,719	$16,435	$22,632,506	$48,187,963
Rivers and Lakes	108	$1,764	$44,926	$190,556	$4,852,000
Marine	17,840	$863	$19,259	$15,398,930	$343,585,185
Shrub	5,410	$619	$2,000	$3,350,390	$10,819,200
Wetlands	7,909	$4,377	$34,213	$34,612,067	$270,574,586
Total	96,601	$49,356		$393,560,186	$3,172,346,817

Source: Resource Dimensions, 2015

Reductions in carbon storage further reduce ecosystem services values by $1 million to $6.2 million (Table 43).

Table 43. Scenario 1: Change in Value of Carbon Storage for Select Land Covers ($/acre)

Land Cover	Acres	Low	High	Low Total	High Total
Estuaries	37,163	$1,166	$7,184	$43,318,099	$266,981,714
Grasslands	2,932	$255	$2,212	$748,082	$6,485,391
Total	40,095			$44,066,181	$273,467,105

Source: Resource Dimensions, 2015

Scenario 2, a spill into Grays Harbor, causes the most severe decrease in ecosystem services values. Scenario 2 reduces ecosystem services values by $113.4 million to $1.6 billion. Values are reduced to $2.98 million to $1.7 billion (Table 44). The most seriously injured ecosystem is marine area, losing almost 17,000 service-producing acres. Damage to estuaries causes the greatest loss of value, reducing total ecosystem services value by $64.7 million to $1.2 billion. Scenario 2 also causes the greatest loss of terrestrial ecosystem services out of all of the scenarios.

Table 44. Scenario 2: Change in Value of Port of Grays Harbor region nearshore ecosystem services, by land cover ($/Acre/Year)

Land Cover	Acres	Low	High	Low Total	High Total
Beaches	4,415	$26,178	$105,988	$115,575,797	$467,935,494
Estuaries	10,649	$2,364	$40,293	$25,175,323	$429,065,066
Forests	19,034	$5,471	$25,401	$104,138,969	$483,488,369
Grasslands	2,580	$7,719	$16,435	$19,916,605	$42,405,407
Rivers and Lakes	521	$1,764	$44,926	$919,254	$23,406,407
Marine	3,227	$863	$19,259	$2,785,445	$62,149,630
Shrub	3,641	$619	$2,000	$2,254,961	$7,281,800
Wetlands	6,220	$4,377	$34,213	$27,222,974	$212,811,472
Total	50,287			$297,989,329	$1,728,543,645

Source: Resource Dimensions, 2015

Reductions in carbon storage in estuaries and grasslands further reduce ecosystem services values by $32 million to $197.4 million (Table 45).

Table 46. Scenario 2: Change in Value of Carbon Storage for Select Land Covers ($/acre)

Land Cover	Acres	Low	High	Low Total	High Total
Estuaries	10,649	$1,166	$7,184	$12,412,376	$76,500,992
Grasslands	2,580	$255	$2,212	$658,312	$5,707,144
Total	13,229			$13,070,689	$82,208,136

Source: Resource Dimensions, 2015

Scenario 3, a spill at the mouth of Grays Harbor, reduces values by $28 million and $347.7 million. Scenario 3 reduces total ecosystem services values to between $383.3 million and $3 billion (Table 47). Marine areas are the most severely damaged ecosystem both in acres lost and total loss of ecosystem services. Scenario 3 causes a loss of almost 15,000 acres of productive marine area, and a $12.5 million to $280.2 million loss of ecosystem services value. Scenario 3 is the only scenario that damages beaches. Beaches lose 574 productive acres and a resulting loss of between $15 and $60 million.

Table 47. Scenario 3: Valuation of Port of Grays Harbor region nearshore ecosystem services, by land cover ($/Acre/Year)

Land Cover	Acres	Low	High	Low Total	High Total
Beaches	3,841	$26,178	$105,988	$100,549,635	$407,098,580
Estuaries	37,863	$2,364	$40,293	$89,514,595	$1,525,604,479
Forests	22,393	$5,471	$25,401	$122,516,434	$568,809,846
Grasslands	2,917	$7,719	$16,435	$22,516,719	$47,941,435
Rivers and Lakes	538	$1,764	$44,926	$949,249	$24,170,148
Marine	5,674	$863	$19,259	$4,897,619	$109,277,037
Shrub	5,635	$619	$2,000	$3,489,990	$11,270,000
Wetlands	8,886	$4,377	$34,213	$38,889,963	$304,016,389
Total	87,747			$383,324,204	$2,998,187,915

Source: Resource Dimensions, 2015

Reductions in carbon storage in estuaries and grasslands further reduce ecosystem services values by $187,998 to $1.2 million (Table 48).

Table 48. Scenario 3:Change in Value of Carbon Storage for Select Land Covers ($/acre)

Land Cover	Acres	Low	High	Low Total	High Total
Estuaries	37,863	$1,166	$7,184	$44,134,045	$272,010,624
Grasslands	2,917	$255	$2,212	$744,255	$6,452,212
Total	40,780			$44,878,300	$278,462,836

Source: Resource Dimensions, 2015

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Appendices

Appendix A. NAICS to IMPLAN bridge table for economic sectors used in impact models

Table A-1. NAICS to IMPLAN bridge table for economic sectors used in impact models

Economy Sector	Economy Industry Name	NAICS Code	NAICS Industry Name	IMPLAN Code	IMPLAN Sector
Construction - Marine	Marine Related Construction	237120 237990	Oil & Gas Pipeline & Related Structures Other Heavy & Civil Engineering Constr.	58	Construction of other new nonresidential structures
Marine Resources	Fish Hatcheries & Aquaculture	112511 112512	Finfish Farming & Fish Hatcheries Shellfish Farming	14	Animal production, except cattle, poultry, eggs
	Fishing	114111 114112	Finfish Fishing Shellfish Fishing	17	Commercial Fishing
	Management & Research	924120	Administration of Conservation Pgms	375	Environmental and misc. technical consulting services
		325411	Medicinal and Botanical Manufacturing	132	Fish liver oils, medicinal, uncompounded
	Commercial fishing equip/supply	423830	Industrial Machinery & Equipment	417	Commercial and industrial machinery and equipment repair and maintenance
	Fishing net materials	314999	Misc. Textile Products	85	All other textile products
	Seafood Processing	311710 311712	Seafood Canning Fresh & Frozen Seafood Processing	61	Seafood product preparation & packaging
	Fish Merchants	424420 424460	Frozen Fish Wholesalers Fish and Seafood Merchant	319	Wholesale trade
	Seafood Markets	445220	Fish and Seafood Markets	400	Retail - Food & beverage
Ship & Boat Building and Repair	Boat Building/Repair Ship Building/Repair	336612 336611	Boat Building & Repair Ship Building & Repair	354 363	Boat Building Ship building & repairing
Tourism & Recreation (Coastal)	Boat Dealers	441222	Boat Dealers	396	Retail - motor vehicles & parts
	Eating & Drinking Places	722110 722111 722112 722113	Full Service Restaurants Limited Service Eating Places Cafés Snack & Nonalcoholic Beverage	501 502 503	Food services & drinking places
	Lodging/Accommodations	721110 721191	Hotels & Motels B&Bs / Inns	411 412	Hotels & motels; incl. casino hotels Other accommodations
	Marinas	713930	Marinas	409	Amusement parks, arcades & gambling
	RV Parks & Campsites Rec/Vacation Camps	721211 721214	RV Parks & Recreational Camps Rec Camps (except Campgrounds)	412	Other accommodations
	Scenic Water Tours	487210	Scenic & Sightseeing Transp., Water	338	Scenic & sightseeing transp. & support

(Continued)

Table A-1. NAICS to IMPLAN bridge table for economic sectors used in impact models (continued)

Economy Sector	Economy Industry Name	NAICS Code	NAICS Industry Name	IMPLAN Code	IMPLAN Sector
Tourism & Recreation (Coastal)	Sporting Goods - Retail & Supply	451110	Sporting Goods Stores	328	Retail Goods: Sporting Goods
		339920	Equipment Mfg.	311	Sporting & athletic goods manufacturing
		423910	Sporting Goods - Supply, Wholesale	319	Wholesale trade
	Amusement & Recreation Services	487990	Scenic & Sightseeing Transp., Other.	338	Scenic & sightseeing transp. & support
		611620	Sports & Recreation Instruction	393	Other educational services
		532292	Recreation Goods Rental	363	Gen & Cons. Goods rental (excl. video)
		713990	Other Amusement & Recreation Svcs	410	Other amusement & recreation industries
	Zoos & Aquaria	712130	Zoos & Botanical Gardens	406	Museums, historical sites, zoos & parks
		712190	Nature Parks & Similar		
Transportation - Marine	Deep Sea Freight Transportation	483111	Deep Sea Freight Transportation	334	Water transportation
		483113	Coastal & Great Lakes Freight Trans		
	Marine Passenger Transport	483112	Deep Sea Passenger Transportation	334	Water transportation
		483114	Coastal & Great Lakes Freight Trans		
	Marine Transportation Services	488310	Port & Harbor Operations	338	Scenic & sightseeing transportation & support activities
		488320	Marine Cargo Handling		
		488330	Navigational Services to Shipping		
		488390	Other Support Act. for Water Transp.		
	Search & Nav. Equip.	334511	Search, Detection, Nav. Guidance, Aero. & Naut. System & Inst. Manuf.	315	Search, detection, & navigational instrument manufacturing
	Warehousing	493110	General Warehousing & Storage	340	Warehousing & Storage
		493120	Refrigerated Warehousing & Storage		
		493130	Farm Product Warehousing & Storage		

Sources: Resource Dimensions, 2015 adapted with guidance from Colgan, C.S. 2007. A Guide to the Measurement of the Market Data for the Ocean and Coastal Economy in the National Ocean Economics Program. National Ocean Economics Program, January 2007; IMPLAN Sector descriptions and NAICS bridge for the 536 IMPLAN sector scheme.

Note: To estimate county-level economic contributions or impacts with IMPLAN, it was necessary to disaggregate county-level data into 27 sectors. This was done using this "bridge table," adapted from Colgan (2007). The last two columns are the IMPLAN industry sector assignments used to estimate the economic contributions of business activities examined in this study.

APPENDIX B. EFFECTS OF OIL CONTAMINATION ON ECONOMICALLY IMPORTANT FINFISH AND SHELLFISH

The following discussion reflects the findings of a literature review for effects of oil contamination on finfish and shellfish. Scientific literature was reviewed to elucidate acutely toxic effects of crude oils (i.e. causing acute mortality); sublethal effects of the same; chronic toxicity resulting from persistent exposure to spilled oil; and generational impacts of oil contamination.

FINFISH

Several species of salmonids (including Chinook, coho and chum salmon and steelhead) and white sturgeon reside in the freshwater and marine habitats of Grays Harbor and its rivers and tributaries.

Grays Harbor is the main conduit of migration for these species, for both adults returning to their home river to spawn, and for juveniles leaving the protection of Grays Harbor's 99 square miles of estuaries for open sea (Jorgensen, 2013).

Fertilized eggs incubate in redds dug into the gravel bottoms of rivers and streams for a few months until they hatch as alevins. Alevins grow in the gravel for several months, protected from predation and environmental threats. After alevins have consumed their yolk sacs they freely swim from the gravel as fry. The Washington Department of Fish and Wildlife (WDFW) notes that "*Chum fry swim directly to the sea. Coho remain in fresh water for an average of one year while Chinook usually have a freshwater residence time of between three months to a year*" (WDFW, 2014).

Fry begin their outmigration to the Pacific Ocean through the Grays Harbor estuary, where they remain for several weeks or months undergoing smoltification (growing into juvenile salmon) and consuming plankton and other nutrients.

Adult salmon, depending on the species, remain in the ocean from six months to four years, until returning to their home river for spawning. Chinook, coho, and chum salmon, and steelhead spawn in Grays Harbor's rivers and tributaries.

In testimony prepared for the State of Washington Shorelines Hearings Board, James E. Jorgensen, Salmon and Steelhead Management Biologist for the Quinault Indian Nation Department of Fisheries, explains the juvenile and adult life stages of salmon in the Grays Harbor area (Jorgensen, 2013, excerpted at 33):

> "*Chinook juveniles rear in the larger tributary and main stem areas where they collect as they progress downstream following their emergence from gravel which can begin after mid-February and continue through September. Juvenile chum leave the lower river and the estuary fairly early moving downstream along main stem areas. Coho during their first summer remain in habitat near or below their natal streams, overwintering then migrating to the ocean at a rapid pace in spring. Juvenile natural origin steelhead typically rear during two summers of residence to smolt*

> *size and migrate to the ocean following their second year of residence. Some coho and steelhead fry appear to pass into the estuary on their first summer and enter the estuary where they may migrate to the ocean following one overwinter in the freshwater."*
>
> *"Adult chinook have the longest river entry period from early May through November….followed by fall Chinook beginning to enter in mid-August and early September. Coho and fall Chinook generally begin their most significant entry into Grays Harbor terminal fishing areas beginning the last week of September through the 3rd week of October…..Coho extend their entry into February. Natural origin winter steelhead enters Quinault Nation fisheries beginning in December and extending through April."*

Much of the research conducted on the toxicity of crude oils to salmonids results from the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska (*Exxon*), specifically on chum salmon and pink salmon (*Oncorhynchus gorbuscha*). This research extends from the effects of direct oil contamination and weathered oil on embryos, to delayed or sublethal effects of oil exposure on adults.

For example, directly after an oil spill event polycyclic aromatic hydrocarbons (PAHs) can immediately cross the cellular membranes of organisms, either as droplets in the water or from coating a substrate (such as the gravel of a redd). Exposure routes include direct physical contact to dissolved PAHs by embryos, alevins and fry, and ingestion of whole oil by juveniles, either from ingesting oil-contaminated prey or from mistaking oil droplets for prey (Carls, et al., 2008; Carls, et al., 1996). In other words, direct physical contact by embryos with spilled or weathered oil is not necessary for lethal or sublethal effects to occur in developing fish; merely the presence of dissolved PAHs makes them potentially toxic to embryos.

Further, the potential for exposure to PAHs by aquatic organisms has been shown to be increased in lower salinity waters, where PAHs are more soluble (i.e. PAHs are more readily dissolved in freshwater and estuarine water than saltwater) (Ramachandran, et al., 2006).

A preponderance of evidence has shown chronic adverse effects to biota from persistent sources of oil after *Exxon*. Some oil remained in subsurface sediments of oil contaminated shores for at least 16 years after the spill (Peterson, et al., 2003; Short, et al., 2007). Subsurface oil did not weather until it was exposed, and posed as a persistent source of oil contamination (Short, et al., 2004).

Bue, Sharr and Seeb (1998) observed that significantly elevated mortality of pink salmon embryos incubated in oil contaminated streams continued for at least four years post-*Exxon.* Heintz, Short and Rice (1999) found that embryonic exposure to a 18.0 parts per billion (ppb) dose of oil-coated gravel resulted in a 25% reduction in survival, and that between the end of exposure and maturity marine survival was reduced a further 15%. Thus, 40% fewer mature adults were produced by the exposed population than by the control (unexposed) population.

In a meta-analysis, Rice, et al. (2001) concluded that long term, persistent exposure to weathered PAHs from *Exxon* caused a decreased rate of growth in fry, and a population decrease from depressed size.

Heintz, et al., (2000) found that pink salmon stocks incurred delayed effects on growth and marine survival resulting from embryonic exposure to conditions similar to that of the ANS crude oil spilled from *Exxon.* A portion of embryos surviving the initial exposure was released to the marine environment. When analyzed upon return two years later, pink salmon exposed to an initial concentration of 5.4 ppb total PAH experienced a 15% decrease in marine survival. Another portion of the exposed embryos were retained in net pens, and showed a delayed effect in juvenile growth (Heintz, et al., 2000).

In addition to acute mortality, exposure to dissolved and weathered PAHs induces sublethal biochemical effects in fish embryos, including cardiac dysfunction, edema, spinal curvature and jaw size reduction (Incardona, Collier and Scholz, 2004). Direct effects of dissolved PAHs to cardiac conduction in developing fish embryos cause secondary effects in heart development, kidney development, neural tube structure and craniofacial skeleton formation. Additional research has shown that the initial effect is due to disruption of cardiac muscle cell processes by dissolved PAHs (Brette, et al., 2014). Different types of dissolved and weathered crude oils cause similar cardiac injuries in fish (Incardona, et al. 2013). For example, direct exposure to *Deepwater Horizon*-contaminated sediments caused edema, craniofacial and spinal defects, and injured tissue in fish (Raimondo, et al., 2014).

Chronic, low-level oil pollution produces similar effects as a one-time event. Hicken, et al. (2011) found that reduced cardiac output due to heart malformation can result in reduced swimming performance in PAH-exposed fish embryos. As salmonids are continuously swimming species, reduced swimming performance could contribute to reduced survival.

These results implicate the potential for population-level effects to result from embryonic exposure to PAHs, in that even at low doses sublethal biochemical effects could occur in developing fish, in the form of biochemical impairments incurred during early development (Heintz, et al., 2000). For example, the need to metabolize and depurate oil in the developing fish could result in less energy available for growth, eventually contributing to reduced marine survival – either from delayed mortality, a lack of swimming ability leading to decreased ability to predate, an increased risk to be predated, etc. Further, reduced jaw size in PAH-exposed fish could impact choices of prey – having implications for survival factors such as size and growth (Incardona, Collier and Scholz, 2004).

SHELLFISH

The Grays Harbor estuary and Pacific coast beaches are home to many shellfish species, including Dungeness crab (*Cancer magister*), razor clam (*Siliqua patula*) and Pacific oyster (*Crassostrea gigas*). When hatched, Dungeness crab larvae are free-swimming and must find a suitable area for growth on the sea floor. The majority of juveniles that settle in the intertidal areas outside of Grays Harbor will migrate into the subtidal waters of the Grays Harbor estuary the spring following settlement (WDFW, 2008).

Juvenile Dungeness crabs given its many sheltered areas (eelgrass beds, woody debris, piling areas, etc.) and ample prey prefer the shallow estuarine environment of Grays Harbor (WDFW, 2008; Schumacker, 2013). The juvenile life stage of the Dungeness crab lasts up to two years after hatching; during this time, juvenile crabs molt up to six times per year. The molting process leaves crabs vulnerable to the environment and predators for days, until their new shell hardens. Thus, juvenile Dungeness crabs actively seek a place to bury themselves for cover in the coastal estuary or nearshore sandy areas during molting (Schumacker, 2013).

Fertilization of razor clam eggs occurs in the water column via free-floating sperm and eggs. Redistribution from swimming or surf action occurs at this time, and after one to four months razor clam larvae 'set' and dig into the sand (USFWS, 1989). Larger juveniles typically remain in place in the upper few inches of sand, whereas adult razor clams usually live about one foot below the surface. Razor clams are rapidly mobile downward but have very limited mobility laterally (USFWS, 1989).

Fertilization of Pacific oyster eggs also occurs in the water column via free-floating sperm and eggs (USFWS, 1988). The free-swimming larvae feed on phytoplankton, and after a few weeks when the larvae reach a length of about 0.3 mm they set as spat, or a juvenile, on a hard substrate. Pacific oysters are sessile – the juvenile oyster will grow to adult size and die where the larvae has set (i.e. they are unable to move themselves around) (USFWS, 1988).

The harm of oil contamination to shellfish can be realized in acute mortality of larvae, juveniles and adults; in sublethal effects leading to less robust larvae; and in the energy expenditures necessary to adjust to an oil-contaminated environment (Jeong and Cho, 2007; Karinen, Rice and Babcock, 1985; Law and Kelly, 2004).

The toxicity of PAHs to shellfish can also be evidenced by exposure pathways, and abilities to metabolize and cleanse themselves of PAHs (Law and Hellou, 1999). The major exposure pathways of shellfish include direct physical contact to oil-contaminated water and ingestion. The biological mechanisms of shellfish will induce an equilibrium-partitioning process – where the concentrations of oil in the aqueous environment are in equilibrium with the concentrations of PAHs in the shellfish (requiring an expenditure of energy). Further, as razor clams and Pacific oysters are filter feeders, they tend to bioaccumulate low molecular weight PAHs that are prevalent in crude oil.

Invertebrates are relatively less able to metabolize xenobiotic (foreign) compounds than vertebrates. Depuration, or the elimination of PAHs by an organism as the concentrations of PAHs in the surrounding aqueous environment decrease, typically takes longer for invertebrates (Law and Hellou, 1999; Law and Kelly, 2004). This is important as shellfish must expend energy for depuration – energy that is not spent elsewhere such as on feeding, etc.

Re-oiling of a substrate, such as in chronic oil spills or persistent oil contamination, can continually adversely affect the same generation or future generations of sessile organisms (Babcock, et al., 1998; Soriano, et al., 2006; Vinas, et al., 2009).

The impact of toxic accumulation of PAHs in shellfish tissue can cause economically and culturally important species, including razor clams and Pacific oysters to be unfit for human consumption (or merely cause the perception that a resource is unsafe for consumption), thereby rendering a product unmarketable (Gilroy, 2000; Law and Kelly, 2004).

Quinault Department of Fisheries biologists note "razor clams may be particularly vulnerable to oil spills" (Schumacker, 2013). For example, a close relative of the razor clam, the pod razor shell (Ensis siliqua) appeared to be exhibit an escape response to spilled oil in Wales, United Kingdom, resulting in stranding of both subtidal and intertidal populations (Law, et al., 1997). If razor clams were to behave similarly by fleeing their burrows, fish and seabirds may predate them if they do not re-burrow quickly. It is unlikely razor clams would reach an area that would not trigger an escape response in a short time (Schumacker, 2013). Further, a drop in genetic variability has been found in pod razor shell populations several years after an oil spill (owing to a reduction in population size from spill-related mortality) (Fernandez-Tajes, et al., 2012).

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APPENDIX C. STUDIES USED TO CALCULATE ECOSYSTEM SERVICES VALUES

Table C-1. Reference Table Values

Land Cover	Author/Publication Year	Values (DOS)		Values ($2015)	
		Min	Max	Min	Max
Beaches	Kline, J. D. & Swallow, S. K. 1998	$40,600	$52,395	$59,706	$77,051
	Rein, F. A. 1999	$25	$27,901	$36	$40,145
	Taylor, L.O. & Smith, V.K. 2000	$482	$482	$671	$671
Estuaries	Armstrong, D.A. et al. 2003	$26	$143	$34	$186
	Batie, S. S. & Wilson, J. R. 1978	$12	$1,451	$44	$5,335
	Bauer D.M., et al. 2004	$380	$380	$482	$482
	Breaux, A., et al. 1995	$156	$20,343	$245	$31,986
	Costanza, R., et al. 1997	$198	$12,431	$296	$18,554
	Creel, M. & Loomis, J. 1992	$570	$625	$974	$1,068
	Hicks, R. et al. 2002	$148	$148	$197	$197
	Leggett, C. G. & Bockstael, N. E. 2000	$50	$50	$70	$70
	Newell, R.I. et al. 2005	$78	$78	$96	$96
	Opaluch, J. et al. 1999	$93	$93	$134	$134
	Pompe, J.J. & Rinehart, J.R. 1995	$269	$709	$423	$1,115
	Wilson, S. J. 2008	$129	$2,569	$144	$2,861
Forests	Costanza, R., et al. 1997	$73	$327	$109	$488
	Hougner, C. 2006	$72	$326	$86	$388
	Kenyon, W. & Nevin, C. 2001	$576	$576	$779	$779
	Lant, C. L. & Tobin, G. 1989	$359	$359	$694	$694
	Nowak, D.J. et al. 2002	$4,369	$17,852	$5,818	$23,771
	Olewiler, N. 2004	$34	$34	$43	$43
	Ribaudo, M. & Epp, D.J. 1984	$1,491	$1,891	$3,443	$4,367
	Shafer, E.L. et al. 1993	$103	$569	$171	$944
	Willis, K.G. 1991	$27	$219	$48	$386
	Wilson, S. J. 2008	$129	$681	$144	$758
	Zavaleta, E. 2000	$17	$582	$24	$811
	Zhongwei, L. 2006	$286	$287	$340	$341

Table C-1 Reference Transfer Values (continued)

Land Cover	Author/Publication Year	Values (DOS) Min	Values (DOS) Max	Values ($2015) Min	Values ($2015) Max
Grasslands	Qiu et al. 2006	$255	$1,249	$303	$1,485
	Rein, F. A. 1999	$25	$4,150	$36	$5,971
	Wilson, S. J. 2008	$426	$426	$474	$474
	Zhongwei, L. 2006	$6,758	$6,758	$8,036	$8,036
	Berrens, R. P., et al. 1996	$2,423	$2,423	$3,699	$3,699
	Bowker, J. M., et al. 1996	$5,088	$12,229	$7,768	$18,670
	Burt, O. R. & Brewer, D. 1971	$597	$654	$3,533	$3,870
	Cordell, H. K. & Bergstrom, J. C. 1993	$158	$2,916	$262	$4,836
	Croke, K., et al. 1986	$595	$651	$1,302	$1,425
	Gibbons, D.C. 1986	$738	$2,850	$1,615	$6,236
	Loomis, J.B. 2002	$12,812	$22,674	$17,060	$30,192
	Mathews, L.G. et al. 2002	$14,980	$14,980	$19,947	$19,947
	Mullen, J.K. & Menz, F.C. 1985	$306	$439	$682	$978
	Ribaudo, M. & Epp, D.J. 1984	$971	$971	$2,242	$2,242
	Sanders, L.D. et al. 1990	$2,644	$2,644	$4,851	$4,851
	Shafer, E.L. et al. 1993	$4,687	$17,903	$7,773	$29,690
	Ward, F.A. et al. 1993	$4,753	$4,753	$7,882	$7,882
	Wu, J. & Skelton-Groth, K. 2002	$142	$3,081	$189	$4,103
Marine	Costanza, R., et al. 1997	$1	$17,812	$1	$26,585
	Kahn, J. R. & Buerger, R. B. 1994	$11	$750	$18	$1,214
	Nunes, P. & Van den Bergh, J. 2004	$109	$109	$138	$138
	Soderqvist, T.& Scharin, H. 2000	$69	$114	$96	$159
Shrub	Bennett, R., et. al. 1995	$286	$286	$450	$450
	Costanza, R., et al. 1997	$1	$1,347	$1	$2,010
	Kenyon, W. & Nevin, C. 2001	$576	$576	$779	$779
	Willis, K.G. 1991	$11	$219	$19	$386
Wetland	Costanza, R., et al. 1997	$2,126	$2,843	$3,173	$4,243
	Doss, C. R. & Taff, S. J. 1996	$4,400	$5,325	$6,718	$8,130
	Hayes, K. M., et al. 1992	$1,396	$3,684	$2,386	$6,297
	Jenkins, W.A. et al. 2010	$583	$583	$641	$641
	Lant, C. L. & Tobin, G. 1989	$202	$2,225	$391	$4,304
	Leschine, T.M. et al. 1997	$1,723	$7,867	$2,572	$11,742
	Olewiler, N. 2004	$325	$912	$412	$1,157
	van Vuuren, W. & Roy, P. 1993	$1,440	$1,440	$2,388	$2,388
	Whitehead, J.C. 1990	$1,098	$2,418	$2,015	$4,437
	Whitehead, J.C. et al. 2009	$254	$254	$284	$284

APPENDIX D. ECOSYSTEM SERVICES VALUES BY SERVICE TYPE AND LAND COVER

Table D-1. Aquatic Habitats Ecosystem Services Provision ($2015)

	Beaches		Estuaries		Rivers/Lakes		Marine	
Service Provided	Min	Max	Min	Max	Min	Max	Min	Max
Provisioning								
Food			$27	$204			$772	$772
Raw Materials							$1	$1
Water Supply			$51	$643	$612	$15,413	$14	$117
Regulating								
Air Quality							$24	$24
Carbon Sequestration			$12	$87				
Natural Hazards Mitigation	$26	$323	$1,830	$1,830				
Pollination								
Soil Formation	$40	$28,705	$80	$12,789			$41	$18,325
Soil Retention								
Waste Treatment	$22,559	$22,559	$65	$20,929				
Water Regulation					$759	$2,932		
Societal/Cultural								
Aesthetic/Amenity	$496	$496	$277	$729	$84	$84		
Recreation and Tourism	$3,058	$53,905	$11	$438	$163	$23,327		
Supporting								
Habitat			$12	$2,643	$146	$3,170	$11	$21
Biodiversity/Genetic Resources								
Total Annual Value ($/acre/year)	**$26,178**	**$105,988**	**$2,364**	**$40,293**	**$1,764**	**$44,926**	**$863**	**$19,259**
Carbon Storage ($/acre)*			$1,166	$7,184				

Table D-2. Terrestrial Habitats Ecosystem Servcies Provision ($2015)

	Forests		Grasslands		Shrub	
Service Provided	Min	Max	Min	Max	Min	Max
Provisioning						
Food						
Raw Materials						
Water Supply	$17	$1,945				
Regulating						
Air Quality	$171	$171				
Carbon Sequestration	$11	$502				
Natural Hazards Mitigation	$47	$701	$26	$4,270		
Pollination	$74	$438	$438	$438	$1	$7
Soil Formation						
Soil Retention			$40	$3,490		
Waste Treatment	$35	$295	$6,953	$6,953		
Water Regulation						
Societal/Cultural						
Aesthetic/Amenity	$4,495	$18,366	$262	$1,285	$14	$14
Cultural/Spiritual						
Recreation and Tourism	$28	$2,390			$11	$1,386
Supporting						
Habitat	$593	$593				
Biodiversity/Genetic Resources					$593	$593
Total Annual Value ($/acre/year)	**$5,471**	**$25,401**	**$7,719**	**$16,435**	**$619**	**$2,000**
Carbon Storage ($/acre)*			$255	$2,212		

Table D-3. Wetland Habitats Ecosystem Services Provision ($2015)

	Wetlands	
Service Provided	Min	Max
Provisioning		
Food	$365	$365
Raw Materials		
Water Supply	$208	$3,273
Regulating		
Air Quality		
Carbon Sequestration		
Natural Hazards Mitigation	$1,773	$8,094
Pollination		
Soil Formation		
Soil Retention		
Waste Treatment	$334	$5,856
Water Regulation		
Societal/Cultural		
Aesthetic/Amenity	$1,481	$5,478
Recreation and Tourism	$215	$11,147
Supporting		
Habitat		
Biodiversity/Genetic Resources		
Total Annual Value ($/acre/year)	**$4,377**	**$34,213**
Carbon Storage ($/acre)*		

Resource Dimensions

Economics | Community Solutions | Land Use | Natural Resources | Regulatory Support

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