# Chapter 2: Costs of Impacts from Cascadia Subduction Zone Earthquake at CEI Hub

January 2022

Prepared for:

Multnomah County Office of Sustainability

and City of Portland Bureau of Emergency Management

Prepared by:

ECONorthwest
ECONOMICS · FINANCE · PLANNING

Enduring Econometrics

# Chapter 2: Table of Contents

# 2-1 Introduction

## 2-1.1 Chapter Overview

Fuel releases from the CEI Hub because of a Cascadia Subduction Zone (CSZ) earthquake will impose substantial economic costs on the region. These costs accrue both as financial costs of responding to the spill, cleaning it up, and restoring the environment, as well non-market economic losses to individual welfare. This chapter builds upon the physical description of direct impacts from the CEI Hub discussed in the previous chapter by calculating the costs of both the immediate and downstream effects of the fuel releases. In addition to the costs of the direct physical effects of the releases, this chapter also describes the costs to the fuel market as well as the costs of cleanup and restoration activities.

## 2-1.2 Scenario Modeling and Uncertainty

There is inherent uncertainty associated with estimating the economic costs of CEI Hub fuel releases due to a CSZ earthquake. A key factor is the quantity of fuel released, which, as discussed in the prior chapter, is predicated by assumptions about the integrity of the tanks and underlying soils, as well as the magnitude of the earthquake. While the Columbia River Area Contingency Plan lays out a framework for a quick response to an oil spill, the CSZ's impacts to roads, bridges, and other infrastructure will impair response times and further affect how far the fuels will spread, particularly in the river.[1] Economic costs are also dependent on the ultimate fate of the fuels. If fuel releases catch fire, there will be additional impacts to property and air quality. However, burning could minimize the amount of fuel that is released into the ground and water and limiting habitat impacts. Additional uncertainty is inherent in the analysis due to the variation based on the environmental conditions of when the spill occurs (e.g., what time of year, the temperature, wind patterns, etc.).

Uncertainty also accrues from the fact that the CEI spill would co-occur with a major earthquake. The interaction of these incidents includes many physical unknowns. What is certain is that the earthquake will increase the difficult of responding to the spill of materials from CEI Hub. An earthquake is more likely to compound harms by delaying clean-up efforts, delaying efforts to re-open shipping, and reducing access to fuels exactly when they are needed for emergency generators and clean-up equipment.

For these reasons, this analysis does not present a single estimate of the costs of fuel releases. Instead, each section describes the specific assumptions and methodologies used to obtain any monetary cost estimates. The assumptions are based upon the best available information to

[1] USCG Sector Columbia River. (2020). *Columbia River Area Contingency Plan*. Available at: https://homeport.uscg.mil/Lists/Content/Attachments/60907/SCR%20ACP%202020-Signed%20LOP%20USCG.pdf. Accessed November 30, 2021.

model the most likely scenario of the magnitude and extent of the impact and corresponding costs. Not all impacts have monetary cost estimates. When possible, costs are described in per unit estimates to provide the information needed to scale the costs based on the magnitude of impacts to demonstrate how costs could change if impacts are more or less severe than modelled. Some impacts, such as impacts to cultural resources, are intentionally not monetized because monetization implies that such values are fungible – but because they are specific to place and history these values are generally not interchangeable with any other good or service.

The costs and damages calculated and described in this chapter are those that are attributable to the release of fuels from the CEI Hub. This distinction between what is attributable to the fuel releases and what is not is determined by establishing the baseline scenario and calculating damages that are in addition to that baseline. The baseline scenario is what would have occurred but for the CEI Hub fuel releases. In the case of CEI Hub fuel releases due to a CSZ earthquake, all damages caused by the earthquake are included in the baseline scenario, and therefore not included as costs and damages attributable to fuel releases from the CEI Hub.

# 2-2 Cost of Direct Impacts to People

The spill and any resulting fires have the potential to cause direct physical impacts to people working at or near the CEI Hub when the earthquake occurs.[2] This analysis estimates the costs of direct impacts to people by estimating mortality and morbidity rates from explosions and fires at other fuel storage locations. Section 1-6.2.1 of Chapter 1 details the specific scenarios that could result in between 0 to 7 people killed, and 2 to 80 people injured. These mortality and morbidity rates do not consider any delays in emergency response or earthquake-related confounding factors that could result in higher rates of death and injury. These values do not include any mortality and morbidity caused by fires or people other than on-site workers being harmed by the event.[3] The values also do not include instances of suicide or mental health, which have been seen after other oil spills.[4,5] For this reason these values should be considered minimum estimates of total direct costs to people.

The standard approach for valuing changes in risk of mortality is the value of a statistical life (VSL). This approach relies on labor market data to decouple the marginal change in pay for working in a profession with a higher risk of mortality. Extrapolating these marginal changes into the value of a whole life produces a single dollar value that is regularly used in economic analysis. The current VSL used by the Federal Government in benefit-cost analysis is $10.3 million.[6,7]

Estimates of injury (i.e., morbidity) are more difficult to discern than mortality because impacts can vary significantly by the type of harm incurred. The most appropriate equivalence to the injuries expected at the CEI Hub are workers compensation claims that include lost wages, medical expenses, and damages from pain and suffering. In 2016, the average worker's compensation payment was $24,900.[8]

---

[2] Other potential harms to people from impacts to air quality and water quality are discussed in later sections.

[3] Health effects from air quality are discussed in Section 2-7 of this Chapter.

[4] Hennessy-Fiske, M. (2010). "Suicide is called another casualty of BP oil spill". *The Los Angeles Times*. June 24. Available at: https://www.latimes.com/archives/la-xpm-2010-jun-24-la-na-oil-spill-grief-20100625-story.html

[5] Rung, A. L., Oral, E., Fontham, E., Harrington, D. J., Trapido, E. J., & Peters, E. S. (2019). The long-term effects of the Deepwater Horizon oil spill on women's depression and mental distress. *Disaster medicine and public health preparedness*, *13*(2), 183-190.

[6] U.S. Environmental Protection Agency. (2016). *Guidelines for Preparing Economic Analyses*.

[7] All dollar values are reported in October 2021 terms using the Bureau of Labor Statistics' Consumer Price Index for all Urban Consumers (CPI-U). https://www.bls.gov/cpi/. Accessed November 30, 2021.

[8] Martindale-Nolo Research. (2016). *2016 Worker's Compensation Trends*. Available at: https://www.lawyers.com/legal-info/workers-compensation/workers-compensation-settlements-awards/workers-compensation-settlements-and-awards-how-much-will-i-get-for-my-injury-or-illness.html

Applying these values to the estimates of mortality and morbidity due to fuel releases from the CEI Hub that cause explosions and fire produces estimates that range from $49,800 to $74.1 million, summarized in Table 1 below.

Table 1. Costs to People due to an Explosion from CEI Hub Fuel Releases

| | Low Rates of Mortality and Morbidity | High Rates of Mortality and Morbidity |
|---|---|---|
| Injury | $49,800 | $1,992,000 |
| Mortality | $0 | $72,100,000 |
| **Total** | **$49,800** | **$74,092,000** |

Source: Calculated by ECONorthwest

# 2-3 Cost of Impacts to Property

## 2-3.1 Impacts to Waterfront Properties

Environmental quality is a key component of the price of residential real estate. Impairments to environmental quality can lead to reductions in property values, however, the transient nature of oil spills means that price changes are normally more pronounced during the period of maximum uncertainty that occurs immediately following an incident. [9] The measured drops in price for river- or ocean-front properties from oil spills range between 0 and 16 percent reductions in property value, with the effects typically disappearing after cleanup.[10,11,12] Persistent drops in home values after a spill cleanup may be attributable to changes in perceived risk of future spills.[13,14] This implies that for any risks of a spill about which homebuyers are already aware, the risk of a spill may be factored into property values. Changes in perceived risk that occur after a prominent spill may then result in more persistent declines in property values.

[9] Winkler, D. T., & Gordon, B. L. (2013). The effect of the BP Oil spill on volume and selling prices of oceanfront condominiums. *Land Economics*, *89*(4), 614-631.

[10] Cano-Urbina, J., Clapp, C. M., & Willardsen, K. (2019). The effects of the BP Deepwater Horizon oil spill on housing markets. *Journal of Housing Economics*, 43, 131-156.

[11] Simons, R. A. (1999). The effect of pipeline ruptures on noncontaminated residential easement-holding property in Fairfax County. *Appraisal Journal*, *67*, 255-263.

[12] Simons, R. A., Winson-Ceideman, K., & Brian, A. (2001). The Effects of an Oil Pipeline Rupture on Single-Family House Prices. *Appraisal Journal*, 410-418.

[13] Hansen, J. L., Benson, E. D., & Hagen, D. A. (2006). Environmental hazards and residential property values: Evidence from a major pipeline event. *Land Economics*, *82*(4), 529-541.

[14] Roddewig, R. J., Brigden, C. T., & Baxendale, A. S. (2018). A pipeline spill revisited: how long do impacts on home prices last?. *The Appraisal Journal*, 86(1), 23-47.

Home values along the southern gulf coast dropped between 4 and 8 percent following the Deepwater Horizon oil spill in 2010, with effects lasting until 2015.[15] Earlier peer-reviewed work found a reduction in home values between $21-$28 per square foot, or 10.1 to 13.5 percent of sale prices, in gulf coast condominiums in Alabama in the 100 days following the same spill, while another study found only an 8.8 percent drop in prices during the summer months prior to the capping of the spill and no net price change following the capping.[16]

Other studies have examined the effect of spills on non-coastal properties. A 2001 study found a 10 percent drop in value of homes with property rights adjacent to the Patuxent River in Maryland following a major spill in April 2000.[17] This work was later expanded in 2018 to show that the negative effects on property values were not persistent, and no price difference was found for affected properties after 18 months following the incident.[18] Following a 1993 rupture of the Colonial Pipeline in Fairfax County, Virginia, homes within 2 miles of the pipeline decreased in value by up to 5.5 percent.[19] There was also a strong negative relationship found between home prices and proximity to the Olympic Pipeline in northwest Washington in the five years following a major rupture in 1999.[20]

#### 2-3.1.1 Potential Property Value Impacts

Downstream riverfront properties between the I-405 and Longview bridges on the Columbia River, as well as properties on the Willamette River, Multnomah Channel, and Scappoose Bay could experience declines in real property value due to CEI Hub fuel releases. Applying a range of estimates from the empirical literature produces impacts that range from $11.7 to $35.4 million, summarized in Table 2.

Table 2. Estimated Residential Property Value Losses for Columbia Riverfront Properties

| Loss Scenario | Clark | Multnomah | Cowlitz | Columbia | Total |
|---|---|---|---|---|---|
| 4% | $1,489,000 | $7,644,000 | $1,253,000 | $1,408,000 | **$11,793,000** |
| 6% | $2,047,000 | $10,511,000 | $1,722,000 | $1,936,000 | **$16,216,000** |
| 8% | $2,977,000 | $15,288,000 | $2,505,000 | $2,816,000 | **$23,587,000** |
| 10% | $3,722,000 | $19,110,000 | $3,132,000 | $3,520,000 | **$29,483,000** |
| 12% | $4,466,000 | $22,932,000 | $3,758,000 | $4,224,000 | **$35,380,000** |

[15] Cano-Urbina, J., Clapp, C. M., & Willardsen, K. (2019). The effects of the BP Deepwater Horizon oil spill on housing markets. *Journal of Housing Economics*, *43*, 131-156.

[16] Winkler, D. T., & Gordon, B. L. (2013). The effect of the BP Oil spill on volume and selling prices of oceanfront condominiums. *Land Economics*, *89*(4), 614-631.

[17] Simons, R. A., Winson-Ceideman, K., & Brian, A. (2001). The Effects of an Oil Pipeline Rupture on Single-Family House Prices. *Appraisal Journal*, 410-418.

[18] Roddewig, R. J., Brigden, C. T., & Baxendale, A. S. (2018). A pipeline spill revisited: how long do impacts on home prices last?. *The Appraisal Journal*, 86(1), 23-47.

[19] Simons, R. A. (1999). The effect of pipeline ruptures on noncontaminated residential easement-holding property in Fairfax County. *Appraisal Journal*, *67*, 255-263.

[20] Hansen, J. L., Benson, E. D., & Hagen, D. A. (2006). Environmental hazards and residential property values: Evidence from a major pipeline event. *Land Economics*, *82*(4), 529-541.

Source: ECONorthwest analysis of assessor data from Clark, Multnomah, Cowlitz, and Columbia counties.

These values exclude commercial, industrial, and agricultural properties. Given that negative price effects have also been seen in properties near, but not adjacent to, rivers, it is possible that additional properties could experience temporary property value declines. In addition, due to the complexity of clean-up following a CSZ earthquake it is possible that the effects will persist longer than the two years of expected effects. Impacts of oiling would also occur to houseboats in the Multnomah Channel. Property value impacts to these in-water homes would likely be larger than the literature values used to calculate the losses. Given these considerations, the property value impact values in Table 2 should be considered minimum values of property value impacts.

These effects are likely to persist for approximately two years following the spill event, and do not include any other property value declines as a result of the CSZ earthquake. Most of the impacts to property values (65 percent) are in Multnomah County while the remaining 35 percent is split relatively evenly across Clark, Cowlitz, and Columbia counties. Realized market losses would be experienced by property owners who choose to sell during the period of depressed values. Even if a homeowner chooses not to sell and their property values eventually rebound, they will experience a loss of ability to enjoy the riverfront amenity of their property or may feel their enjoyment of living there will diminish due to the fear of future spills.

Most of the riverfront properties in the area are commercial, industrial, and other non-residential properties (about $2.5 billion in total riverfront property value). Although these markets operate differently than residential markets, these properties could be subject to additional reductions in property value.

There are over 30 marinas or ports downstream of the CEI Hub but upstream of the Longview Bridge that would likely be oiled based on river transport from the spill site, particularly during higher winter river flow periods. There are over 4,000 boat slips on these properties and hundreds of floating houses. These in-river properties would experience direct oiling of their built property, in addition to oiling of the shoreline. We do not explicitly value the additional property damages from oiling, but acknowledge that it is a likely additional cost.

### 2-3.2 Impacts to Water Users

Downstream of the CEI Hub, the Columbia River is not a direct primary municipal water source. As such, there are not expected to be direct effects to water users from CEI Hub fuel releases. There are groundwater sources downstream of the CEI Hub that could have a hydrological connection with contaminated surface water. Because of these groundwater-surface water interactions, the groundwater supply may be contaminated in sites downstream from the spill. Heavy oils would post particular risks to groundwater resources as they are more likely to sink, infiltrate, and remain in the environment over time.

Due to the risk of contamination, it is likely that downstream groundwater sources would need to be tested for volatile organic compounds and other hazardous materials. For example, the Ranney collector wells that supply water to the City of St. Helens are adjacent to the Columbia River and would likely require testing to ensure the water is not contaminated with residual fuels. Groundwater testing costs approximately $380 per test.[21] Modern filtration systems should be able to remove any residual fuel materials. If water treatment systems fail to remove the fuel materials, then the costs of additional treatment methods would be in the millions of dollars.

Other permit holders for wastewater discharge and water intake could be affected, particularly those downstream of the spill. There are 153 permits for wastewater release into the Lower Columbia River for Oregon and 41 for Washington. For the duration of the cleanup period, these permit holders may be affected by not being allowed to discharge over this period.

[21] Melstrom, R. T., Reeling, C., Gupta, L., Miller, S. R., Zhang, Y., & Lupi, F. (2019). Economic damages from a worst-case oil spill in the Straits of Mackinac. *Journal of Great Lakes Research*, 45(6), 1130-1141.

# 2-4 Cost of Impacts to Navigation

Major oil spills often lead to closures of navigational shipping channels. The 2014 Texas City Y oil spill led to a five-day closure of the Houston Ship Channel, stranding nearly 100 vessels at the ports of Houston and Texas City.[22] Similarly, releases of fuel into the Willamette River, Multnomah Channel, or Columbia River would impact vessels that rely on these shipping channels for navigation when the channels are closed during the cleanup period. These vessels will incur costs due to increased expenses during the time of the delay. Additional operating expenses from delays include the costs of crew, maintenance and repair, and fuel costs.

The length of delays due to closure of the navigation channels depends on the length of cleanup. The most likely closure period is between three to seven days – but harm from the earthquake will complicate cleanup activities and could extend this timeframe further. This analysis provides estimates for one day and one week. The analysis uses the number of vessels that use navigation channels between the I-405 bridge on the Willamette River to the Longview Bridge located downstream on the Columbia River, as described in Section 1-6.3 in Chapter 1.

Vessel operating costs are based on hourly estimates from Nathan Associates (2012)[23] that are multiplied by 24 and inflated to 2021 dollars to obtain a daily closure cost on low, average, and high traffic days. Table 3 summarizes the average daily and weekly costs for the three types of volume days. A one-week closure of the navigation channel would result in operating costs of approximately $16.2 million during a period of average vessel traffic.

Table 3. Average Daily Vessel Operating Costs in Area of Analysis (2021 Dollars)

| Vessel Traffic | Count of Vessels | Average Daily Operating Cost | Average Weekly Operating Cost |
|---|---|---|---|
| Low | 33 | $1,690,000 | $11,830,000 |
| Average | 42 | $2,315,000 | $16,205,000 |
| High | 47 | $2,552,000 | $17,864,000 |

Source: Calculated by ECONorthwest
Note: Values have been rounded to the thousands.

[22] ESI Inc. (2014). Case Study – Houston Ship Channel Oil Spill. Available at: http://www.green-marine.org/wp-content/uploads/2014/06/ESI-Case-Study-Houston-Shipping-Channel-Oil-Spill-V-1.01.pdf. Accessed November 30, 2021.

[23] Nathan Associates Inc. (2012). *Economic Analysis of North Atlantic Right Whale Ship Strike Reduction Rule*. Prepared for the National Oceanic & Atmospheric Administration. December.

# 2-5 Costs of Impacts to Commercial Fisheries

Fuel releases into the Willamette River from the CEI Hub have the potential to cause harm to aquatic species (see Section 1-6.6.1 in Chapter 1 for information about how species can be harmed by fuel releases). Many aquatic species in Oregon are sources of economic value because they contribute to commercial enterprises or contribute value to tribal and subsistence fisheries.[24]

Coastal commercial fisheries in Oregon have an annual harvest value of $153.8 million (2017 dollars, excluding distant water fisheries).[25] Washington commercial fisheries generate approximately $65.1 million in sales (2006 dollars).[26] This economic activity supports personal income for employees and owners who patriciate in harvest, as well as wholesalers, processors, and the many other supply chain operations that rely on catch from coastal waters. The Port of Astoria at the mouth of the Columbia River alone supports $209 million in annual economic activity (i.e., output) from the direct and secondary effects of the commercial fishing industry.[27] Cowlitz County, which includes the Port of Longview on the Columbia River, had a commercial fishing value of $380,000 in 2006.[28] Commercial fishing in the Lower Columbia River is dominated by salmon fishing. The Lower Columbia River accounts for 1.8 percent of the commercial fisheries sales in Washington and had a value of $1.2 million in 2006.[29] There is limited commercial fishing in the Upper Columbia River, but the area does support recreational and tribal fishing. There is limited commercial fishing on the Willamette River. In addition to commercial harvest, fisheries in Oregon and Washington also support commercial charter fishing enterprises.

Tribal fisheries will be impacted in the same way as commercial fisheries. However, tribal fisheries could experience disproportionate adverse impacts because tribal fishing occurs in-river and is reliant on fish populations that are more likely to travel through the Lower Columbia River and be exposed to CEI Hub fuel releases. The residual contaminants from the CEI Hub failures could result in fishing advisories to limit consumption of aquatic species in

[24] Impacts of fuel releases to recreational fishing is discussed in Section 2-6, impacts to tribal fisheries are discussed in Section 2-10.

[25] ECONorthwest. (2019). *Economic Contributions of Oregon's Commercial Marine Fisheries*. Prepared for Oregon Department of Fish and Wildlife. October.

[26] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

[27] ECONorthwest. (2019). *Economic Contributions of Oregon's Commercial Marine Fisheries*. Prepared for Oregon Department of Fish and Wildlife. October.

[28] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

[29] TCW Economics. (2008). *Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State.* Prepared for Washington Department of Fish and Wildlife. December.

this area.[30] These advisories are more likely to apply to resident, non-anadromous fish species such as trout, carp, brown bullhead, bass, and walleye. These species are also sources of food for people who participate in subsistence fishing – including both tribal and non-tribal populations.

To the extent that fuel releases impact harvestable catch there will be declines in economic activity (e.g., the income for operators and employees, number of jobs supported through direct and secondary effects, and contribution to economic value added in Oregon) and value for tribal and subsistence fisheries. The impact on commercial fisheries and charter operations will be proportional to any increases in the difficulty of catch. The Lower Columbia River commercial fisheries are the most likely to experience loss of revenue caused by declines in salmon populations because they are reliant on Columbia River Basin species. At-sea and coastal off-shore commercial fisheries have access to a range of species from other river basins.

If releases of fuel from the CEI Hub cause less reproduction of certain anadromous fish species during the spawning season that could reduce the population of the species in later years when they would have otherwise been available to be commercially harvested. Fish populations are also likely to be impacted by sedimentation from the earthquake and experience additional stresses that could harm survival and reproduction in the aftermath of the event.

[30] There are currently fishing advisories for resident fish populations in the Lower Willamette River due to high concentrations of PCBs.

# 2-6 Cost of Impacts to Recreation

Recreation could be impacted by fuel releases from the CEI Hub due to contamination of water resources as well as any harm caused by fires ignited by the fuel releases. As discussed in Section 1-6.4 of Chapter 1, fishing, hunting, swimming, and boating are the most likely to be affected due to fuel releases. The impact to recreation will be closures initially until cleanup is complete, followed by water quality advisories and fish consumption advisories.

The cost to recreation is the value of the cancelled trips that cannot occur because of the fuel releases. The effects of the earthquake will also impact recreation because of harm to infrastructure like roads, docks, boat ramps, parking lots, as well as hazard trees. The lingering effects of fuel releases could lead to additional fish consumption and swimming advisories due to residual toxins in the water. Long-term impacts to recreation due to CEI Hub fuel releases would also occur if a fire damages recreational sites – particularly Forest Park because burned trees would take decades to replace with regrowth.

Recreational use associated with public goods is a source of two distinct types of economic value. The first, known as 'consumer surplus' accrues to recreators and is a measure of the difference between an individual's willingness to pay to engage in outdoor recreation, and the amount they actually have to pay. Because many types of outdoor recreation do not have access fees that are competitively priced, these consumer surplus values can be substantial. Past empirical research has estimated an average consumer surplus value for motorized boating of $68.14 per person per day. If the river is closed or contaminated as a result of releases from the CEI Hub, recreational boaters would do something else, and this value represents the loss to the participant that would be incurred from being unable to engage in their preferred activity.

Table 4. Per Person per Day Consumer Surplus Values by Activity Type (2021 Dollars)

| Activity | Consumer Surplus Value |
|---|---:|
| Fishing | $83.50 |
| Hiking | $98.60 |
| Hunting | $90.37 |
| Motorized boating | $68.14 |
| Nature related | $70.20 |
| Nonmotorized boating | $127.17 |
| **Average** | **$80.13** |

Source: Rosenberger, R. S., White, E. M., Kline, J. D., & Cvitanovich, C. (2017). Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW-GTR-957. US Department of Agriculture, Forest Service, Pacific Northwest Research Station. Table 3.
Note: Inflated to 2021 dollars using the CPI Inflation Calculator. Values are for Forest Service Region 6: Pacific Northwest.

The second type of economic value that accrues from recreation is the economic activity that occurs. Recreators spend money on food, gasoline, lodging (if overnight), equipment purchases, and entry fees. During a spill, this economic activity would not accrue to these businesses. Average per trip expenditures are summarized in Table 5. These values represent the per trip spending that could be lost if trips do not occur due to fuel releases from the CEI Hub. This spending supports economic activity by supporting owners and workers where the spending occurs and through supply chain effects. As an example of the magnitude of the importance of recreational spending, in 2019 the recreational fishing industry for the Lower Columbia River supported a total of $7.29 million in economic contributions to Oregon.[31,32]

Table 5. Per Trip Expenditures by Activity Type (2021 Dollars)

| Activity | Per Trip Expenditures |
|---|---|
| Fishing | $195.74 |
| Hunting | $386.95 |
| Shellfishing | $478.49 |
| Wildlife Viewing | $97.89 |

Source: Dean Runyan. (2009). *Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon, 2008*. Prepared for Oregon Department of Fish and Wildlife and Travel Oregon.
Note: Inflated to 2021 dollars using the CPI Inflation Calculator.

The impacts on fuel releases from the CEI Hub will be impacted by the damage caused by the earthquake to other infrastructure. In the short-term (days to weeks after the event) recreation will be limited due to access and potential contaminants from other sources. Fishing advisories after the event are most likely to cause long term impacts that are specific to CEI Hub fuel releases. A one-month closure of the Lower Columbia River and Lower Willamette River for salmonid fishing would result in a loss of consumer surplus of $3.4 million and a loss of $3.2 million in direct trip spending (2021 dollars), based on the number of anglers for 2020. These values do not account for any substitute trips to other sites or any additional fishery closures beyond the salmonid values provided in the recreational data (see Table 14 in Section 1-6.4.1 of Chapter 1). These values also do not account for non-fishing boating trips that could also be lost due to recreational access closures, or any other type of impacted recreation, such as closures due to fire damage.

[31] The Research Group, LLC. (2021). *Oregon Commercial and Recreational Fishing Industry Economic Activity Coastwide and in Proximity to Marine Reserve Sites for Years 2018 and 2019*. Prepared for Oregon Department of Fish and Wildlife, Marine Reserve Program and Marine Resource Program. June.

[32] The Lower Columbia River is defined as downstream of Bonneville Dam to the mouth of the Columbia River.

# 2-7 Cost of Impacts to Human Health

Regardless of whether the fuel released from the CEI Hub would volatilize or burn, there are potential substantial acute air quality impacts to nearby residents, workers, and first responders. These air quality impacts present themselves as health effects, and due to the substantial volume of fuel spill, may be unavoidable.

## 2-7.1 Deepwater Horizon Health Costs

For people in the immediate area of fuel releases the primary risk is death or injury from explosions and fires. These potential harms are discussed in Section 2-2. Health impacts to people in the immediate area can also accrue from exposure to petrochemical fumes, both from vapor as well as fire plumes. The immediate area is the area where the fumes are located with the highest density during and immediately after the fuel releases. Workers and first responders are most at-risk to health effects from exposure in this area.

The Deepwater Horizon Oil Spill incident provides an example of health costs that can arise from large fuel spills. The Deepwater Horizon incident exposed response workers, volunteers, and residents to hazardous chemicals in the form of burning crude oil and from the clean-up chemicals, including Corexit oil dispersant. Many of the response workers were people who lived and work in the area, including fishermen who were valuable to use for their boats and labor.

The Gulf Long-term Follow-up Study (GuLFSTUDY) is a study overseen by the National Institute of Environmental Health Sciences to study the health of individuals who helped with the oil spill response and clean-up, took training, signed up to work, or were sent to the Gulf to help in some way after the Deepwater Horizon disaster.[33] A study of medical records for responses workers seven years after the event found that people involved in the oil spill cleanup operations still experience persistent alterations or worsening of their hematological, hepatic, pulmonary, and cardiac functions.[34]

In January 2013, a settlement was approved to compensate workers and residents for health effects from the oil spill. The medical settlement was included in the $7.8 billion settlement for all private claims.[35] Not all people are allowed to file medical claims under this settlement agreement – people must have been either a "clean-up worker" or "resident" for at least 60 days during the timeframe of the spill and response. People who experienced acute conditions were eligible for a lump-sum payment amount of $1,300 for response workers and $900 for residents.

---

[33] More information about the GuLFSTUDY is available at: https://gulfstudy.nih.gov/en/index.html

[34] D'Andrea, M. A., & Reddy, G. K. (2018). The development of long-term adverse health effects in oil spill cleanup workers of the Deepwater Horizon offshore drilling rig disaster. *Frontiers in Public Health*, 6, 117.

[35] NOAA, *Deepwater Horizon oil spill settlements: Where the money went*, Available at: https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

As of 2019, BP has paid $67 million toward medical claims and has funded an additional $105 million effort to operate community-based health programs along the Gulf Coast.[36] There are report of lump-sum values not being sufficient, difficultly navigating the process to submit medical claims, long timeframes to receive compensation, and difficultly obtaining compensation for chronic injuries among claimants. For these reasons, the $172 million is not the full health costs of the Deepwater Horizon Oil Spill incident, but rather only the amount that was compensated out of much larger costs to human health. Despite the many, ongoing efforts to study health effects, there is no estimate of the total costs to human health from Deepwater Horizon.

### 2-7.2 Health Risks from Exposure to Toxins

Acute exposure to high levels of airborne gasoline chemicals has been shown to cause adverse respiratory, cardiovascular, and hematological outcomes. Respiratory illnesses have been observed in animals subject to prolonged exposure to concentrations of only 100 ppm over twelve weeks.[37] Cardiovascular and neurological issues have also been observed after prolonged exposure in animals and humans. Symptoms such as headaches, dizziness, eye irritation, breathing difficulties, and nausea can occur from acute gasoline exposure. Chemical pneumonia also is one of the primary risks of exposure to very high concentrations. A 2019 review of 26 studies on the effect of gasoline exposure on pulmonary function found a significant negative relationship between lung function and length of chemical exposure.[38] As demonstrated in the follow up studies from the Deepwater Horizon incident, long-term health effects for clean-up workers and nearby residents include disorders and diseases of the blood, liver, and heart.[39]

In addition to physical health effects there are also mental health costs of oil spills. The most common mental health symptoms of large oil spill events are depression, anxiety, and post-traumatic stress disorder (PTSD).[40] Other mental health effects can include stress, suicide, domestic violence, and substance abuse.[41] There is also evidence of inequities in how mental

---

[36] Sneath, S. (2019). "8 years after BP oil spill, thousands of medical claims still not paid". *NOLA*. Available at: https://www.nola.com/news/environment/article_50997394-26d7-50c2-9a64-1a7d1eec1d45.html

[37] U.S. Department of Health and Human Services. (1995). *Toxicological Profile for Gasoline*. Atlanta, GA: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp72.pdf.

[38] Moghadam, S. R., Afshari, M., Moosazadeh, M., Khanjani, N., & Ganjali, A. (2019). *The effect of occupational exposure to petrol on pulmonary function parameters: a review and meta-analysis.* Reviews on environmental health, 34(4), 377-390.

[39] D'Andrea, M. A., & Reddy, G. K. (2018). The development of long-term adverse health effects in oil spill cleanup workers of the Deepwater Horizon offshore drilling rig disaster. *Frontiers in Public Health*, 6, 117.

[40] Weir, K. (2012). "Class Act: The Oil Spill's Reverberations". *American Phycological Association*. Available at: https://www.apa.org/gradpsych/2012/03/oil-spill

[41] MDB Inc. (2013). *Mental Health Following the Deepwater Horizon Oil Spill.* Prepared for the National Institute of Environmental Health Sciences. December.

health is experienced - lower income individuals are more likely to report a higher level of overall distress.[42]

In addition to acute health risks from exposure, there is also a risk of fatality in the immediate zones surrounding the potential fire location. Fatalities have occurred from inhalation of gasoline vapor at very high concentrations, above 5,000 ppm.[43]

## 2-7.3 Health Costs from Hazardous Air Quality

Airborne pollutants from CEI Hub fuel releases and fuel ignition are likely to lead to adverse health outcomes for the areas with high levels of immediate acute exposure to gasoline chemicals and the broader area of lower levels of particulate matter exposure. Exposure to particulate matter can cause a range of acute health impacts, which include non-fatal heart attacks, hospital admissions, emergency department visits, bronchitis, respiratory symptoms, asthma exacerbation, lost workdays, and minor restricted activity days.[44]

Each of these health impacts cause increases in health care costs, as well as decreases in welfare for the individuals affected. The EPA uses both components when evaluating the economic benefits and costs of air quality regulations. The economic cost per case for each ailment is summarized in Table 6. Column two of the table shows the derived rates of incidence of exposure to $PM_{2.5}$ levels for 4,000 tons of airborne gasoline chemicals based on scenario modelling for a fuel spill incident in California. Assuming a similar release of particulate matter from the CEI Hub spill (likely a conservative assumption, given that the magnitude of oil spilled would likely exceed 4,000 tons of airborne gasoline chemicals), the health costs to the population affected by exposure to the airborne gasoline would be approximately $8.9 million based on exposure to all populations in Multnomah and Clark Counties. Additional long-term outcomes that could lead to more severe chronic health outcomes or mortality are possible but not quantified. As such, this estimated health cost should be taken as a lower bound estimate.

Table 6. Costs from Acute Exposure to Air Pollution from Oil Spill

| Health Effect | Cost per Case | Cases per 1,000 Exposures | Cost of Exposure in Multnomah and Clark Counties |
|---|---|---|---|
| Non-Fatal Heart Attacks | $157,540 | 0.02 | $4,969,000 |
| Hospital Admissions-Respiratory (all ages) | $37,366 | 0.01 | $165,000 |
| Hospital Admissions-Cardiovascular (over age 18) | $51,868 | 0.01 | $578,000 |
| Emergency department visits for asthma (all ages) | $596 | 0.01 | $9,000 |

[42] Drescher, C. F., Schulenberg, S. E., & Smith, C. V. (2014). The Deepwater Horizon Oil Spill and the Mississippi Gulf Coast: Mental health in the context of a technological disaster. *American Journal of Orthopsychiatry*, 84(2), 142.

[43] U.S. Department of Health and Human Services. (1995). *Toxicological Profile for Gasoline*. Atlanta, GA: Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp72.pdf.

[44] U.S. Environmental Protection Agency [U.S. EPA]. (2012). *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter.* EPA-452/R-12-005.

| Health Effect | Cost per Case | Cases per 1,000 Exposures | Cost of Exposure in Multnomah and Clark Counties |
|---|---|---|---|
| Acute bronchitis (age 8-12) | $661 | 0.05 | $38,000 |
| Lower respiratory symptoms (age 7-14) | $30 | 0.67 | $23,000 |
| Upper respiratory symptoms (asthmatics age 9-11) | $46 | 0.97 | $53,000 |
| Asthma exacerbation (asthmatics ages 6-18) | $79 | 2.42 | $210,000 |
| Lost workdays (ages 18-65) | $212 | 4.30 | $333,000 |
| Minor restricted-activity days (ages 18-65) | $95 | 25.43 | $2,520,000 |
| **Total Avoided Morbidity Benefit** | | | **$8,898,000** |

Source: Created by ECONorthwest using data from U.S. Environmental Protection Agency. (2012). *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter*. Available at: https://www3.epa.gov/ttnecas1/regdata/RIAs/finalria.pdf. Tables 5-18, 5-19 and 5-20.
Note: Values have been inflated to 2021 dollars using the BLS CPI-U. Level of exposure relates to a reduction of 4,000 tons of $PM_{2.5}$ in a seven-county area of California.

Estimating both acute and chronic medical costs can be done by taking a proportional value based on the Deepwater Horizon settlement claims. This is an imperfect and likely lower bound estimate because it is based on the environmental conditions and clean up that occurred in Deepwater Horizon, which was an event at-sea, rather than in a large urban metropolitan area. As discussed above, the values are for medical claims, rather than medical costs. For these reasons the estimates are likely a lower-bound value and actual health costs would be higher. Based on a value of $1.28 per gallon from Deepwater Horizon (including $105 million for community-based health programs) the total compensated costs for acute and chronic conditions would be between $121 million to $248 million, depending on the extent of fuel releases.

Table 7. Compensated Health Costs of CEI Hub Fuel Releases, Deepwater Horizon Transfer Method

| | Gallons Released | Cost |
|---|---|---|
| Low | 94,634,005 | $121,470,514 |
| High | 193,687,251 | $248,613,486 |

Source: Created by ECONorthwest

## 2-7.4 Evacuation Costs

The air and water pollutant hazards and fire risk or possibility of active fires would trigger emergency evacuations in affected areas surrounding the CEI Hub. Based on the modeling of air pollutant dispersal (and depending on the weather and wind conditions during the spill), the areas likely facing toxic levels of pollutants would be immediately surrounding the tanks in the Linnton neighborhood, as well as the neighborhoods west and east of the St. John's Bridge (portions of the St. Johns, University Park, Cathedral Park and Portsmouth neighborhoods). If all census tracts areas within the outer extent of the air plume shown in the map are evacuated, this means a population of about 89,500 people will need to evacuate either to emergency shelter, friends and family, outside lodging, or other locations. Additional evacuations could occur as a precautionary measure. The harm to transportation infrastructure could increase the costs of evocations or make evacuations infeasible, which would increase health costs.

Costs accrue through a combination of providing emergency services, temporary lodging, gas, food, and other essentials. Other costs include those associated with missed work or additional physical or emotional health consequences. A 2003 study on the costs of a 1998 hurricane in North Carolina found that the direct costs to evacuees ranged from $81 for households who moved to shelters and $418 for residents who stayed in a hotel.[45] Although the length of stays away from home varied across survey respondents, the average length of time was 5 days.

Table 8: Evacuation Costs Per Household from Hurricane Bonnie

| Expenditure | Hotel | Friends/Family | Shelter | Other |
|---|---|---|---|---|
| Lodging | $247 | $0 | $0 | $0 |
| Food | $143 | $95 | $70 | $26 |
| Entertainment | $19 | $1 | $4 | $0 |
| Other | $8 | $35 | $7 | $3 |
| Total Direct Costs | $418 | $131 | $81 | $30 |
| Percent of Cases | 16% | 6% | 70% | 9% |

Source: Whitehead, J. C. (2003). One million dollars per mile? The opportunity costs of hurricane evacuation. *Ocean & coastal management*, 46(11-12), 1069-1083. Inflated to 2021 dollars using consumer price index data from the US Bureau of Labor Statistics.

Applying the costs breakdown from Table 6 to the 89,500 number of potentially evacuated residents (35,800 households) results in an estimated total cost of $4.7 million in private costs borne by evacuees. This excludes the cost of providing shelter and emergency services during the evacuation, in addition to time and travel costs to residents and the costs of missed work.

# 2-8 Cost of Impacts to Habitats and Species

When hazardous chemicals and oil spill into the environment, natural resource Trustees are authorized by several federal and state laws to assess and recover damages for injury to natural resources and their supporting habitats.[46] These laws have outlined a Natural Resource Damage Assessment (NRDA) process that identifies the extent of harm as well as the amount of compensation necessary to make the public whole. The NRDA process relies on well-established environmental and economic measurement techniques under a strict legal and regulatory framework to ultimately determine the monetary damages as a result of environmental harm. This section of this report describes the potential magnitude, extent, and

---

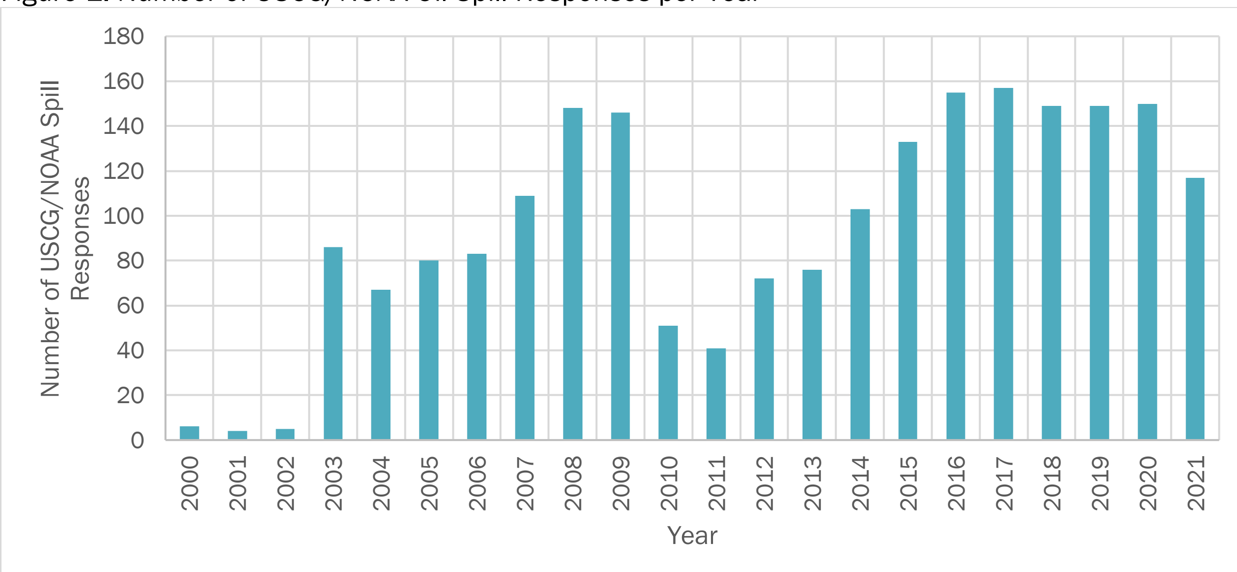
[45] Whitehead, J. C. (2003). One million dollars per mile? The opportunity costs of hurricane evacuation. *Ocean & coastal management*, 46(11-12), 1069-1083.

[46] Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 USC §9601, et seq. (CERCLA) and the Oil Pollution Act of 1990, 33 USC. §2701, et seq. (OPA).

duration of the environmental injury caused by a potential spill at the CEI Hub and the expected damages as determined by the NRDA process.

Unfortunately, oil spills in marine waters are not a particularly uncommon occurrence. Anytime there is a spill or potential spill in U.S. waters, the U.S. Coast Guard is notified and depending on the size of the spill, will engage NOAA's Emergency Response Division to provide emergency scientific support to aid in projecting the trajectory of the oil and identify potential resources at risk. From 2000 through 2021, NOAA's Emergency Response Division provided support for over 2,000 potential spills, with the last five years averaging approximately 150 incidents per year (Figure 1).[47]

Figure 1. Number of USCG/NOAA Oil Spill Responses per Year




Source: NOAA Office of Response and Restoration, Raw Incident Data. https://incidentnews.noaa.gov/raw/index. Accessed 11/17/21.

While this frequency of spills may seem discouraging from an environmental-quality perspective, it has resulted in a well-developed system for responding to and assessing oil spills in U.S. waters. Due to a combination of State and Federal statutes (including ORS 468 and the Oil Pollution Act of 1990), this same mechanism would be enacted following a spill at the CEI Hub. Following the release of oil into the environment, all NRDAs are structured to:

1. Evaluate the pathway by which the oil interacts with natural resources;
2. Measure the degree to which those resources are exposed to the oil;
3. Quantify the degree to which those resources are injured by the oil;
4. Identify a set of restoration projects that will adequately compensate the public; and

[47] NOAA Office of Response and Restoration, *Raw Incident Data*, available at: https://incidentnews.noaa.gov/raw/index.

5. Determine the damages as either the loss of value or the cost of restoration.

Most natural resources and ecosystems recover to their baseline state following an oil spill. This can be aided by cleaning up the contamination or implementing other techniques (i.e., primary restoration) to accelerate this recovery. However, even if an ecosystem fully recovers from a spill several years into the future, there is still a period of interim loss, during which the ecosystem was impaired because of the spill, and as a result, the public lost value. This interim loss can be addressed through compensatory restoration actions that "provide services of the same type and quality, and of comparable value as those injured."[48] For example, constructed or enhanced wetlands can serve as compensatory restoration for oiled wetlands. They can also serve as compensation for oiled birds by supplementing necessary habitats that may otherwise be regionally limited.

Determining the sufficient quantity of restoration is performed through one of several scaling techniques. When damages are determined via the cost of restoration that provides equivalent ecological services or resources, the appropriate amount of restoration is calculated using service-to-service or resource-to-resource methods.

When applied to habitats, techniques such as Habitat Equivalency Analysis (HEA) or the Habitat-Based Resource Equivalency Method (HaBREM) use metrics representing the set of ecological services or biological productivity flowing from a habitat (and their relative change as a percentage of total services provided) over time as inputs.[49] Using a fixed discount rate $r$, the present value stock of services, $S$, from a given habitat, $h$, is calculated as the integral of discounted service flows over time, $t$, multiplied by the spatial area, $A_h$, from which those services are generated.[50] This value, for a given habitat, is referred to as discounted service acre years ($DSAYs_h$) and is calculated as:

$$DSAYs_h = A_h \cdot \int_t^T e^{-rt} \cdot \left(S_{h,0}(t) - S_{h,1}(t)\right) dt$$

The HEA/HaBREM approach measures both the loss of ecological services caused by an injury as well as the gain in services from a given restoration project.

When applied to resources (e.g., fauna), the Resource Equivalency Analysis (REA) method functions in a similar framework to HEA/HaBREM; however, it now captures the flow of ecological services provided by an animal over its lifetime. For instance, the general set of ecological services provided by an animal for any year related in present value terms is a discounted-species-year, or $DSY$. These services are provided in a binary condition by the

[48] 15 CFR Part 990.53(c)(2)

[49] The HaBREM approach is a similar habitat-based assessment technique that can be applied to the measurement of ecological injury; however, the scaling metric applied is some objective measure of habitat productivity rather than the degree of ecological services provided. Additional discussion can be found in Baker et al. (2020).

[50] A description of the choice of the discount rate in HEA and REA can be found in Julius (1999).

existence of the animal, so marginal declines in services are not applied in a REA. *DSYs* for a given species are calculated:

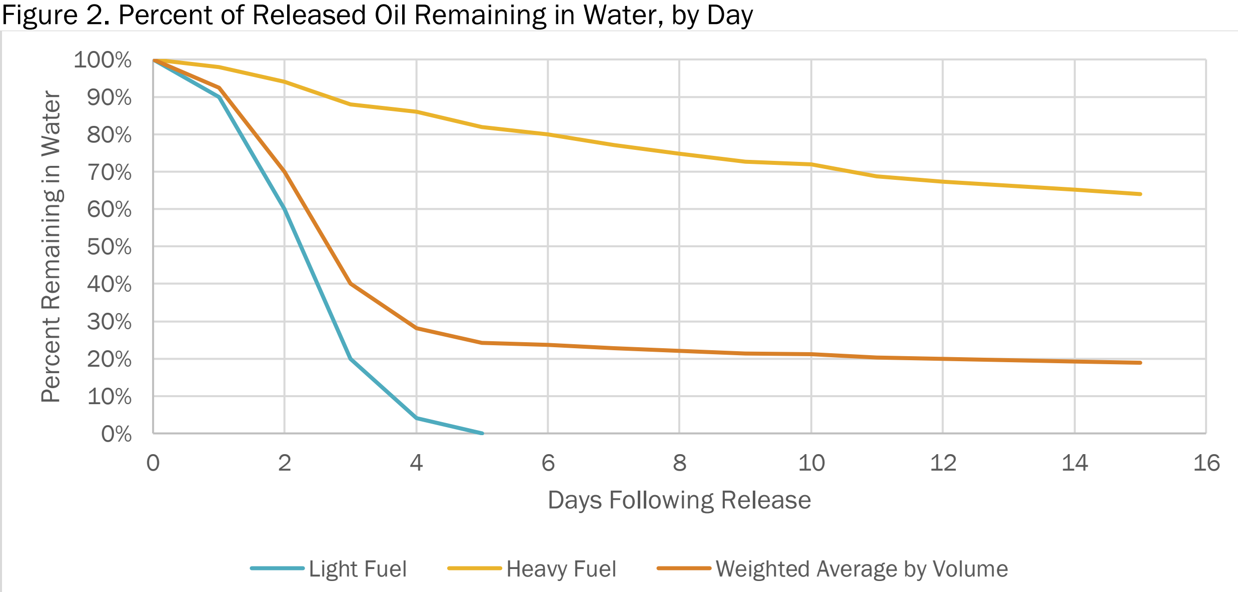
$$DSYs_a = \int_t^T e^{-rt} \cdot \left(Q_{a,0}(t) - Q_{a,1}(t)\right) dt$$

where $Q_a(t)$ is the quantity of animal-years in a given state. This approach can also incorporate information on the life history (e.g., survival and fecundity) of the species and incorporate population-level indirect measures of injury.

### 2-8.1 Release, Pathway, Exposure

As described in Section 1-4.2 of Chapter 1 of this report, oil released as a result of a failure at the CEI Hub will undergo both weathering and transport in the days following the spill. The degree of weathering – through dispersion or evaporation – is dependent on the type of oil, with lighter, more volatile fuels disappearing from the Willamette and Columbia Rivers more quickly than heavier fuels. While lighter fuels are more detrimental to air quality impacts, they are relatively less harmful in an aquatic environment. Figure 2 shows the percent of the oil that is expected to remain in the waters of the Willamette and Columbia Rivers, by day, following the release.

Figure 2. Percent of Released Oil Remaining in Water, by Day




Source: Enduring Econometrics

In a marine environment, oil spills tend to disperse across the surface of the water, with physical processes determining the ultimate thickness of the surface sheen and potential for accumulation on shorelines. In marine spills, oil sheens are generally categorized by thickness and visual characteristics, with "rainbow sheens" approximately less than 0.005 millimeters thick, "thin metallic-appearance films" between 0.005 and 0.08 millimeters thick, "emulsified oil" between 0.08 and 1 millimeters thick, and strands of "thick, emulsified oil" that are generally greater than 1 mm in thickness.[51]

A riverine environment is fundamentally different, particularly when a sufficient volume of oil is released into a constrained area, leading to an increased thickness of the surface sheen and greater shoreline oiling. Current estimates of the quantity of oil expected to reach the Willamette and Columbia rivers (between 40.7 and 82.5 million gallons) divided by the total surface area where the oil is expected to travel (~89,405 acres) indicates that the release from the CEI Hub is large enough to generate sheens of nearly continuous emulsified oil through the rivers, even when accounting for the seasonal effects of river flow and weathering (Table 9).

Table 9. Expected Thickness of Oil Sheen on the Willamette and Columbia Rivers

| Season | Low-Release Estimate | High-Release Estimate |
|---|---|---|
| **Winter** | 0.30 (emulsified oil) | 0.60 (emulsified oil) |
| **Summer** | 0.08 (emulsified oil) | 0.16 (emulsified oil) |

Source: Enduring Econometrics

## 2-8.2 Injury to Habitats

This comparatively thick oil sheen will travel down the Columbia and Willamette rivers and accumulate along shorelines and in the river (Table 10). These habitats are essential in the life history of many animals, with wetlands and benthic environments providing particularly productive ecological services.

Table 10. Acres, by Habitat Type, Potentially Affected by CEI-Hub Release

| Habitat Type | Acres |
|---|---|
| Wetlands | |
| Freshwater Emergent | 19,948 |
| Freshwater Forested/Shrub | 19,475 |
| Estuarine and Marine | 22,140 |
| In-Stream (Benthos) | |
| Freshwater Pond | 1,485 |
| Lake | 7,123 |
| Riverine | 26,099 |
| Estuarine and Marine Deepwater | 54,698 |

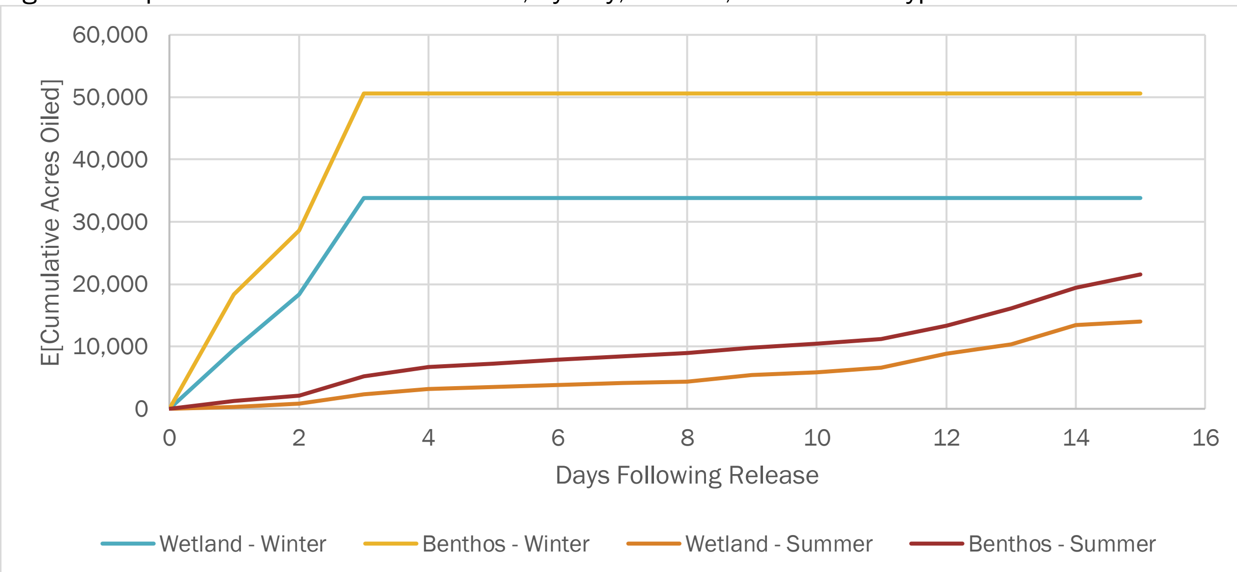
Source: Created by ECONorthwest using information from U.S. Fish and Wildlife Service, National Wetland Inventory mapper

The degree of oiling of these habitats is dependent on the fate and transport of the oil on the rivers, which, as described earlier, is dependent on the mix of oil released and the seasonal velocity of the rivers. In winter, higher river velocity will cause a larger density of oil to reach

[51] Svejkovsky, J., Hess, M., Muskat, J., Nedwed, T. J., McCall, J., & Garcia, O. (2016). Characterization of surface oil thickness distribution patterns observed during the Deepwater Horizon (MC-252) oil spill with aerial and satellite remote sensing. *Marine Pollution Bulletin*, *110*(1), 162-176.

habitats further downstream before natural weathering of the released oil can occur. The comparative acres oiled by day following the release by habitat type are displayed in Figure 3. Due to the higher river flows, a release from the CEI Hub in winter will lead to a larger expected number of acres of habitat oiled compared to a release in summer.

Figure 3. Expected Cumulative Acres Oiled, by Day, Season, and Habitat Type

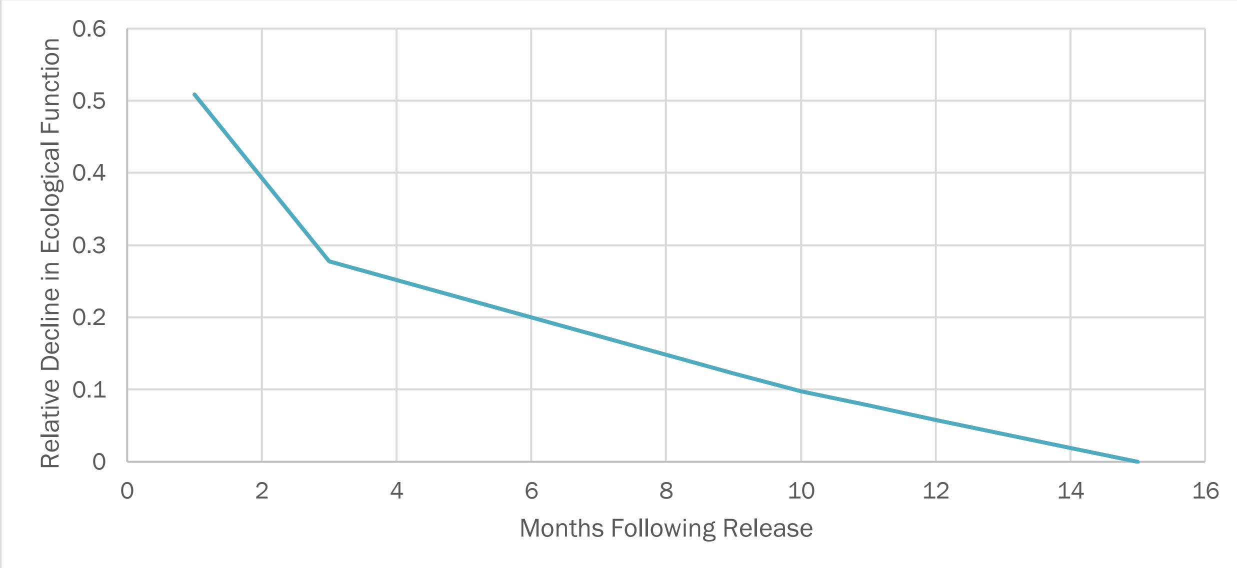



Source: Enduring Econometrics

After the oil accumulates in wetlands and along the river bottom, it causes both a physical injury and chemical injury to the ecological function of those habitats. Fortunately, these impairments are not permanent, and evaluations following other oil spills in estuarine environments found that the decline in function following an oil spill tends to resolve approximately 15 months following the release. While the initial injury can be profound (exceeding a 50 percent decline in ecological function) in the first months after a spill, as the oil weathers and moves around in a dynamic riverine environment, the initial injury slowly dissipates, and the habitats recover to a point where they eventually reach baseline conditions, as shown in Figure 4.[52] These effects can be exacerbated or mitigated by the initial baseline function of the habitat and other co-occurring anthropogenic stressors or cleanup activity.

[52] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

Figure 4. Recovery of Loss in Ecological Function of Wetland Habitat Following an Oil Spill




Source: NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

#### 2-8.2.1 Habitat Restoration as Compensation for Habitat Injury

The combination of the magnitude, extent, and duration of the injury to wetland and benthic habitats, applied to a HEA or HaBREM framework, provides a calculated value of either DSAYs or some other present value measure of lost ecological productivity. This value is then compared to the gains from potential restoration projects, measured using an equivalent or comparable metric. While wetlands and benthic habitats provide different types of ecological services, their relative productivity can be scaled to a single type of wetland restoration project. Specifically, an acre of wetland generally contributes 2.5 times as much productivity to ecological function as an acre of riverine benthic habitat.[53] Applying this scaling factor allows a single restoration type (constructed wetland) to compensate for both types of injured habitat.

Constructed wetland restoration generally takes areas that (prior to human involvement) were historically naturally occurring wetlands and reverts them to wetlands by improving the underlying hydrology and introducing native plant species. This can occur either through filling dredged river areas, removing levees or berms, or removing fill that had been used to elevate former wetlands. Following the construction of a wetland, it still takes several seasons (and up to 18 years) for the habitat to become fully colonized and begin producing ecological services of the same type and function as the habitat it was designed to replace.[54] These

---

[53] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

[54] Baker, M., Domanski, A., Hollweg, T., Murray, J., Lane, D., Skrabis, K., ... & DiPinto, L. (2020). Restoration scaling approaches to addressing ecological injury: the habitat-based resource equivalency method. *Environmental management*, 65(2), 161-177.

constructed habitats require extensive monitoring and adaptive management to ensure they become fully established.

These constructed habitats themselves, however, are not immune to the effects of climate change and sea-level rise and are generally expected to cease producing ecological benefits at some point in the future. The ecological service flows produced by the habitat from its construction to its eventual cessation of services can be similarly calculated in present value as a number of DSAYs or some other measure of productivity gained over time. Dividing the present value of ecological services or productivity lost as a result of the spill by the services or productivity gained from an acre of restoration determines the number of acres of restoration needed to fully compensate the public for the spill. Using a common set of injury and restoration metrics, a restoration project that is anticipated to be constructed five years following the spill, take 18 years to reach full function (per Baker et al., 2020) and produce compensatory ecological services for a total of thirty years, results in between 175 - 418 acres of constructed wetland necessary to compensate for the injury from the spill at the CEI Hub.

Table 11. Summary of Habitat Injury and Restoration Requirements from CEI Hub Spill

| | Wetland-Equivalent DSAYs Lost due to Injury | Wetland DSAYs Gained from an Acre of Restoration | Acres Wetland Needed |
|---|---|---|---|
| Winter | 4,505 | 10.8 | 418 |
| Summer | 1,885 | 10.8 | 175 |

Source: Enduring Econometrics

## 2-8.3 Injury to Resources

The oil released into the environment causes additional direct and indirect mortality to birds, fish, and mammals that utilize and rely on the Willamette and Columbia Rivers. While the habitat is necessary for their vitality, the direct injury to animals as a result of oiling is an additive component of an NRDA injury assessment. There are many species of birds, fish, and marine mammals that are particularly susceptible to injury from a spill at the CEI Hub. NOAA Environmental Sensitivity Index (ESI) data identify the species and numbers of animals that utilize the Willamette and Columbia Rivers by river mile and time of year.[55] Cleanup costs for rescue and rehabilitation of species are included in "Response and Cleanup Costs" in Section 2-9 of this Chapter.

### 2-8.3.1 Avian Injury

Many birds use the rivers downstream of the CEI Hub for foraging, nesting, and as a stopover during seasonal migration. Birds are generally cannot discern oil from water and often become coated in oil if it is in waterways. This oil causes both a physical and chemical injury to the birds, with some dying soon after exposure to oil. For other birds, the oil disrupts their ability to shed water from their plumage, impairing foraging behavior and leading to starvation and

[55] NOAA Office of Response and Restoration, *Environmental Sensitivity Index Maps and Data*, available at: https://response.restoration.noaa.gov/resources/environmental-sensitivity-index-esi-maps.

eventual death.[56] A common visual following oil spills is the extensive cleanup and rehabilitation of oiled birds; however, following their release, these birds still exhibit high rates of mortality and generally do not re-enter the breeding population.[57, 58, 59]

The expected avian injury from a spill at the CEI Hub is a function of both the degree of oiling, by river mile, and the seasonal population of birds. Table 12 below lists the potential population of birds exposed to oil by guild and river mile in summer, while Table 13 lists potential populations exposed in winter. The source of this data is the Environmental Sensitivity Index (ESI) classification system, which is environmental data designed and collected specifically to inform oil spill planning and response. ESI data characterize the marine and coastal environments and wildlife by their sensitivity to spilled oil.

---

[56] Burger, A. E. (1993). Estimating the mortality of seabirds following oil spills: effects of spill volume. *Marine pollution bulletin*, 26(3), 140-143.

[57] De La Cruz, S. E., Takekawa, J. Y., Spragens, K. A., Yee, J., Golightly, R. T., Massey, G., ... & Ziccardi, M. (2013). Post-release survival of surf scoters following an oil spill: an experimental approach to evaluating rehabilitation success. *Marine Pollution Bulletin*, 67(1-2), 100-106

[58] Anderson, D.W., F. Gress, and D.M. Fry. 1996. Survival and dispersal of oiled brown pelicans after rehabilitation and release. *Marine Pollution Bulletin*. 32(10): 711-718;

[59] Anderson, D.W., S.H. Newman, P.R. Kelly, S.K. Herzog, and K.P. Lewis. 2000. An experimental soft-release of oil-spill rehabilitated American coots (Fulica americana): I. Lingering effects on survival, condition and behavior. *Environmental Pollution.* 107: 285- 294.

Table 12. Potential Bird Populations Exposed to Oil by River Mile (Day), Summer

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Mile | 7.2 | 14.4 | 21.6 | 28.8 | 36 | 43.2 | 50.4 | 57.6 | 64.8 | 72 | 79.2 | 86.4 | 93.6 | 100 | 108 |
| Degree Oiling | 92% | 70% | 40% | 28% | 24% | 24% | 23% | 22% | 21% | 21% | 20% | 20% | 20% | 19% | 19% |
| **Population Potentially Exposed** | | | | | | | | | | | | | | | |
| Ducks | - | - | 1,000 | 1,300 | 1,000 | - | - | - | 300 | 20,250 | 40,000 | 6,000 | 1,000 | 1,000 | - |
| Gulls | - | - | - | - | - | - | - | - | - | - | 450 | 900 | - | 41,300 | - |
| Cormorants | - | - | - | - | - | - | - | - | - | - | - | - | 220 | 17,920 | 200 |
| Herons | - | - | - | 1,007 | - | - | - | 100 | 100 | 120 | 700 | - | - | - | - |
| Bald Eagle | 2 | 2 | 8 | 22 | - | 2 | 8 | 12 | - | 44 | 16 | 62 | 44 | 38 | 16 |

Source: NOAA ESI Maps and Data, Available at: https://www.fisheries.noaa.gov/inport/item/40258.

Table 13. Potential Bird Populations Exposed to Oil by River Mile (Day), Winter

| Day | 1 | 2 | 3 |
|---|---|---|---|
| River Mile | 36.0 | 72.0 | 108.0 |
| Degree Oiling | 92% | 70% | 40% |
| **Population Potentially Exposed** | | | |
| Ducks | 595,700 | 42,550 | 155,100 |
| Gulls | - | - | 22,850 |
| Cormorants | - | - | 18,340 |
| Herons | 1,007 | 320 | 700 |
| Shorebirds | 31,000 | - | 2,000 |
| Bald Eagle | 32 | 66 | 176 |
| Brown Pelican | - | - | 20,000 |
| Sandhill Crane | 4,575 | - | - |

Source: Enduring Econometrics

Applying measures of the percent mortality of birds, by oiling category, from past spills to expected oiled populations by season in the Willamette and Columbia Rivers produces estimates of the direct injury from a spill at the CEI Hub. A REA evaluation of the life-histories of these species produces a discounted present value indirect injury of both future fledgling mortality and decreased reproductive success.[60] The resulting direct and indirect injury to birds as a result of a spill at the CEI Hub is presented in Table 14 and Table 15 below. The greater extent of oiling and increased presence of birds in winter results in a greater injury.

Table 14. Expected Bird Injury, Summer

| | Ducks | Gulls | Cormorants | Herons | Bald Eagle |
|---|---|---|---|---|---|
| **Direct Injury** | 826 | 645 | 261 | 17 | 2 |
| **Discounted Lost Productivity - Mortality** | 1,621 | 929 | 519 | 24 | 3 |
| **Discounted Lost Productivity - Reproductive Failure** | 788 | 199 | 76 | 5 | - |

Source: Enduring Econometrics

Table 15. Expected Bird Injury, Winter

| | Ducks | Gulls | Cormorants | Herons | Shorebirds | Bald Eagle | Brown Pelican | Sandhill Crane |
|---|---|---|---|---|---|---|---|---|
| **Direct Injury** | 35,159 | 719 | 544 | 50 | 5,386 | 5 | 281 | 148 |
| **Discounted Lost Productivity - Mortality** | 68,981 | 1,035 | 1,081 | 70 | 7,737 | 7 | 393 | 207 |
| **Discounted Lost Productivity - Reproductive Failure** | 33,532 | 222 | 159 | 15 | - | - | - | - |

Source: Enduring Econometrics

[60] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

### 2-8.3.2 Habitat Restoration as Compensation for Avian Injury

Bird populations are often habitat or food limited, and appropriate habitat restoration can serve as direct compensation for an injury to bird populations. This approach relies on directly relating the biological productivity of habitats to specific bird species and making adjustments based on their ecological efficiency (ability to convert wetland biomass into bird biomass).[61] Values vary by bird guild based on their average weight, the type of food they eat (vegetation, insects, or fish), and the ability of an acre of wetland habitat to provide sufficient additional food to support additional birds. This approach is regularly used to calculate the additional acres of wetland needed to compensate for a bird injury and utilizes a standard set of REA criteria in measuring benefits across time as the injury.[62] The full set of inputs necessary are listed in Table 16 below and result in an additional restoration requirement of between 39 – 1,219 acres of constructed wetland, depending on the season of the spill.

[61] French McCay, D.P and Rowe, J.J. (2003). Habitat Restoration as Mitigation for Lost Production at Multiple Trophic Levels. *Marine Ecology Progress Series*. 264:233- 247.

[62] NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey.*

Table 16. Habitat Restoration Scaling for Bird Injury, by Guild

| | Ducks | Gulls | Cormorants | Herons | Shorebirds | Bald Eagle | Brown Pelican | Sandhill Crane |
|---|---|---|---|---|---|---|---|---|
| Average Wet Weight (kg) | | | | | | | | |
| Adult | 1.21 | 0.53 | 2.3 | 2.3 | 0.06 | 4.79 | 3.5 | 4.295 |
| Juvenile | 1.09 | 0.36 | 2.3 | 2.3 | 0.06 | 4.79 | 3.5 | 4.295 |
| Ecological Efficiency | 0.02 | 0.04 | 0.04 | 0.04 | 0.02 | 0.04 | 0.04 | 0.04 |
| Dry Weight to Wet Weight | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Dry Weight to AFDW | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Compensatory Production Required | | | | | | | | |
| Summer | 31,899 | 3,292 | 8,674 | 474 | - | 109 | - | - |
| Winter | 1,357,669 | 3,667 | 18,058 | 1,372 | 6,929 | 259 | 10,369 | 6,708 |
| Spartina Marsh Secondary Productivity | 1,153 | 1,153 | 1,153 | 1,153 | 1,153 | 1,153 | 1,153 | 1,153 |
| Compensatory Acres Marsh Required | | | | | | | | |
| Summer | 28 | 3 | 8 | 0 | - | 0 | - | - |
| Winter | 1,178 | 3 | 16 | 1 | 6 | 0 | 9 | 6 |

Source: NOAA, et al. (2009). *Final Restoration Plan and Environmental Assessment for the November 26, 2004, M/T Athos I Oil Spill on the Delaware River near the Citgo Refinery in Paulsboro, New Jersey*.; French McCay, D.P and J.J. Rowe. 2003. Habitat Restoration as Mitigation for Lost Production at Multiple Trophic Levels. Marine Ecology Progress Series. 264:233- 247.

### 2-8.4 Aquatic Injury and Restoration

The lower Columbia River is an important habitat for a number of fish, including several species whose populations are threatened or endangered. Anadromous fish types expected to be harmed by the spill include both juvenile and adult sockeye, fall and spring chinook, Coho, chum, and summer and winter steelhead. Other species with high utilization of the spill area include starry flounder and white sturgeon. Due to the life histories of many of these species, direct mortality from an oil spill can result in substantial population impacts for many subsequent generations. Particularly at risk are juvenile migrating fry and embryos, with studies following the Exxon Valdez spill finding that elevated egg mortality continued for at least four years after the spill.[63]

Existing anthropogenic stressors on wild populations of fish make quantifying a potential aquatic injury particularly complex. Existing habitat degradation, impairment due to hydropower dams, competition with hatchery fish, and ongoing harvest are known as the "four Hs" impeding the recovery of these threatened and endangered species.[64] A spill from the CEI Hub will exacerbate these dynamics and potentially lead to a greater injury than would otherwise be observed in a non-threatened population.

Table 17 summarizes the threatened and endangered species that are present in the Lower Columbia River. The summer months have the highest returning populations, but species return throughout the year – meaning fuel releases from the CEI Hub could impact reproduction for these species no matter when the event occurs.

Table 17. Threatened and Endangered Species Present in the Lower Columbia River

| Species | Federal Status | Freshwater Entry Period |
|---|---|---|
| Snake River Sockeye | Endangered | April to October |
| Snake River Chinook | Threatened | February to October |
| Lower Columbia River Chinook | Threatened | February to October |
| Upper Willamette River Chinook | Threatened | February to October |
| Upper Columbia River Chinook | Endangered | February to October |
| Columbia River chum salmon | Threatened | October to December |
| Upper Columbia River steelhead | Threatened | Year-round |
| Snake River Basin steelhead | Threatened | Year-round |
| Lower Columbia River steelhead | Threatened | Year-round |
| Upper Willamette River steelhead | Threatened | Year-round |

[63] Rice, S. D., Thomas, R. E., Carls, M. G., Heintz, R. A., Wertheimer, A. C., Murphy, M. L., ... & Moles, A. (2001). Impacts to pink salmon following the Exxon Valdez oil spill: persistence, toxicity, sensitivity, and controversy. *Reviews in Fisheries Science*, *9*(3), 165-211.

[64] Hoekstra, J. M., Bartz, K. K., Ruckelshaus, M. H., Moslemi, J. M., & Harms, T. K. (2007). Quantitative threat analysis for management of an imperiled species: Chinook salmon (Oncorhynchus tshawytscha). *Ecological Applications*, *17*(7), 2061-2073.

| Species | Federal Status | Freshwater Entry Period |
|---|---|---|
| Middle Columbia River steelhead | Threatened | Year-round |
| Pacific Eulachon/Smelt | Threatened | December to May |
| Bull Trout | Threatened | Not Anadromous |
| Pacific Lamprey | None (State Species of Concern) | Parasitic (varies by host) |

Source: Oregon Department of Fish and Wildlife, Threatened, Endangered, and Candidate Fish and Wildlife Species, available at: https://www.dfw.state.or.us/wildlife/diversity/species/threatened_endangered_candidate_list.asp

Early studies have estimated that the total cost of salmon recovery in the lower Columbia River is $1.6 billion (in 2021 dollars), yet only approximately 22 percent of these costs have been fully funded.[65,66] While an estimate of the restoration costs of an aquatic injury are complex and very scenario-dependent, they may require sufficient funding of upwards of $1.2 billion to minimally place fish in the lower Columbia River on a recovery trajectory, with a likelihood that the assessed restoration costs for just the impacts from the spill would be much lower. Surveys in Oregon and beyond suggest that households are willing to pay up to $179 per year for recovery of salmon populations (2019 dollars).[67]

In past spills in riverine environments, aquatic restoration amounted to 3 percent of the cost of habitat and bird restoration. These estimated based on prior spills suggests a habitat injury restoration cost of $580,000 to $4.5 million, with a median value of $2.5 million (Table 18). Fuel releases are less common in the Pacific Northwest, meaning that there are fewer empirical examples of the effect of large-scale fuel releases on native fish populations in this location. The actual costs are likely to be closer to the higher end of the range of the restoration costs due to the importance of aquatic species to the riverine ecosystems of the Columbia River and Willamette River.

Table 18. Estimated Aquatic Injury Habitat Restoration Costs

| Restoration | Total Cost | | Median Cost |
|---|---|---|---|
| | Summer | Winter | |
| Aquatic Injury (3% of habitat restoration) | $587,912 | $4,497,248 | $2,542,580 |

Source: Enduring Econometrics

[65] Dennis Canty, Funding for Salmon Recovery in Washington State, Evergreen Funding Consultants, Olympia WA, March 2011, p. 6, https://rco.wa.gov/wp-content/uploads/2019/07/GSRO-SalmonRecoveryFundingEvergreen-2011.pdf. Accessed on 11/29/21.

[66] Washington State RCO (2020). State of Salmon in Watersheds in 2020. https://stateofsalmon.wa.gov/statewide-data/funding/. Accessed on 11/29/21.

[67] Lewis, D.J., Dundas, S.J., Kling, D.M., Lew, D.K., and Hacker, S.D. 2019. The non-market benefits of early and partial gains in managing threatened salmon. *PLoS ONE* 14(8): e0220260. https://doi.org/10.1371/journal.pone.0220260

## 2-8.5 Marine Mammal Injury and Restoration

Many marine mammals spend time in the lower Columbia River, including summer populations of approximately 1,100 California sea lions and 90 Stellar sea lions; and a year-round population of harbor seals that exceeds 1,800 animals.[68] While adult marine mammals rarely exhibit direct mortality from oil spills, they do exhibit serious health effects that cause an increased risk of death from disease, as well as loss of reproductive success following exposure to oil. Following the Deepwater Horizon Oil Spill, dolphins living in areas with higher concentrations of oil were more likely to exhibit hypoadrenocorticism, moderate to severe lung disease, and higher rates of early fetal loss and late-term abortions.[69]

Conversely, however, many marine mammals in the lower Columbia River are considered a nuisance species due to their predation of threatened and endangered salmonids. The Endangered Salmon Prevention and Predation Act of 2018 amended the Marine Mammal Protection Act (MMPA) to allow the removal of up to 540 California sea lion and 176 Steller sea lions between 2020 and 2025.[70] This population control measure is a direct response to the already depleted salmon populations. Thus, following an oil spill, it is unlikely that restoration will be conducted to enhance marine mammal populations that are already considered to be at nuisance levels. However, the amendments to the MMPA do not authorize other types of mortality to sea lions in the Lower Columbia, and any mortality due to an oil spill would still be a compensable injury. One possibility for compensating for the unpermitted take of marine mammals could be supplemental funding for salmonid restoration.

## 2-8.6 Restoration Costs

Scaling approaches used allow all habitat and resource injuries to be compensated through additional wetland restoration. These restoration costs can vary wildly by the type of restoration action, the availability of suitable acreage, and regional cost differences. Recent projects in the lower Columbia River range from $31,500 to $151,600 per acre.[71,72] Large restoration projects performed as compensation for an oil spill would likely land at the upper end of this range due to the scarcity of available restoration sites and expansive monitoring and

[68] NOAA ESI Maps and Data. https://www.fisheries.noaa.gov/inport/item/40258. Accessed 11/19/21.

[69] Lane, S. M., Smith, C. R., Mitchell, J., Balmer, B. C., Barry, K. P., McDonald, T., ... & Schwacke, L. H. (2015). Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the Deepwater Horizon oil spill. Proceedings of the Royal Society B: Biological Sciences, 282(1818), 20151944.; Schwacke, L. H., Smith, C. R., Townsend, F. I., Wells, R. S., Hart, L. B., Balmer, B. C., ... & Rowles, T. K. (2014). Health of common bottlenose dolphins (Tursiops truncatus) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. Environmental science & technology, 48(1), 93-103.

[70] National Marine Fisheries Service (2020). https://www.fisheries.noaa.gov/feature-story/noaa-fisheries-authorizes-states-and-tribes-remove-sea-lions-preying-protected-fish. Accessed 11/19/21.

[71] NOAA Restoration Center Community-based Restoration Program (2006). "Ramsey Wetland Complex Off-channel Habitat Design and Restoration."

[72] Crest (2020). Otter Point Restoration and Enhancement Project. LCREP Grant #03-2011.

adaptive management requirements. The expected total costs for habitat restoration are $39.7 million should the spill occur in the summer, and $304.3 million if it occurs in the winter.

Table 19. Estimated Habitat Restoration Costs

| Restoration | Acres Required | | Average Cost per Acre | Total Cost | |
|---|---|---|---|---|---|
| | **Summer** | **Winter** | | **Summer** | **Winter** |
| Habitat Injury | 175 | 418 | $91,575 | $16,025,625 | $38,278,350 |
| Avian Injury | 39 | 1,219 | $91,575 | $3,571,425 | $111,629,925 |
| Total Habitat Restoration | | | | $19,597,050 | $149,908,275 |
| Aquatic Injury (3% of habitat restoration) | | | | $587,912 | $4,497,248 |
| Marine Mammal Injury | | | | Included in Aquatic Restoration | |
| **Total Restoration Costs** | | | | **$39,782,012** | **$304,313,798** |

Source: Enduring Econometrics

### 2-8.7 NRDA Assessment Costs

In addition to the restoration required as compensation, the Oil Pollution Act of 1990 requires responsible parties to pay Trustee assessment costs while also paying for their own consultants, attorneys, and contractors to navigate the NRDA process and implement restoration. As a share of total expenditure by PRPs, these assessment costs can be substantial. Following 1996 T/V Julie N oil spill in Portland, Maine, total costs of designing, implementing, and managing restoration amounted to $1.8 million, while assessment costs totaled $2.4 million (a multiplier of 1.2).[73] Including assessment costs and restoration costs, total damages from injury to habitats and natural resources are expected to range between $87 million in the summer to $669 million in the winter.

Table 20. Total Habitat and Resource Restoration and Assessment Costs

| Category | Total Cost | |
|---|---|---|
| | **Summer** | **Winter** |
| Total Restoration Costs | $39,782,012 | $304,313,798 |
| Expected Assessment Costs | $47,738,413 | $365,176,557 |
| **Total Habitat and Resource Damages** | **$87,520,425** | **$669,490,356** |

Source: Enduring Econometrics

## 2-9 Response and Cleanup Costs

While the total NRDA costs are substantial, they only play a minor burden in the ultimate expenditure by responsible parties following an oil spill. Although sizable, past evaluations of

[73] Mauseth, G. S., & Csulak, F. G. (2003). Damage Assessment and Restoration Following the JULIE N Oil Spill: A Case Study. In *International Oil Spill conference* (Vol. 2003, No. 1, pp. 409-412). American Petroleum Institute.

oil spill response and NRDAs have estimated these total costs to amount to only 26 percent of the total known costs of an oil spill.[74] Other costs include penalties, third-party damages, and response and cleanup costs. This section focuses on the expected costs of responding to the spill, including the costs of cleaning up the oil using best practices to minimize harm to the environment.

There are many factors that affect the cost of responding to an oil spill. Magnitude of the spill, geography, type of oil, and the time of year all affect costs.[75] The concurrent effects of a CSZ event and the oil spill will severely limit agencies and companies from responding to an oil spill in a way they might in any other state of the world. Thus, these costs should be inferred as a substantial lower bound that do not take into account the broader response efforts expected in the days and weeks following the earthquake.

The amount of fuel spilled has a non-linear effect on cleanup costs. Larger spills are more logistically complex and may require additional technologies and resources that are not regionally available.[76] In addition to volume, the length of the shoreline oiled also has a dramatic, non-linear effect on cleanup costs for the same reasons.[77]

Aside from volume and linear shoreline, the type of oil spilled is a substantial determinant of cleanup costs. Lighter oils are easier to remove from the water; however, they produce significant health and safety hazards for response workers. On the other hand, heavier oils, while less volatile, are more persistent and produce a greater physical challenge for cleanup efforts. Combined, however, cleanup costs for lighter oils tend to be lower.[78]

Empirically analyses have evaluated past spills by volume and shoreline extent of oiling to determine a per-gallon cost of fuel spilled.[79] Applying those estimates to the projected oil-in-water estimate from the CEI Hub results in a range of costs that vary between $109 million to $1.4 billion, depending on the methodology applied (Table 21). The value of costs for fuel releases at the CEI Hub will likely be between these values because less booming/staging would be needed than for an open-water spill, but extensive shoreline treatment will still be required. The higher proportion of light fuels – compared to the heavier fuels that cause more oiling of shorelines – could result in lower levels of clean-up costs compared to the $16.60 per gallon.

---

[74] Helton, D., & Penn, T. (1999). Putting response and natural resource damage costs in perspective. In *International Oil Spill Conference* (Vol. 1999, No. 1, pp. 577-583). American Petroleum Institute.
[75] Etkin, D. S. (1999). Estimating cleanup costs for oil spills. In *International oil spill conference* (Vol. 1999, No. 1, pp. 35-39). American Petroleum Institute.
[76] Montewka, J., Weckström, M., & Kujala, P. (2013). A probabilistic model estimating oil spill cleanup costs–a case study for the Gulf of Finland. *Marine pollution bulletin*, *76*(1-2), 61-71.
[77] Etkin, D. S. (2000). Worldwide analysis of marine oil spill cleanup cost factors. In *Arctic and marine oilspill program technical seminar* (Vol. 1, pp. 161-174). Environment Canada; 1999.
[78] Moller, T. H., Parker, H. D., & Nichols, J. A. (1987). Comparative costs of oil spill cleanup techniques. In *International Oil Spill Conference* (Vol. 1987, No. 1, pp. 123-127). American Petroleum Institute.
[79] Moller, T. H., Parker, H. D., & Nichols, J. A. (1987). Comparative costs of oil spill cleanup techniques. In *International Oil Spill Conference* (Vol. 1987, No. 1, pp. 123-127). American Petroleum Institute.

These cleanup costs are in addition to all aforementioned costs in the prior sections for impacts to habitats.

Table 21. Expected Range of Response and Cleanup Costs

| | | Volume Estimate | | Total Response Cost | |
|---|---|---|---|---|---|
| **Source of Cost Estimate** | **Cost per Gallon** | **Low** | **High** | **Low** | **High** |
| All Large Marine Spills | $2.67 | 40,751,753 | 82,503,352 | $108,807,181 | $ 220,283,950 |
| Marine Spills with Similar Shoreline Oiling Extent | $16.60 | 40,751,753 | 82,503,352 | $676,479,100 | $1,369,555,643 |

Source: Enduring Econometrics

# 2-10 Impacts to Cultural Values

Traditional monetary measures of economic importance are inappropriate to describe the value of cultural and tribal use of natural resources that could be impacted by fuel releases from the CEI Hub. Monetization implies substitutability (i.e., that monetary compensation at some level can make whole the loss of the service, because equivalent services may be purchased). Given that many, if not all, cultural services are defined by place, tradition, and continuity of use and practice, no alternative resource could provide a sufficient substitute for the resources in question. Because of the uncertainty, complexity, and inadequacy involved with identifying a monetary measure for cultural values, they are not monetized or quantified – but should be considered to have significant economic value and importance.

Federally recognized tribes do have Trustee authority to claim losses to cultural values, and several NRDA settlements include restoration projects to specifically address these injuries, separate from those designed to compensate for losses to habitats and resources. The federally recognized tribes that rely on the resources of the Willamette River and Columbia River include the:

- Confederated Tribes of the Warm Springs Reservation of Oregon,
- Confederated Tribes and Bands of the Yakama Nation,
- Nez Perce Tribe,
- Confederated Tribes of the Umatilla Indian Reservation,
- Confederated Tribes of Grand Ronde, and
- Confederated Tribes of Siletz.

# 2-11 Cost of Impacts to Fuel Prices

An indirect effect of fuel releases at the CEI Hub is a loss of the primary liquid fuel supply source for Oregon. The CEI Hub stores approximately 90 percent of Oregon's liquid fuel supply, including all of the jet fuel for the Portland International Airport and the gasoline and diesel for the Portland metropolitan region. The loss of the fuel supply would occur at the same time as other impacts from the Cascadia earthquake. As a result, pipelines, roads, tankers, barges, and other infrastructure would be impeded from delivering more fuel to the region. Because of the impacts to roads and transportation infrastructure, there will be less transportation, suggesting less demand for fuel. Fuel shortages caused by CEI Hub fuel releases will also result in delays and shortages for earthquake recovery efforts.

There will be fuel shortages after the fuel supply at the airport and commercial fueling stations is depleted. Much of Oregon will likely run out of gasoline and diesel within 1 week (based on the average six-day delivery cycle for pipeline transfers to the CEI Hub).[80] The Portland International Airport requires approximately 500,000 gallons of jet fuel per day and has limited storage on site.[81] The airport will likely run out of jet fuel in 1 to 2 days if pipeline deliveries stop due to damage or fuel releases. Truck capacities for jet fuel are only 10,000 gallons maximum, which would not be sufficient to replace the pipeline supply. Natural gas stored at the CEI Hub is used to address peak winter fuel demand – so there will potentially be higher natural gas costs if the CSZ earthquake occurs when demand for natural gas is high.[82]

The resulting shortage of fuel supply will likely result in price increases. While these price increases will be a response to increased scarcity, these changes tend to be “sticky” and relatively slow to respond, thus leading to shortages of fuel. Additional fuel will likely need to arrive by road or barge. Due to earthquake damage to transportation infrastructure, it will likely not be possible in the short-term to deliver fuel supplies to the Portland area or the Oregon coast. Areas of Oregon that are able to access alternative fuel supplies will experience higher fuel costs due to the costs of transportation and reduction in supply.

The disruption of the fuel supply will impose direct costs on all businesses that are reliant on commercial transportation. Some of these businesses will already be harmed by the effects of the earthquake because the roads are inaccessible for transportation. Other businesses will incur costs if their goods are not able to be delivered to them or if their products are not able to be distributed to their customers. Other business activities that are reliant on liquid fuel, such as manufacturing machines, may not be able to operate while the fuel shortage occurs.

---

[80] Wang, Y., Bartlett, S.F., Miles, S.B. (2012). *Earthquake Risk Study for Oregon’s CEI Hub. Prepared for Oregon Department of Geology and Mineral Industries (DOGAMI)*.

[81] Port of Portland. (2014). *Regular Commission Meeting Agenda*. January 8. Available at: http://cdn.portofportland.com/pdfs/Jan14_AG_Fin.pdf

[82] Only a maximum 10 percent of the supply from the natural gas tank at NW Natural is expected to be released. However, connection failures and other impacts from the earthquake could impede natural gas delivery to customers.

## 2-11.1 Price Effects

Although no perfect comparisons exist for the specific case of the Cascadia Subduction Zone Earthquake oil spills from the CEI Hub, several similar large-scale protracted supply shocks offer a good comparison for understanding the potential impact on fuel prices and fuel-dependent business activity.

The 2011 Great East Japan Earthquake caused fuel supply to be shut off to 1.66 million households in three prefectures of the Tohoku region in northern Japan for nearly six weeks.[83] After early periods of fuel buying following the earthquake, demand dropped by 30 percent after the earthquake. However, supply shutdowns due to earthquake damage in the Tohoku region (accounting for about a 30 percent drop in crude oil processed in the month after the earthquake) led to an overall jump in prices following the earthquake of about 1.1 to 3 yen per liter (about 4 to 12 cents per gallon in USD). The impacts of fuel shortages were alleviated by importing oil tank trucks from other regions to aid with long-distance oil transportation. This, coupled with the easing of regulatory restrictions by the government (such as lowering stockpiling requirements and promoting sharing of resources) allowed the supply and prices to rebound to pre-earthquake levels within about 3 months after the disaster.

### 2-11.1.1 Retail Gasoline Price Effects of Shutoff

The Colonial Pipeline, which provides refined petroleum products for nearly half of the eastern U.S., was forced to shut off service between May 7 and May 12, 2021, due to security and privacy concerns from a ransomware attack.[84] A gasoline shortage ensued across the mid- and lower-Atlantic, with rising prices seen throughout the pipeline's service area between New Jersey and Houston. Because the shortage was uncorrelated to other economic indicators, it provides a useful case study in the price and consumer effects of a pipeline failure. The analysis that follows uses the Colonial Pipeline shortage as a case study on the effects of a pipeline failure on fuel prices and consumer demand for gasoline.

Many East Coast states experienced acute price jumps in gasoline in the week or and week following the Colonial Pipeline service outage. Figure 5 shows data from Gas Buddy, a fuel price tracking app that publishes daily price data at the state- and metro-level for retail gasoline. Prices in Virginia and North Carolina jumped by about 7.5 percent, or 20 cents per gallon, between May 7, when the shutoff began, and May 16, when prices peaked following the shortage.[85] Oregon prices, which were unaffected by the shortage, are shown for reference.

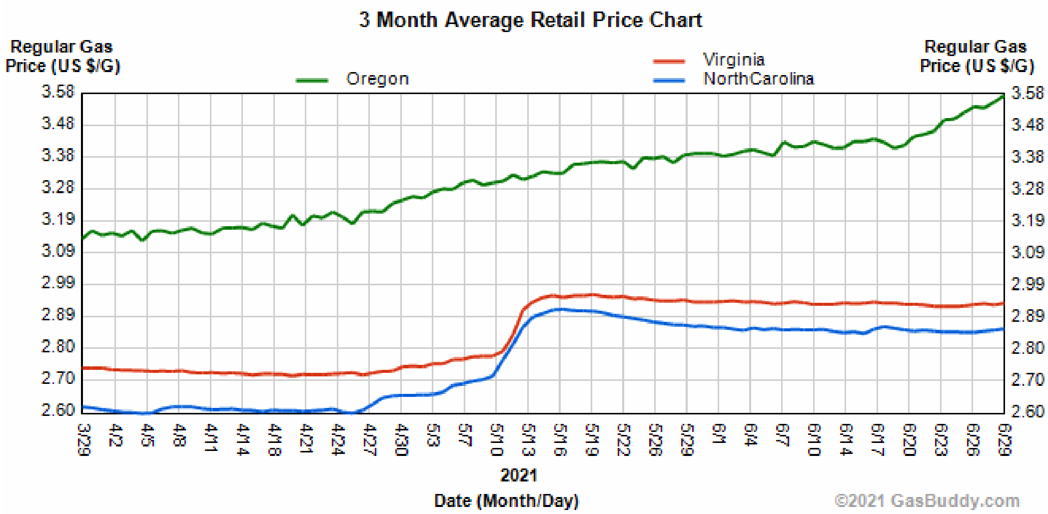
---

[83] Asia-Pacific Energy Research Center. (2015). *The Impact on Oil Distribution by the Great East Japan Earthquake, and future issues and countermeasures.*

[84] Hall, M. (2021). "The Colonial Pipeline is back up, but gas shortages have gotten worse and it'll take time to make up the shortfall". *Business Insider*. Available at: https://www.businessinsider.com/when-will-colonial-pipeline-gas-shortages-end-2021-5

[85] GasBuddy, *18 Month Average Retail Price Chart*, available at: https://www.gasbuddy.com/charts

Figure 5: Retail Gasoline Prices in VA, NC, and OR: April to June 2021




Source: GasBuddy, *18 Month Average Retail Price Chart*, available at: https://www.gasbuddy.com/charts

Data from the Energy Information Administration (EIA), which is reported weekly at the regional level, shows a similar trend across the Atlantic Region (which includes all East Coast states between Maine and Florida). Gas prices rose 8.6 and 16.1 cents per gallon in the region during the week of and week following the service shutoff, or a 5.6 percent net jump in prices[86] (Figure 5). During the last 10 years in this period, the average price change in the same period of May has been -0.2 percent, suggesting that all of this price increase is likely attributable to the service shortage.

The Colonial Pipeline shutoff had a differential effect on gas prices in states based on their reliance on the pipeline for their total fuel supply. The pipeline provides refined petroleum products to 45 percent of the East Coast US, but across states there is a large variation in the overall dependence on the pipeline for gasoline supply. Across much of the lower Atlantic, for example, over 70 percent of the supply of liquid fuel comes from the pipeline, while in Mississippi and the North Atlantic, less than 30 percent of gasoline is supplied by the pipeline Table 22. Factors such as the presence of port cities to receive fuel shipments and abundance of refineries in each state affects their overall dependence on the Colonial Pipeline for supply. The Plantation Pipeline, which runs parallel with much of the Colonial Pipeline, supports a smaller portion of the petroleum supply in each state.

The gulf coast states of Mississippi, Alabama and Georgia have a low, medium, and high level of reliance on the pipeline, respectively, and each experienced different gas price effects (Table 22). As shown in Figure 5, the higher reliance on the pipeline for gasoline supply was associated with a greater rise in gas prices. Although other factors may have contributed to this relationship, it suggests that states with a greater diversification of fuel supply sources may

[86] U.S. Energy Information Administration, *Gasoline and Diesel Fuel Update*, available at: https://www.eia.gov/petroleum/gasdiesel/

have been better able to maintain supply and avoid greater price surges during the pipeline shutoff.

Table 22: Gasoline Prices in Gulf Coast States During Colonial Pipeline Shutoff

| State | Proportion of Liquid Fuel Provided by Colonial Pipeline | May 5 ($/gal) | May 8 ($/gal) | May 11 ($/gal) | May 14 ($/gal) | Total 11-day Price Increase ($) |
|---|---|---|---|---|---|---|
| Mississippi | Less than 30% | $2.57 | $2.59 | $2.64 | $2.71 | $0.14 |
| Alabama | Between 30% and 70% | $2.65 | $2.68 | $2.73 | $2.84 | $0.19 |
| Georgia | Over 70% | $2.69 | $2.72 | $2.85 | $2.92 | $0.23 |

Source: GasBuddy and Colonial Pipeline

### 2-11.1.2 Market Implications of Pipeline Shutoff

Although primarily a supply-side phenomenon, the price effects were driven both by the reduced supply and increased demand for gasoline over concerns of a long-term shortage. According to data from GasBuddy, demand rose by 1.5 percent on the East Coast after the shutoff[87].

The shutoff likely had other implications. The shutoff led to gas station outages in fifteen states and the District of Columbia during the weeks following the shutoff. Up to 88 percent of gas stations in DC had fuel outages at the height of the shortage, according to tracking by GasBuddy[88]. These outages, as well as long lines waiting for gasoline driven by jumps in demand, led to lost wages and productivity for those waiting to buy gas or those unable to fuel commuter vehicles. Additionally, some airlines altered their flight paths and were forced to find alternative sources of fuel[89]. The temporary high costs of fuel, gas outages, and effects on fuel-dependent sectors of the economy also likely had ripple effects on supporting industries.

### 2-11.1.3 Summary of Economic Effects of Colonial Pipeline Service Outage

In summary, a brief pipeline outage led to a prolonged two-week shortage of retail gasoline in the East Coast US, due to a supply crunch and the resultant panic-buying. This outage drove a roughly 16 cent increase in East Coast gasoline prices, with price jumps increases exceeding 20 cents per gallon in some states. This led to an estimated $35 million in surplus prices paid by retail gasoline consumers on the East Coast over two weeks and may have imposed additional economic losses on workers, transportation industries and other fuel-dependent sectors. States

---

[87] GasBuddy. (2021). *National Average Sees Big Jump Thanks to Colonial Outage*. Available at: https://www.gasbuddy.com/go/national-average-sees-big-jump-thanks-to-colonial-outage

[88] GasBuddy. (2021). *Colonial Pipeline Shutdown: Fuel Outages by State*. Available at: https://www.gasbuddy.com/go/colonial-pipeline-shutdown-fuel-outages-by-state

[89] Krauss, C., Chokshi, N., and Sanger, D.E. (2021). "Gas Pipeline Hack Leads to Panic Buying in the Southeast". *The New York Times*. May 12. Available at: https://www.nytimes.com/2021/05/11/business/colonial-pipeline-shutdown-latest-news.html

that were less reliant on the pipeline for their fuel supply may have experienced less of a price drop in response to the shutoff.

#### 2-11.1.4 Estimating the Fuel Price and Consumption Effects in CEI Hub

The Oregon Department of Environmental Quality reported that about 1.738 million gallons of gasoline and 789.1 million gallons of diesel were consumed in Oregon in 2019. Given the nature of the projected fuel shutoff from a CEI Hub disaster, it is estimated that two primary forces will impose a cost for gasoline users. First, the loss of fuel will result in a temporary loss in ability to consume gasoline, particularly in any portions facing severe infrastructure damage. These losses will primarily be faced by residents in the Portland metro area. Second, the loss of fuel supply for the rest of the state will force other cities to meet fuel demand through importing from more costly sources. This means the rest of the state is likely to face higher prices of gasoline during the period of supply adjustment or potentially the entire duration that the CEI Hub is offline. These two portions of the total economic cost are quantified here.

First, the period of near total shutdown of fuel supply in the hardest-hit areas of Portland is expected to last anywhere from several days to weeks or even months. Conservatively assuming a loss of three days' worth of fuel supply to Portland, this translates to about 2.2 million gallons of lost gasoline consumption and 895,000 gallons of diesel consumption. Since the price of gasoline reflects the level of benefits people receive from its use, the value of the lost gasoline consumption reflects a lower boundary on the direct economic costs of the shutoff. At average current fuel prices in Oregon, this cost would be about $11.7 million (Table 23).

Table 23: Value of Lost Fuel Consumption in Portland Following Spill

| Fuel Type | Price per Gal | Lost Consumption in Portland Over 3 Days (gal) | Value of Lost Consumption |
|---|---|---|---|
| Gasoline | $3.80 | 2,183,000 | $8,297,000 |
| Diesel | $3.80 | 895,000 | $3,400,000 |
| Total | $3.80 | 3,078,000 | $11,697,000 |

Source: Created by ECONorthwest using gas price data from American Automobile Association, available at https://gasprices.aaa.com/?state=OR, and 2021 Clean Fuels Forecast by the Oregon Office of Economic Analysis and Oregon Department of Environmental Quality, available at: https://www.oregon.gov/deq/ghgp/Documents/cfp-Forecast2021.pdf.

Second, the fuel price effects are likely to be seen statewide as demand is met from more costly sources. Given the length of time for prices to adjust after the Japan earthquake and the Colonial Pipeline shutoff, it is likely that consumers across the state would face higher prices for the duration of time the CEI Hub is offline. The price increases seen in Georgia, which was over 70 percent dependent on the Colonial Pipeline for fuel supply, during the May 2021 shutoff were about $0.23 per gallon, with prices remaining high even after the pipeline returned back to service. With average daily statewide gasoline consumption of 4.8 million gallons of gasoline and 1.95 million gallons of diesel, assuming only a temporary drop in demand, this means the total economic cost to consumers of the higher fuel prices may be between $18.8 million (for a two-week duration as during the Colonial Pipeline shutoff) and $120.8 million (for a three-week duration as during the Great Japan Earthquake) (Table 24).

Table 24: Fuel Price Effects of CEI Hub Supply Interruption

| Fuel Type | Assumed Increase in Fuel Price | *Two-Week Interruption* | | *Three Month Interruption* | |
|---|---|---|---|---|---|
| | | Statewide Fuel Consumption | Cost of increased prices to consumers (assuming highly inelastic demand) | Statewide Fuel Consumption | Cost of increased prices to consumers (assuming highly inelastic demand) |
| Gasoline | $0.20 | 66,663,000 | $13,333,000 | 428,548,000 | $85,710,000 |
| Diesel | $0.20 | 27,317,000 | $5,463,000 | 175,611,000 | $35,122,000 |
| Total | $0.20 | 93,980,000 | $18,796,000 | 604,159,000 | $120,832,000 |

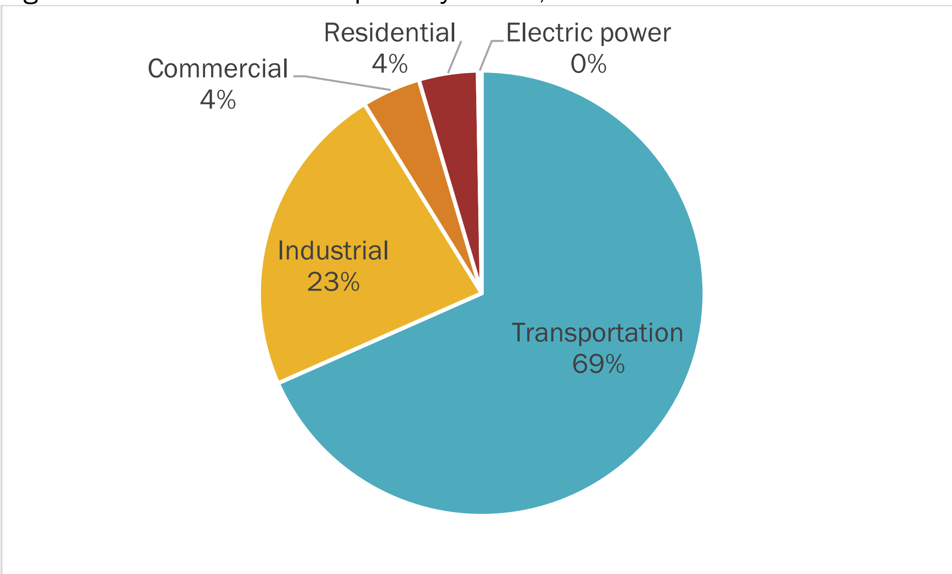
Source: ECONorthwest analysis of data from GasBuddy for states impacted by the Colonial Pipeline Shutoff and the 2021 Clean Fuels Forecast by the Oregon Office of Economic Analysis and Oregon Department of Environmental Quality, available at: https://www.oregon.gov/deq/ghgp/Documents/cfp-Forecast2021.pdf.

These costs do not include any costs caused by an inability to perform earthquake recovery efforts due to fuel shortages. To the extent that fuel scarcity impedes emergency response activities, there will be financial and non-financial costs, including injury and loss of life.

## 2-11.2 Business Responses

The direct effect of lost fuel supply would mean fuel-dependent businesses would likely face a temporary halt in operations until a replacement fuel source became widely available. Based on data collected by the Energy Information Administration, the transportation sector is the largest consumer of petroleum fuel (24 quadrillion btu annually in the U.S.), compared to about 8 quadrillion btu by the industrial sector and less than 2 btu for the commercial and residential sectors (Figure 6).

Figure 6. Petroleum Consumption by Sector, U.S. Total




Source: Created by ECONorthwest using data from the U.S. Energy Information Administration, *Gasoline and Diesel Fuel Update*, available at: https://www.eia.gov/petroleum/gasdiesel/

Although the transportation sector is most directly reliant on petroleum fuel, the commercial, retail and manufacturing sectors all rely on the transportation sector, in addition to many of the crucial emergency response activities. Because it is difficult to project infrastructure damage, it is uncertain how much the transportation sector and businesses that depend on transportation infrastructure to operate will be impacted. However, the Oregon Resilience Plan identifies transportation as a key sector to ensure an efficient and effective response to a Cascadia earthquake[90]. Fuel may be prioritized through directing initial resources to fuel depots for emergency and critical transportation use.

Fuel shortages, or higher-priced fuel, are both likely to compound the structural damages caused by the earthquake. About 80 percent of buildings in the Portland metro area are projected to suffer damage from the earthquake according to FEMA[91]. Since many retail and commercial businesses rely on electricity from non-petroleum fuel sources, these sectors would likely suffer more indirectly from supply chain disruptions or added costs from shipping and moving of intermediate and final goods.

[90] Oregon Seismic Safety Policy Advisory Commission (OSSPAC). (2013). *The Oregon Resilience Plan*. February. Available at: https://www.oregon.gov/oem/documents/oregon_resilience_plan_final.pdf

[91] U.S. Department of Homeland Security. (2011). *National Infrastructure Simulation and Analysis Center Homeland Infrastructure Threat and Risk Analysis Center Office of Infrastructure Protection National Protection and Programs Directorate.* November 18. Available at: https://www.bluestonehockley.com/wp-content/uploads/2016/01/FEMA-earthquake-study.pdf

## 2-11.3 Non-Commercial Costs

The fuel shortage will also impact households through disrupting the ability to commute to work, access childcare, or necessary services. Such costs may exacerbate existing inequities in access to work and essential goods and services. For example, a 2008 report found that working poor individuals spend a substantially higher portion of income on commuting—8.4 percent of total income for the working poor who drive to work compared to only 3.8 percent for other workers.[92] This means that added fuel costs are likely to hit low-income workers particularly hard. These fuel shortages will also complicate the ability for individuals to evacuate, add to prices at grocery stores, and constrain leisure travel.

[92] Puentes, R., and Roberto, E. (2008). *Commuting to Opportunity: The Working Poor and Commuting in the United States.* Available at: https://www.brookings.edu/research/commuting-to-opportunity-the-working-poor-and-commuting-in-the-united-states/

# 2-12 Summary of Costs

The costs of fuel releases from the CEI Hub are from a variety of sources including both direct physical impacts, fuel market impacts, cleanup, and losses in economic value. Not all costs are able to be monetized due to lack of data, uncertainty, confounding variables caused by the earthquake, and/or difficulty valuing the resource. The costs are based upon a multitude of assumptions and scenarios about the type and magnitude of fuel releases, emergency response actions and timelines, and natural phenomenon like air, water, and fire dispersion. Table 25 summarizes the range of values for each category of costs. In addition to these values there could be other costs associated with rebuilding and repairing of fossil fuel infrastructure at the CEI Hub, if that occurs, such as environmental impact studies, infrastructure recertification, infrastructure abandonment, and other operational costs.

The minimum costs to society of potential fuel releases at the CEI Hub range from **$359 million to $2.6 billion.** Because not all costs were monetized, this range of costs represents only a portion of the total costs likely to be imposed on society from fuel releases from the CEI Hub. The social costs do not include fines, penalties, lost revenue, or equipment replacement costs borne by the CEI Hub operators. Prior large oil spills demonstrate the large costs to both society as well as the operating companies imposed by oil spill events. For example, Deepwater Horizon resulted in a total cost to BP of $61.6 billion for all penalties, claims, and liabilities.[93] Although the fuel releases at CEI Hub would be occurring under very different circumstances than Deepwater Horizon, the similar volume of releases suggests that there could be similar large costs to CEI Hub operators. The subsequent chapter discusses if and how costs to society would be reimbursed through the existing claims processes.

Table 25. Summary of Costs of Fuel Releases from the CEI Hub due to a Cascadia Earthquake

| Category of Costs | Summary of Costs | Range of Monetized Costs for the Modelled Scenario |
|---|---|---|
| Direct Impacts to People | Assuming an explosion occurs, between 0 to 7 people could be killed and 2 to 80 people could be injured. The range of costs for mortality and morbidity are between $49,000 to $74.1 million, with an average cost of $37.1 million. | $49,000 to $74.1 million |
| Impacts to Property | Assuming fuels in the water travel downstream to the Longview Bridge, the potential impact on residential properties values is up to $35.4 million. There is $2.5 billion in total riverfront property value in the downstream area. | $11.8 million to $35.4 million |
| Impacts to Navigation | A one-week closure of the shipping channel between the I-405 bridge and Longview Bridge would result in additional operating costs for commercial vessels of between $11.8 million and $17.8 million. | $11.8 million and $17.8 million |

[93] NOAA, *Deepwater Horizon oil spill settlements: Where the money went*, Available at: https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

| Category of Costs | Summary of Costs | Range of Monetized Costs for the Modelled Scenario |
|---|---|---|
| Impacts to Fisheries | To the extent that fuel releases reduce reproduction or cause direct mortality to aquatic species there will be a reduction in income to the fishing industry, impacting owners, employees, and suppliers who rely on these funds. Increases in hatchery production would likely be needed, which would result in additional costs. | Not Monetized – Potential for significant mortality to commercial fisheries species and loss to commercial fishing entities |
| Impacts to Recreation | Average per-trip values of recreation for participants (i.e., consumer surplus) are between $68 to $130 per person per day. Recreationalists contribute spending to local economies at an average value of between $98 to $478 per trip. Cancelled recreational trips due to fuel releases would reduce both value for the participant and economic activity for the businesses that rely on the recreational spending. A one-month closure of the Lower Columbia River and Lower Willamette River for salmonid fishing would result in a loss of consumer surplus of $3.4 million and a loss of $3.2 million in direct trip spending. | Not Monetized – Damage to recreational resources that cannot be easily rebuilt, such as fire damage to Forest Park, will result in long-term losses to recreation. |
| Impacts to Human Health | The health costs of exposure to toxins for nearby people and response workers is $121 million to $249 million for both acute and chronic conditions. The primary health costs are increased risk of heart attack, decreases in productivity, and lost workdays. Additional costs would be borne from evacuations and strains on emergency response services. | $121 million to $249 million – with potential for additional costs to mental health and non-documented physical health costs. |
| Impacts to Habitats and Species | Habitats and species would be harmed from fuel releases. The costs of habitat restoration as compensation for habitat injury would require between 175 and 418 acres of wetland to be restored. An additional 39 to 1,219 acres of constructed wetland could be needed to compensate for injuries to bird populations. There is also the potential for compensation needed for aquatic and mammal species that are injured by the event. The expected total costs for habitat restoration are $39.7 million in the summer and $304.3 million in the winter. Total damages from injury to habitats and natural resources and required compensation are expected to range between $87 million in the summer to $669 million in the winter. | $87 million to $669 million |
| Cleanup Costs | Cleanup costs are projected to be between $109 million to $1.4 billion. | $109 million to $1.4 billion |
| Impacts to Cultural Values | Fuel releases in the Willamette River and Columbia River would harm cultural resources that are of particular importance to Tribal populations for subsistence, transportation, commerce, and ceremonial purposes. Impacts to this area would perpetuate historical inequities to a water resource already contaminated as part of the Portland Harbor Superfund. | Not Monetized – Impacts to waterways and aquatic species like salmon would result in large cultural losses. |
| Impacts to Fuel Prices | Releases of fuel from the CEI Hub would reduce the supply of fuels needed for transportation and | $18.8 million to $120.8 million – with additional |

| Category of Costs | Summary of Costs | Range of Monetized Costs for the Modelled Scenario |
|---|---|---|
| | commercial activity in Oregon. The effects of the earthquake on transportation infrastructure will alter the demand for fuels. A lack of fuel could constrain emergency response activities. The total economic cost to consumers of the higher fuel prices and reduction is between $18.8 million and $120.8 million. The lost value of consumption from fuel scarcity would be $11.7 million for a three-day period. | costs from loss of consumption and delays in recovery efforts |
| **Total Monetized Costs** | | **$359 million to $2.6 billion** |