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WASCO COUNTY PLANNING COMMISSION AGENDA PACKET

FOR

Hearing Date: September 6, 2016

Hearing Time: 3:00 pm
Hearing Location: Columbia Gorge Discovery Center, Theater/Auditorium
5000 Discovery Drive
The Dalles, Oregon 97058

Action Item(s):

QUASI JUDICIAL HEARING:

PLASAR-15-01-0004

Request by Union Pacific Railroad and their land use consultants, CH2M Hill, to expand an existing railroad siding on either side of Mosier, Oregon for 4.02 miles of new second mainline track and realigned existing track; place five new equipment shelters; install drainage structures, a retaining wall, new lighting and signage, and wireless communication poles; modify existing utilities, temporary landing zones for construction; construct temporary and permanent access roads; and a property line adjustment. The request also includes off-site wetland mitigation east of the primary project site.

VOLUME #8

Wasco County Planning Department

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Date: August 30, 2016
To: Wasco County Planning Commission
From: Wasco County Planning Office
Subject: Submittal for Hearing dated September 6, 2016

QUASI JUDICIAL HEARING:

PLASAR-15-01-0004

Request by Union Pacific Railroad and their land use consultants, CH2M Hill, to expand an existing railroad siding on either side of Mosier, Oregon for 4.02 miles of new second mainline track and realigned existing track; place five new equipment shelters; install drainage structures, a retaining wall, new lighting and signage, and wireless communication poles; modify existing utilities, temporary landing zones for construction; construct temporary and permanent access roads; and a property line adjustment. The request also includes off-site wetland mitigation east of the primary project site.

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FRIENDS OF THE COLUMBIA GORGE

VIA FIRST CLASS MAIL

August 23, 2016

Angie Brewer, Planning Director
Wasco County Department of Planning and Economic Development
2705 East Second Street
The Dalles, Oregon 97058

Re: Union Pacific Railroad Mosier Area Expansion – PLASAR-15-01-0004

Dear Ms. Brewer:

Please accept the enclosed materials, place them before the Planning Commission, and add them to the record for the proposed Union Pacific Mosier Area double track project PLASAR-15-01-0004. These materials come from the Washington Energy Facility Site Evaluation Council's adjudication of the Tesoro-Savage Vancouver Energy oil-by-rail terminal proposal. The documents fall into a few rough categories:

- There are several studies included that analyze the decrease in real estate values brought about by freight rail traffic and by increased hazards;
- There is testimony on the impact train traffic along the Columbia River has on tribal communities and their treaty rights;
- There is transportation incident related information including studies and testimony on the costs of cleanup should oil be spilled into the Columbia River; and
- There is footage of the incident in Mosier.

Thank you for the continued opportunity to comment.

Sincerely,

Steven D. McCoy
Staff Attorney
Friends of the Columbia Gorge

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MAY 16 2016
ENERGY FACILITY SITE
EVALUATION COUNCIL

BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	NO. 15-001 COUNSEL FOR THE ENVIRONMENT'S PRE-FILED DIRECT EXPERT WITNESS TESTIMONY OF JAMES V. HOLMES

I. EXPERT QUALIFICATIONS

1. I am a Principal Associate/Scientist and Vice President at Abt Associates. I am co-director the environmental sciences and natural resource damage assessment (NRDA) practice in the Environment and Natural Resource Division of the company. I have an MS in earth sciences from Dartmouth College and a BA in environmental biology from Middlebury College. My resume is attached as Exhibit 1501 ENV.

2. I have worked on NRDAs, contaminant fate and transport analyses, surface and groundwater assessments, ecological effects assessments, and natural resource restoration planning since 1991. I have worked on assessments of petroleum discharges as an employee of Abt Associates and predecessor companies Stratus Consulting and Hagler Bailly. I have worked on all phases of NRDA, including pre-assessment screens, assessment plans, preliminary evaluations of injuries and damages, injury quantification, habitat and resource equivalency methods for estimating damages, and spatial analyses of adverse impacts. I have presented methods for evaluating natural resource injuries and damages at professional

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conferences, and I have taught NRDA methods to natural resource trustees in the U.S. and internationally. I have served as a testifying expert on NRDAs in federal court and in multiple New Jersey district court cases.

II. SUMMARY OF OPINIONS

3. The Tesoro Savage Petroleum Terminal LLC has submitted an Application for Site Certification to the Washington State Energy Facility Site Evaluation Council (EFSEC) to construct and operate the Vancouver Energy Distribution Terminal Facility at the Port of Vancouver in Vancouver, Washington. My colleagues and I at Abt Associates were tasked with estimating potential natural resource damages from two effective worst-case oil spill scenarios: a tanker grounding in the Columbia River near Vancouver, Washington, and a train derailment near the Bonneville Dam. The opinions in this proffer summarize work that I conducted with Abt Associates colleagues working under my direction. We presented the work in a report that we wrote with Dr. Eric English of Bear Peak Economics. That report is attached as Exhibit 1503 ENV.

4. The scope of this task was restricted to assessing the impacts in the Columbia River from these two scenarios; we did not evaluate potential impacts in the Pacific Ocean or along the Pacific Coast. We also did not separately assess how the public or Indian Tribes would value the potential losses to natural resources if either of these spills were to occur, although these values may be at least partly accounted for in the methods we used. Because of this limited scope of our work, my estimates of potential natural resource damages from these spill scenarios do not consider all potential damages.

5. Both of the oil spill scenarios that we evaluated would result in birds, fish, pinnipeds, and other biota being exposed to oil in the lower Columbia River, including to oil slicks on the river surface; stranded oil in sediments, along the banks, and in the floodplain; and polycyclic aromatic hydrocarbons (PAHs) in the water column.

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6. Oil exposure adversely affects birds. Data from the literature (including data from studies that Abt Associates managed as part of the *Deepwater Horizon* oil spill) suggest that most birds exposed to oil are impaired and may die from symptoms ranging from hemolytic anemia to hypothermia to heart failure. Oiled eggs rarely produce offspring, and oiled feathers impair flight behavior, which could lead to increased predation and decreased hunting and migration success.

7. Oil exposure also adversely affects fish. Recent literature and studies that Abt Associates managed or conducted as part of the *Deepwater Horizon* oil spill suggest that the concentrations of PAHs expected in the Columbia River from these spill scenarios could exceed thresholds for multiple toxic endpoints in early life-stage fish.

8. Recent literature also suggests that PAH exposure can reduce the physiological fitness of juvenile and adult fish. Physiological impairment of out-migrating salmon smolt and returning adults could adversely affect the ability of salmon to complete their life cycle and successfully migrate to spawning grounds.

9. To estimate potential natural resource damages, I used a habitat equivalency analysis (HEA). This is a commonly used technique where damages are based on the cost to restore habitat and/or natural resource services equivalent to those that were harmed by the oil.

10. In a HEA model, future adverse impacts and environmental gains from habitat restoration are discounted to a base year using a three percent discount rate to reflect a time preference reflected in social discount rates. This approach is standard practice in conducting HEAs in the U.S.

11. Using this approach, the discounted losses and gains in each year were summed, creating an estimate of total natural resource injuries in units of discounted service acre-years (DSAYs), and an estimate of total restoration benefits in DSAYs per acre. Dividing the total injuries (DSAYs) by the benefits of restoration (DSAYs per acre) provides an estimate of the

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number of acres of marsh habitat restoration required to offset the estimated adverse effects from the hypothetical spill scenario.

12. I used HEA methods similar to those that natural resource Trustees (including the National Oceanic and Atmospheric Administration and the State of Washington) developed for NRDAs in Puget Sound (Commencement Bay/Hylebos Waterway, Elliot Bay/Duwamish River). In this model, restoration benefits are scaled using estuarine marsh habitat as the preferred restoration alternative. If oil caused harm (injury) to natural resource services in other habitats, those service losses were scaled to an amount of marsh habitat that provides equivalent services.

13. I estimated the service loss from oil exposure based on available data and knowledge from other spills. For this analysis, I estimated injury in terms of service losses to estuarine and freshwater marsh habitats both in the river channel and in the floodplain adjacent to the river channel. I assumed that these wetland habitats (as designed in the National Wetlands Inventory) provide equivalent services to restored estuarine marsh.

14. I also estimated injury in terms of service losses to riverine, subtidal, and other habitats in the river channel. I assumed these non-wetland river channel habitats provide 10 percent of the environmental services of an estuarine marsh, using scaling methods similar to those used in the Commencement Bay NRDA. The exception was a short 4.8-mile reach of river that includes protected spawning habitat downstream of the Bonneville Dam, for which I assumed services provided are equivalent to those of a restored marsh rather than being adjusted to only 10 percent of marsh habitat services.

15. For these scenarios, I assumed that the spill occurs in the spring of 2016 (present year, for discounting purposes) and that most of the service losses occur in 2016 and 2017. Complete recovery to pre-spill conditions occurs slowly thereafter until 2025.

16. I further assumed that marsh restoration required to offset these potential impacts would be completed in 2021. It would take 15 years for the marsh to become fully

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established and provide 100 percent of marsh habitat services (Commencement Bay Natural Resource Trustees, 2002), and those restored services would be provided for 100 years. This provides 20.5 DSAYs of restoration credit per acre of marsh restored.

17. In reviewing the available information, I found a wide range of unit costs for restoring estuarine marsh habitat. Costs for marsh habitat restoration ranged from a few thousand dollars per acre for very simple projects such as breaching a dike to flood fields, up to more than $1 million per acre for more complex projects that involve purchasing land, removing and disposing of fill materials, regrading, and planting vegetation to create new habitat.

18. I used the recent Fir Island restoration in the Skagit Valley (WDFW, 2014) as a reasonable intermediate project for the basis of estimating average marsh restoration cost. This estuarine marsh restoration project provided new habitat for Chinook salmon, preserved habitat for waterfowl such as snow geese, and was accomplished at a unit cost lower than but close to average costs that I found for this type of restoration. The Fir Island project restored 130 acres of marsh habitat at a cost of $110,000 per acre.

A. Tanker Grounding Scenario

19. The "effective worst-case discharge" for a tanker grounding in the lower Columbia River is a spill of 189,845 bbls (about eight million gallons) of Bakken crude oil (EFSEC, 2015). Based on data from a 1984 oil spill in the river as well as models presented in the Draft Environmental Impact Statement (DEIS; EFSEC, 2015), oil would travel approximately 40 miles downstream from Vancouver to Longview (Reach 2) in one day. It would then travel slowly from Longview through the estuary to the mouth of the river (Reach 1) after an additional four days.

20. Assuming the spill occurs near Vancouver in the spring (mid-April to mid-May), an estimated 20,000 to 60,000 adult salmon adult salmon swimming upstream

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could be exposed in Reach 2, and an additional 45,000 to 70,000 could be exposed to the oil in Reach 1. These estimates are based on adult salmon counts from the Bonneville Dam.

21. An estimated 1.4 million to 1.6 million juvenile salmon (smolts) swimming downstream also could be exposed to the oil in the river over the approximately five days that the oil is in the river before discharging into the Pacific Ocean. This is based on average daily smolt counts at the Bonneville Dam between 2011 and 2015, as well as data from the literature that suggest that smolts linger in the estuary for several days before swimming out to sea. This estimate does not include any additional smolt recruitment that might occur from tributaries in the 40 river miles from the Bonneville Dam to Vancouver.

22. Other natural resources likely to be exposed to oil in the lower Columbia River and estuary include other anadromous fish (i.e., shad, green sturgeon), resident fish (including white sturgeon), pinnipeds (i.e., Steller sea lions, California sea lions, harbor seals), thousands of birds across a wide range of guilds, and other aquatic biota.

23. Based on the likelihood that exposure to oil would cause a suite of adverse impacts to fish and birds exposed to oil in river channel habitats, I estimated a 90 percent service loss in Reach 2 and 75 percent service loss in Reach 1 in 2016, with both reaches recovering to 10 percent service loss in 2017 and no service loss in 2025. Using data in a geographic information system (GIS), the total area of the river channel from Vancouver to the mouth is 16,152 acres of wetland habitats and 91,579 acres of riverine/subtidal habitat. I calculated 21,276 DSAYs of natural resource injury (HEA "debit") for these habitats.

24. With 21,276 DSAYs of debit and 20.5 DSAYs per acre restored, the total quantity of restoration required to offset injuries to river channel habitats is 1,040 acres. At a cost of $110,000 per acre, the total damages for injuries to the river channel habitats would be about $114.4 million.

25. Wetlands in the 100-year floodplain that are not in the designated river channel could be directly exposed to oil if the river stage is high, they could have stranded oil on the

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margins, and the birds residing in the wetlands could be exposed to surface oil on the river channel. I assumed that these floodplain wetlands would suffer service losses because of the oil spill as well.

26. For floodplain wetland habitats, I estimated a 25 percent loss in Reaches 1 and 2 in 2016, recovering to a five percent service loss by the end of 2017, and reaching pre-spill conditions by 2025. For the 29,867 acres of floodplain wetland habitat in these two reaches, the total HEA debit is 10,580 DSAYs.

27. With a total calculated debit of 10,580 DSAYs and a credit of 20.5 DSAYs per acre of marsh restored, the total quantity of restoration required is 517 acres. At a cost of $110,000 per acre, the total damages would be about $56.9 million.

28. The total estimated damages based on the HEA approach for river channel habitats and wetland habitat in the adjacent floodplain is $114.4 million + $56.9 million = $171.3 million. This estimate does not include natural resources damages from potential oil impacts in the Pacific Ocean, along the Pacific Coast, or in the Willamette River. It also does not include an analysis of the value that the public and Indian Tribes place on natural resources in the lower Columbia River. It is likely that this is an underestimate of damages.

B. Train Derailment Scenario

29. According to the DEIS, the effective worst-case discharge for a train derailment is a spill of 20,000 bbls (840,000 gallons) of Bakken crude oil (EFSEC, 2015). The worst-case scenario would be for the oil spill to occur immediately upstream of the Bonneville Dam, with most of the oil going through the spillway and mixing into the water column. This could potentially expose white sturgeon (and other resident aquatic species) to highly elevated PAH concentrations in their protected spawning grounds in the 4.8-mile reach immediately downstream of the Bonneville Dam (Reach 4), in addition to exposing adult salmon migrating upstream to spawn and smolts migrating downstream to the Pacific Ocean.

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30. An estimated 2,000 to 9,000 adult salmon swimming upstream could be exposed to the oil in Reach 4 immediately below the Bonneville Dam, based on 2011-2015 average daily adult salmon counts from the dam in mid-May. Data from the literature suggest that migrating salmon take up to three weeks to travel from the mouth of the river to the dam; all of these daily cohorts of adult salmon could potentially be exposed to PAHs in the water, with lower concentrations with distance from the dam.

31. In mid-May between 2011 and 2015, the daily smolt count at the dam ranged from 27,000 to 220,000. A daily cohort of smolts going downstream with the oil could be exposed to the oil in the river over the approximately five days that the oil is in the river before discharging into the Pacific Ocean. Data from the literature suggest that smolts remain in the estuary for several days before swimming out to sea, potentially exposing additional daily cohorts of smolts to the oil in the estuary.

32. Based on the potential for adverse impacts to fish and birds exposed to oil in the river channel, I estimated a 90 percent loss of habitat services in Reach 4, a 50 percent loss in Reach 3 (which extends to Vancouver), and a 15 percent loss in Reaches 2 and 1 in 2016. I assumed that Reaches 4 and 3 would recover to a 10 percent service loss by the end of 2017 and to pre-spill conditions by 2025. I further assumed that Reaches 2 and 1 would recover to a five percent service loss by the end of 2017 and to pre-spill conditions by 2025.

33. According to data compiled in GIS, the total area of the river channel from the Bonneville Dam to the mouth is 16,687 acres of wetland habitat and 110,316 acres of riverine/subtidal habitat. Assuming the service losses above (and assuming that riverine habitat in Reach 4 provides the equivalent of 100 percent of estuarine marsh services), I calculated 10,135 DSAYs of natural resource injury (HEA debit).

34. With 10,135 DSAYs of debit and 20.5 DSAYs per acre restored, the total quantity of restoration required to offset injuries to river channel habitats is 495 acres. At a

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cost of $110,000 per acre, the total damages for injuries to the river channel habitats would be about $54.5 million.

35. Consistent with the methods for the tanker grounding, I assumed that floodplain wetlands would have service losses because of the oil spill. I assumed a 75 percent loss of floodplain wetland habitat services in Reach 4, a 25 percent loss in Reach 3, and a 10 percent loss in Reaches 2 and 1 in 2016. Reach 4 would recover to a 25 percent service loss by the end of 2017 and to pre-spill conditions by 2025. Reach 3 would recover to a 10 percent service loss by the end of 2017 and to pre-spill conditions by 2025. Reaches 2 and 1 would recover to a two percent service loss by the end of 2017 and to pre-spill conditions by 2025.

36. Based on GIS calculations, there are 32,055 acres of wetlands in the floodplain downstream of the Bonneville Dam. Assuming the service loss to these habitats in each reach as described above, I calculated 5,643 DSAYs of natural resource injury (HEA debit).

37. With a total debit of 5,643 DSAYs and a credit of 20.5 DSAYs per acre of marsh restored, the total quantity of restoration required is 276 acres. At a cost of $110,000 per acre, the total damages would be about $30.4 million.

38. The total estimated damages based on the HEA for the river channel and adjacent floodplains is $54.5 million + $30.4 million = $84.9 million.

C. Comparison with Other Spills

39. These estimates of natural resource damages are considerably less than major oil spill settlements such as *Exxon Valdez* or *Deepwater Horizon*. Although damages to natural resources are not scalable based on the volume of oil discharged and vary based on the specifics of each spill, prior oil spill settlement can provide some illustrative context. My review of such settlements suggests that the damage estimates I developed for the hypothetical spill scenarios are generally consistent with other large oil spills.

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III. REFERENCES CITED IN TEXT

Commencement Bay Natural Resource Trustees. 2002. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Public Review Draft. March 14.

EFSEC. 2015. Tesoro Savage Vancouver Energy Distribution Terminal Facility, Draft Environmental Impact Statement. State of Washington, Energy Facility Site Evaluation Council, Olympia, WA. November.

WDFW. 2014. Skagit Wildlife Area, Fir Island Farms Reserve Unit: Fir Island Farms Final Design Project. Washington Department of Fish and Wildlife. Available: http://wdfw.wa.gov/lands/wildlife_areas/skagit/final_restoration_study.php. Accessed 5/2/2016.

IV. EXHIBITS

Exhibit 1501 ENV: Resume of James V. Holmes

Exhibit 1503 ENV: Potential Fishing Impacts and Natural Resource Damages from Worst Case Discharges of Oil on the Columbia River: Report in the Matter of Application No. 2013-01, Vancouver Energy Distribution Terminal, EFSEC Case Number 15-001. Prepared for Matt Kernutt, Washington Attorney General's Office. Prepared by Abt Associates and Bear Peak Economics. May 6, 2016.

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I declare under the penalty of perjury under the laws of the state of Washington that the foregoing is true and correct.

DATED this 12th day of May, 2016.

Abt Associates Inc.

James V. Holmes
Principal Associate/Scientist,

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Bob Ferguson
ATTORNEY GENERAL OF WASHINGTON
Government Compliance & Enforcement Division
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May 13, 2016

Washington Energy Facility Site Evaluation Council
1300 S Evergreen Park Dr. SW
PO Box 43172
Olympia, WA 98504-3172

Re: **Tesoro-Savage Vancouver Energy**
No. 15-001

Dear WEFSEC:

Enclosed for filing please find an original and one copy of the Counsel for the Environment's Pre-Filed Direct Expert Witness Testimony of Eric P. English, Counsel for the Environment's Pre-Filed Direct Expert Witness Testimony of James V. Holmes, and Certificate of Service. Copies have been sent to the parties electronically.

Sincerely,

Meaghan Kohler
Legal Assistant to
Matthew R. Kernutt
Assistant Attorney General

:mlk
Enclosures

ORIGINAL

PC 1 8-3467

Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles

Michael Futch*

November 11, 2011

Abstract

This paper measures the impact of infrastructure expansion on local home values and examines the persistence of that impact over distance. Specifically, I exploit a natural experiment in which rail traffic from the Los Angeles seaport, one of the busiest in the country, was permanently redirected from several tracks to a central line, termed the Alameda Corridor. I link a rich, repeat-sale housing dataset to plausibly exogenous changes in local rail traffic to estimate these effects, controlling for local price trends using a Case-Shiller style housing index. Using the actual traffic changes the result is an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. The welfare impact of concentrating a negative externality on a smaller population should depend on the convexity of the cost function, but I find evidence that suggests the marginal cost is symmetric for winners and losers. Instead, the total welfare impact hinges on the efficiency gains achieved by relocating the traffic from circuitous routes to the more direct Alameda Corridor, thereby affecting fewer homeowners. While the net gains are minimal, the re-routing of traffic resulted in a transfer of housing wealth of approximately $200 million.

*Email: mfutch@ucsd.edu. I would like to thank Craig McIntosh, Gordon Dahl, Paul Niehaus, Mark Jacobsen, Josh Graff Zivin and UCSD seminar participants for their helpful comments.

PC 1 8-3468

1 Introduction

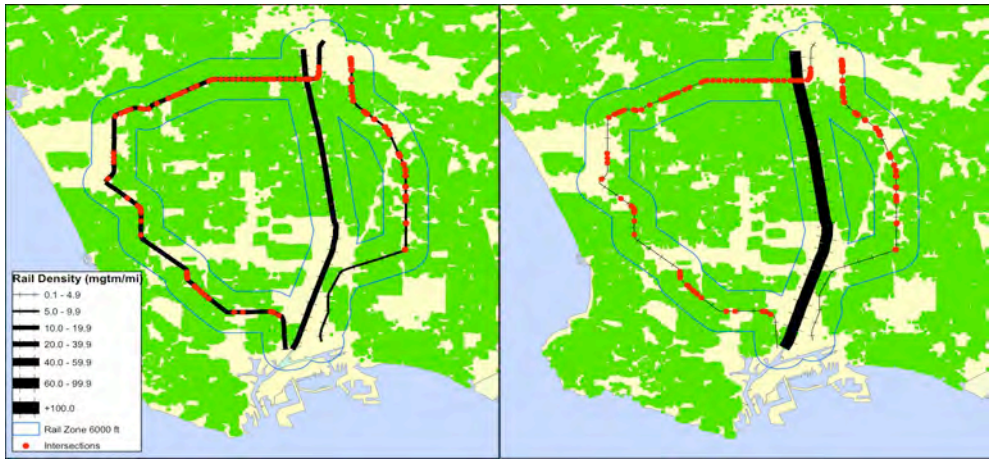
Economic reforms often do not benefit everyone involved; instead, there are typically winners and losers. Identifying who wins and who loses and by how much is important when evaluating policy options especially because many of the groups affected often do not have representation at the negotiating table. This process is further complicated when policy actions impact groups or individuals external to the original intent of the policy.

This is particularly true of public infrastructure projects. Causal identification of public infrastructure impact is often challenging as the location is rarely random and may correlated with wealth and political clout. Using year to year changes in the intensity of an externality is also problematic as these changes are also likely to be correlated with local growth patterns. When concentrating a negative externality on a segment of the population it is important not just to measure the marginal effect at a point, but to understand the convexity of the cost imposed on individuals. If the marginal cost of the externality were increasing, this would suggest distributing the exposure to the externality among as many people as possible. If the marginal cost were decreasing, a case could be made for concentrating greater amounts of a negative externality on a smaller population.

This paper examines these issues in the context of urban rail in Los Angeles. This setting offers an attractive natural experiment, solving some of the identification issues discussed above by exploiting a shift in the way rail traffic travels through the city. The Alameda Corridor, an urban infrastructure project in Los Angeles, allowed for consolidation of most freight rail traffic into and out of the San Pedro port facilities from three geographically distinct tracks into one higher capacity line. Figure 1 depicts the level of rail traffic in the region before and after the opening of the Alameda Corridor. Rail traffic involves negative environmental spillovers onto local communities in the form of air and noise pollution, along with congestion effects caused by long waits at rail crossings. Because the rail traffic involved is freight and not transportation, there are fewer demand-side effects that could cause upward or downward pressure on housing values apart

PC 1 8-3469

Figure 1: Rail Traffic Density - Before and After



from the pollution and congestion caused by rail traffic alone. Most interestingly, the change in the flow of rail traffic was approximately zero-sum overall, providing a very straightforward window on the extent to which a redistribution generated net social gains or harm.

This setting allows me to directly measure the distribution of an externality using the cost inflicted on homeowners, exploiting substantial variation (both upwards and downwards) in the intensity of the externality. Many papers relate the existence of an externality to house prices, but most lack the data to clearly identify the costs actually induced by the environmental harm. I find that an increase in rail traffic by 10 million gross ton miles per mile (MGTM/mi) causes a 0.7 percentage point lower growth in home values within a 1/3 mile band around the tracks. Furthermore, under a stronger set of assumptions our results suggest that the response of property values is linear in the degree of damage in both positive and negative directions for an identical size change, indicating that a zero-sum redistribution of environmental damage has no overall effect on total welfare. Using the actual traffic changes this results in an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. Aggregating our estimates over the number of homes affected yields a net home value increase of $23 million - a negligible sum considering the total housing value for homes inside the one-mile zone was roughly $36 billion in 1997.

PC 1 8-3470

The rest of the paper is organized as follows: Section 2 discusses identification strategies and the data available, Section 3 outlines the estimation strategy and counterfactual selection, Section 4 presents the estimating equations, Section 5 discusses the results, and Section 6 concludes.

2 Identification Strategy and Data

2.1 Causal Identification Issues

While understanding the impacts of public infrastructure on local communities is of much interest, clean causal identification is typically difficult or impossible in many circumstances. The first hurdle to causal identification is due to the non-random nature in which locations are chosen for infrastructure. If the location for a project, say a new railroad track, is chosen based on unobservable factors that are related to the outcome of interest, OLS estimates of the treatment effect will be biased. There have been many papers that have taken this approach using cross-sectional data: Espey and Lopez (2000) and Cohen and Coughlin (2006) both look at the impact of airport proximity on housing values. Kim, Phipps, and Anselin (2001) use a cross section of home values and to measure the impact of air pollution on housing prices in South Korea. Chay and Greenstone (2005) look at air pollution and housing values, but circumvent this identification hurdle by instrumenting for air pollution using regulation changes triggered by county pollution levels.

If the housing data available spans several time periods, it could be tempting to use changes in pollution or changes in the external costs of public infrastructure (greater freeway or airport traffic) to identify the causal impact on house price changes. However, changes in infrastructure intensity or air pollution are likely to be correlated with other important variables that may drive the outcome measure. Greater freeway traffic may negatively impact nearby home values, but that increased traffic may be a result of higher employment in the city center which could drive up home prices. If causal effects are to be identified using changes in the externality, an argument

PC 1 8-3471

must be made for the exogeneity of the changes. If the changes are not exogenous, an instrumental variables or a natural experiment approach could be used if possible. Currie and Walker (2010) use a repeated cross section data set to exploit the creation of EZ-Pass toll lanes to find the impact of automobile congestion and poor birth outcomes. The main results of their paper are focused on health outcomes, but they do look for house price impacts and find none.

A housing data set that includes repeated sales of the same property is especially attractive once the exogeniety issues have been ironed out. Repeat sale data are useful because they allow better control of individual house idiosyncrasies. There have been several recent papers that utilize repeat sale data to estimate the impact of some spatially sourced event. Case et al. (2006) looks at the effect of water contamination on home prices. Cutter et al. (2009) follow a similar approach but look at the positive impact of open space preserves on home prices and raise the issue of finding the appropriate counterfactual. They craft an appropriate counterfactual using matching methods of Ho, Imai, King, and Stewart (2007). The data Case et al. use has a narrow time window before the sudden water contamination, so there is little opportunity to gauge the appropriateness of the counterfactual house trends.

2.2 Natural Experiment

This paper exploits a natural experiment to avoid the common identification pitfalls highlighted in the previous section. The setting for the natural experiment is freight rail traffic between the Los Angeles/Long Beach port complex and transfer facilities near downtown Los Angeles about 20 miles away. The Los Angeles and Long Beach seaports rank first and second in terms of container traffic into and out of the United States and combined comprise the fifth busiest port in the world. Until recently, much of that traffic passed through the city of Los Angeles on a collection of low speed rails to reach Union Pacific and BNSF transfer facilities. From there containers continue on to destinations throughout the United States. In April 2002, the Alameda Corridor opened,

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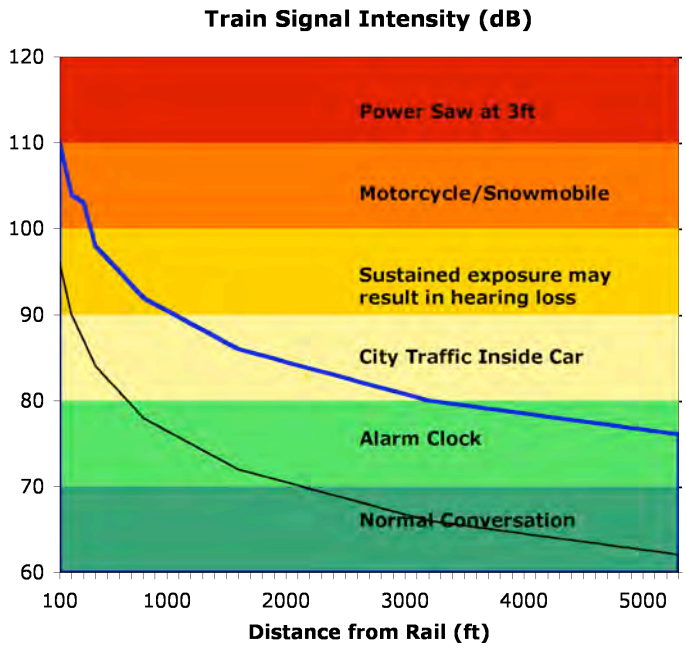
Figure 2: Bounds on Rail Noise Decay



connecting the port facilities to the rail yards by a more direct and higher capacity track. Also installed were a series of bridges, trenches, and underpasses at intersections with the purpose of eliminating more than 200 street level crossings. The goal of the $2.2 billion Alameda Corridor project was to increase the speed at which cargo travels through the port and to reduce the noise and traffic congestion caused by slow freight trains at street level. The opening of the Alameda Corridor should have reduced air and noise pollution in neighborhoods near the tracks through reduced rail traffic and fewer idling automobiles at railroad crossings. Upper and lower bounds on the noise decay from train signals are plotted in Figure 2, illustrating the potential noise impact fading to conversation level after approximately one mile.

The shift in rail traffic induced by the Alameda Corridor was a structural redistribution that decreased traffic along two of the three main routes between the port and the transfer facilities increased traffic on the third line. This exogenous redistribution is used to identify the causal impact of pollution and congestion from freight traffic on local home prices. The spatial shift can be seen clearly in Figure 1 while the annual changes are plotted in Figure 4. The y-axis in

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Figure 4 is the rail density code indicating the level of rail traffic as reported by the Federal Rail Administration and the year is on the x-axis. The west and east rails are the non-corridor rails where traffic decreased, while the center graph shows the sharp spike in traffic on the Alameda Corridor after the completion of the project.

2.3 Timing of Experiment and Perfect Foresight

Consolidation of the three rails into one higher speed track had been a topic of discussion in Los Angeles since the early 1980s, but did not become a reality until the late 1990s. Because the Alameda Corridor required nearly five years of construction before it opened in 2002 it is unlikely that homeowners near the corridor were taken by surprise when rail traffic skyrocketed after the opening. Due to the premeditated nature of this intervention, I am likely to see the impact begin to be capitalized into house prices before the actual opening of the corridor. The housing data available begin in 1995, before funding was secured or construction commenced, allowing capture of the full treatment period.

2.4 Housing Data

The housing data from DataQuick include all home sales in ZIP codes within 25 miles of the rails. The data set includes parcel number, address, sale price, sale date, lot size, bathrooms, bedrooms, and square feet. The data span the years 1995 to early 2009 and contain nearly 400,000 households that appear more than once - allowing for creation of a rich panel data set. The data is geolocated using the address and a streetline GIS file. After geocoding the housing data, a number of additional variables can be linked to each house including distance from rail lines, proximity to rail crossings, and Census block/tract.

Table 1 displays summary statistics for housing sales in the different rail zones. A house is considered to be in a rail zone if it is within one mile of the affected rail. This distance will be broken out into smaller increments in later analysis. Homes in the rail zones are on average smaller

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Table 1: Home Sale Summary Statistics: 1995-2009

	Sales	Price	Sq. Feet	Beds	Baths
Corridor Zone	10,991	171,705	1,165	2.67	1.46
West Rail Zone	33,222	276,197	1,392	2.80	1.89
East Rail Zone	19,634	208,478	1,246	2.64	1.63
Greater LA	519,258	356,324	1,582	2.84	2.05

Table 2: Difference-in-Difference Estimates

One Mile Bands		Incremental Bands DID	
Log Price in Corridor Before	11.68	Corridor 0 - 1/3 mile	-0.033
Log Price in Corridor After	12.29		(0.015)**
Difference	0.61	Corridor 1/3 - 2/3 mile	-0.025
Difference-in-Difference w/ LA	-0.018		(0.013)**
Standard Error on DID	(0.008)**	Corridor 2/3 - 1 mile	-0.002
			(0.013)
Log Price in Non-Corridor Before	12.03	Non-Corridor 0 - 1/3 mile	0.034
Log Price in Non-Corridor After	12.67		(0.010)***
Difference	0.64	Non-Corridor 1/3 - 2/3 mile	0.002
Difference-in-Difference w/ LA	0.013		(0.009)
Standard Error on DID	(0.006)**	Non-Corridor 2/3 - 1 mile	0.012
			(0.009)
Log Price in LA Before	12.32		
Log Price in LA After	12.95		
Difference	0.627		
Standard Error on Difference	(0.002)***		

and less expensive compared to homes in the rest of the city. Among the rail zones, the homes around the Alameda Corridor tend to be the smallest and least expensive. The differences in value and size of the homes in different zones highlight the need for care in controlling for localized price trends. As motivation for further study of home price trends in the rail zones we provide a simple difference-in-difference in Table 2. This table shows that the prices for homes within a mile of the Alameda Corridor, where rail traffic increased considerably, grew about 1.8 percent slower than homes in the rest of Los Angeles. The negative effect was also stronger for homes closest to the rail as can be seen when the one mile zone is broken into increments. For homes nearest to the non-corridor rails, where traffic was decreased, home prices outpaced the rest of Los Angeles by 1.3 percent. Again, the effect is strongest for homes nearest to the rail. Using the rest of Los Angeles as the counterfactual may not be correct and this will be explored later, but the simple difference in difference result motivates further inquiry.

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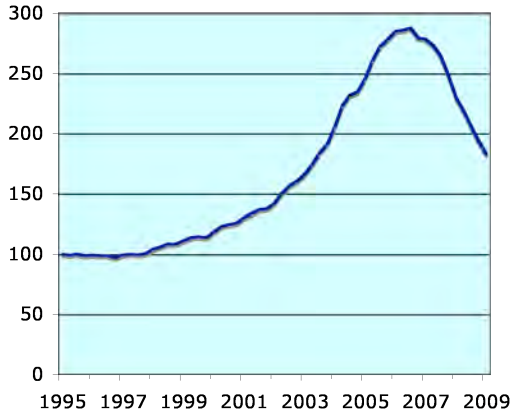
Figure 3: Los Angeles HPI (1995=100)



2.5 Housing Boom and Bust

The period under examination here contains the growth and subsequent popping of the house price bubble in the United States. Home prices in Los Angeles were not exempted from this phenomenon in the slightest. Figure 3 shows the rapid price growth witnessed in Los Angeles during the late 1990s and early 2000s and an equally rapid decline in prices when the bubble burst in 2006. The volatile nature of home prices during this period is even more reason to be careful when choosing a counterfactual set. Additionally, we want to be sure that our estimates are not being driven by the unusual events of the time period. We will report estimates that include the entire time period, boom and bust, and as a robustness check we restrict the sample to the period directly after the opening of the Alameda Corridor and drop transactions that occurred during the crash.

2.6 Rail Traffic Data

Rail traffic data are provided by the National Transportation Atlas published by the Bureau of Transportation Statistics. The data include a GIS map of the rail network along with a categorical measure of rail traffic density for each rail segment from 1995 to 2006. Rail density is a measure of the gross ton-miles of cargo traveled over a section of rail, divided by the length of the rail segment.

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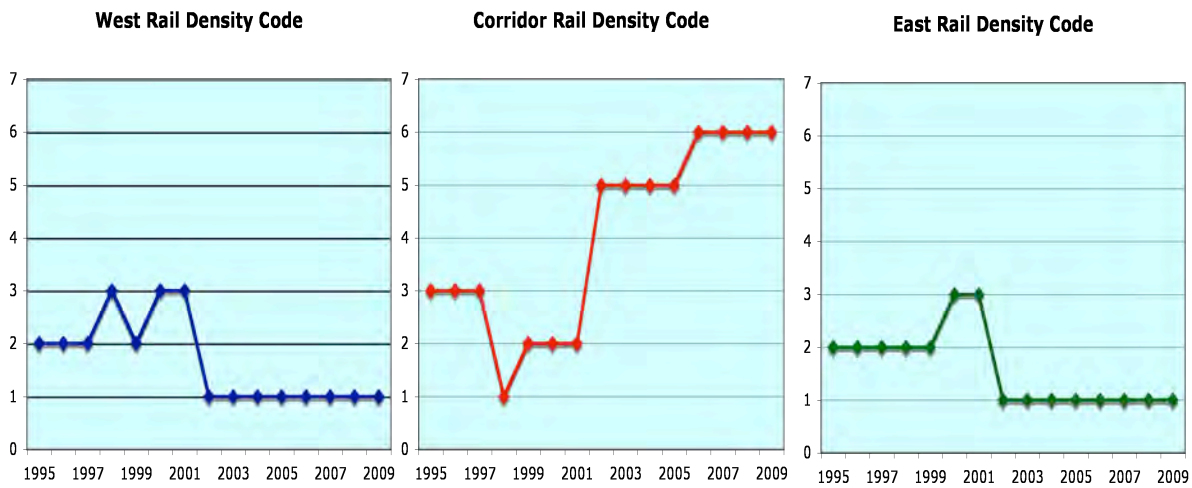
Figure 4: Annual Rail Traffic Density



For example, if a 100 mile track had only one gross ton of cargo traveling its length it would have a density of one gross ton mile per mile. A shorter track with the same number of gross ton miles would clearly have a much higher density. While not a perfect measure of the number of trains traveled, we believe it is an excellent proxy.

3 Estimation Strategy

3.1 Repeat Sale Framework

To estimate the causal impact of an increase in rail traffic on local home values we begin with the assumption that home prices follow a hedonic price function:

$$p_{i,t} = \alpha_i + \tau_t + \beta DEN_{i,t} * Proximity_i + \eta' x_i + u_{i,t} \tag{1}$$

where $p_{i,t}$ is the log price of home i at time t, τ_t is the local home price index at time t, $DEN_{i,t}$ is the rail density of the nearest rail interacted with some indicator for proximity to the rail, and x_i is a vector of home characteristics. Because our data contain repeated observations we can difference this equation with its previous sale, eliminating individual home idiosyncrasies and giving us the

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following equation:

$$\Delta p_{i,t} = \Delta\tau_t + \beta\Delta DEN_{i,t} * Proximity_i + v_{i,t} \tag{2}$$

The term $\Delta\tau$ represents the change in the local house price index between time t and the period in which the home was last sold. In order to estimate β we will need to first identify the appropriate counterfactual group, then use the methods pioneered by Case and Shiller (1987) to estimate local house price trends and find fitted values $\widehat{\Delta\tau_t}$ for each home sale. If a home was sold in 1995Q2 and again in 1999Q4, the fitted value for $\Delta\tau$ for that home will yield the expected price change for a home that sold in those time periods if the rail traffic pattern had not changed. The x_i could contain time-varying characteristics capturing home remodels or additions, though our housing characteristic data are limited in this respect and do not vary over time.

3.2 House Price Index Calculation

To control for counterfactual price changes and to evaluate whether a set is an appropriate counterfactual we estimate Case-Shiller style house price indices. Standard repeat sale estimation begins with log home price as the dependent variable and an indicator for time period sold on the right hand side of the equation.

$$P_i = \gamma + \tau_1 T_{i,1} + ... + \tau_n T_{i,n} + u_i \tag{3}$$

We arrive at the estimating equation by taking a first difference:

$$\Delta P_i = \tau_1 \Delta T_{i,1} + ... + \tau_n \Delta T_{i,n} + v_i \tag{4}$$

so that a home sold first in period s and subsequently in period t would have a value of 1 for $\Delta T_{i,t}$ and a value of -1 for $\Delta T_{i,s}$. The predicted log price change would then be given by $\hat{\tau}_t - \hat{\tau}_s$

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or, fitting with earlier notation, $\Delta\tau_t$. The τ coefficients are estimated using GLS, applying the standard heteroskedasticity correction for differing lengths of time between sales.

3.3 Selection of Counterfactual Set

Measuring the impact of rail traffic on housing prices requires an appropriate counterfactual to control for local price trends. House price trends are location specific, so the overall trend in a city or region may not be a good predictor of changes in a neighborhood. Other approaches have used matching methods to create a counterfactual group that resembled the affected homes in physical attributes. The approach taken here is to create a house price index (HPI) using homes that closely follow the pre-treatment trend in the rail zones, but are outside the one mile radius that we use to define the rail zone. The house price index can then be used to generate predicted values for the expected price change.

To find an appropriate counterfactual for homes in the affected rail zones we first compare the house price index for Los Angeles in general with the indices generated by homes in each zone. This is accomplished by running the standard repeat sale estimation equation and also interacting the housing index regressors with indicators for the relevant zone. If homes in each zone follow the same house price trend as the rest of the city, the difference in coefficients for each time period before the treatment should be insignificant. These differences are plotted for each zone in Figure 5. Panel (a) shows the difference between HPI coefficients for the west zone versus those for the rest of Los Angeles, panel (c) shows the same difference but for homes in the east zone, and finally panel (e) shows the differences for the corridor zone versus the rest of Los Angeles. Each of the three zones show statistically different house price index coefficients from Los Angeles as a whole. This is especially true for the east and corridor zones in panels (c) and (e). This indicates that using home prices for the rest of Los Angeles is not going to provide the correct counterfactual changes.

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As an alternative to using city-wide trends as the counterfactual, we propose using homes in the "marginal" rail zone, homes one to two miles from each affected rail. To test the validity of this counterfactual group we follow the same method as before. The difference in coefficients for each zone and its marginal zone are plotted in panels (b), (d), and (f) of Figure 5. In each case the HPI coefficients are statistically indistinguishable from those for the accompanying marginal zone - confirming that the marginal zones are indeed providing the correct counterfactual changes. For the remainder of the paper, the marginal zones around each rail will be used to produce fitted values to control for counterfactual changes in the absence of the rail shift, though using the city of Los Angeles as the counterfactual instead does not fundamentally alter the results.

4 Estimation

This section presents the basic estimation equations for measuring the impact of rail traffic density. While the rail traffic density decreased in the east and west zones and increased in the corridor zone, the coefficients on each density change regressor below are all expected to be negative reflecting the disamenity value of rail traffic in a neighborhood. The magnitude of the coefficients should be decreasing in absolute value as the distance from the rail increases, as homes further from the track are likely to experience lower noise, pollution, and congestion. In each specification below, the log price change for a home is regressed on the change in rail density, the predicted house price based on the relevant WRS index, and a vector of seasonal and neighborhood dummies. The method for choosing a predicted house price will be addressed in the following section.

4.1 Model 1 - Baseline

The first model examines the impact of the rail traffic changes in 1/3 mile-incremental bands around each affected rail without distinguishing between the Alameda Corridor and the other two rails. The assumption that all rail traffic affects home prices in the same way will be relaxed in later

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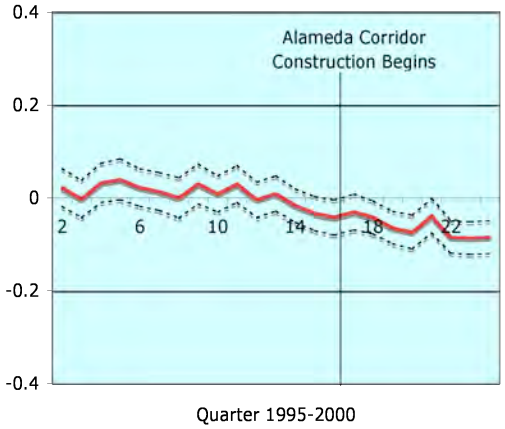
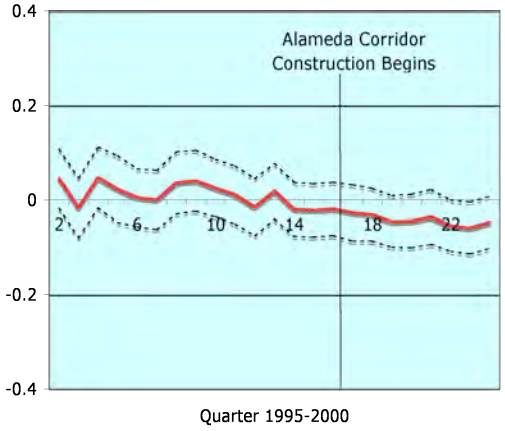
Figure 5: HPI Coefficient Differences and 95% Confidence Bands on Point Estimates

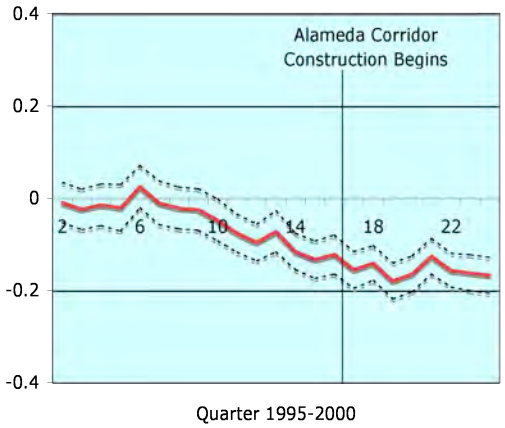
(a) West vs. LA



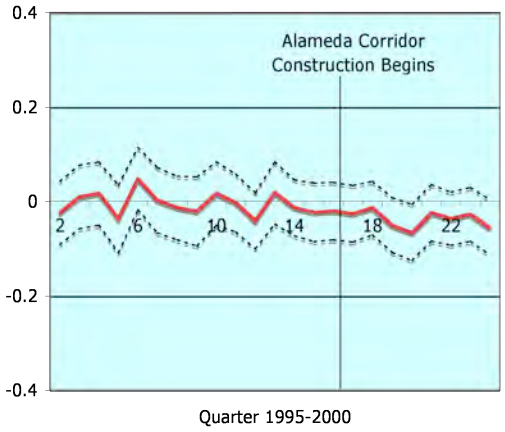
(b) West vs. Marginal West



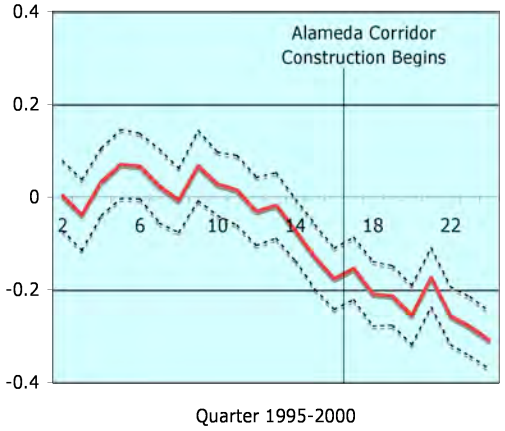
(c) East vs. LA



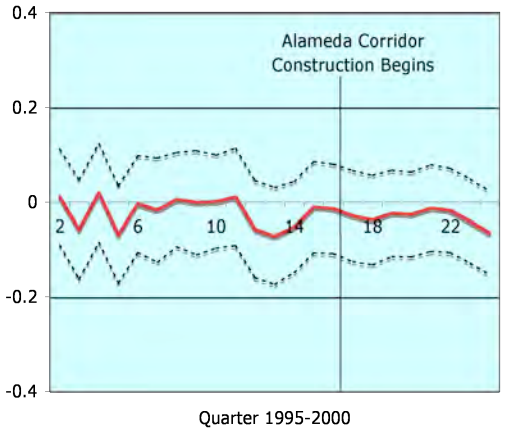
(d) East vs. Marginal East



(e) Corridor vs. LA



(f) Corridor vs. Marginal Corridor



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analysis.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \beta' x_i + u_i$$

The format for regressors indicating the zone in which the house is located is as follows:

$$AnyRail_{1,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (0,\ .33) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{2,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.33,\ .67) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{3,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.67,1) \\ 0 & \text{otherwise} \end{cases}$$

4.2 Model 2 - Railroad Crossing Increments

The second specification includes an indicator for proximity to railroad crossings. Federal law requires trains to sound their horn when approaching street crossings, which is likely to augment the already negative impact of train traffic through a neighborhood. Train signals are required to be heard between 96 and 110 dB from a distance of 100 feet. Figure 2 displays lower and upper bounds on the sound decay of a train signal as you move further away from the track. Because the Alameda Corridor was constructed using a series of trenches and bridges, railroad crossings only exist on the east and west rail lines. This model divides the intersection zone into 500 foot increments to explore how the impact of rail density evolves with distance around these intersections. Each home in the intersection crossing zone will also be located in the zone closest to the rail, so the full effect of a density change for these houses will be the sum of ψ_1 and λ. As with the incremental zone variables, the impact of the traffic change at an intersection is expected to fade with increased distance.

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$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * (Crossing_{j,i} * AnyRail_{1,i}) + \beta' \bar{X}_i + u_i$$

4.3 Model 3 - Heterogeneous Rail Traffic Impacts

Part of the intent for the Alameda Corridor was to move containers through the city without the need for rail crossings. This was accomplished through a series of bridges, trenches and underpasses. To allow for heterogeneous impacts from rail traffic density, the previous two models are expanded to distinguish between corridor and non-corridor rail traffic. The non-corridor traffic will be further disaggregated by geography.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * NonCorr_{j,i} + \sum_{j=1}^{3} \phi_j \Delta DEN_i * Corridor_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * Crossing_{j,i} + \beta' \bar{X}_i + u_i$$

5 Results

5.1 Locally Weighted Regressions

Before presenting the full regression results, inspection of Figure 6 helps to motivate the more detailed study. In each figure, the unexplained price change is non-parametrically regressed on the distance from the rail for home sale pairs both before and after the opening of the Alameda Corridor. The unexplained price change is found by taking the actual log price change less the predicted price change using the appropriate "marginal" rail zone discussed above. Panels (a) and (c) include homes within one mile of the rails where traffic was drastically reduced. Homes closest to the rail that were sold before the change in rail traffic grew in price about 10 percent less than expected, an effect that gradually fades toward zero as the distance increases, at least for the westernmost rail. The price-distance pattern is clearly different for the homes sold after the rail change. Homes close to the rail sold for more than expected and as the distance from the

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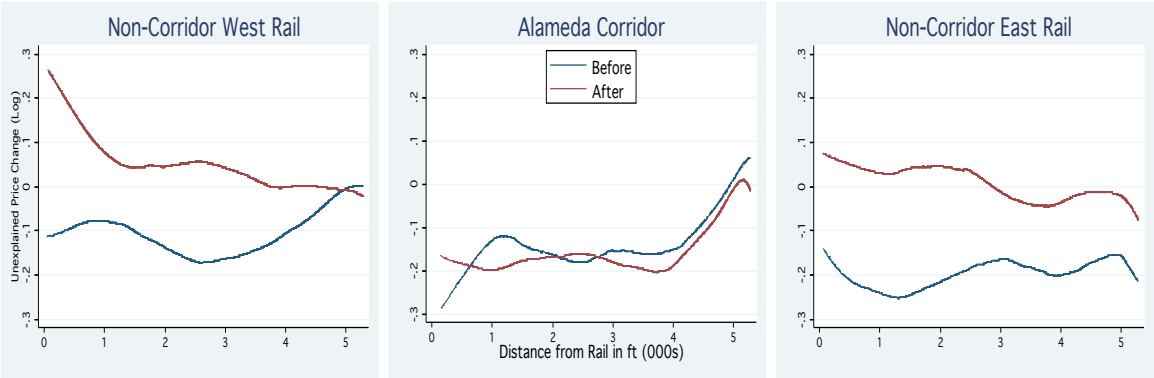

(a) Non-Corridor West Rail (b) Alameda Corridor Zone (c) Non-Corridor East Rail

Figure 6: Locally Weighted Distance Regressions

rail increases the difference between the actual and expected price change falls toward zero. These patterns give evidence that the rail change was not anticipated by home buyers in the rail zone and that the redirection of traffic has given a noticeable boost to home prices close to the rail, eventually fading as you get further from the line.

The plot in panel (b) shows the same non-parametric regression but for the homes around the Alameda Corridor itself where rail traffic was significantly increased. Regardless of whether it was sold before or after the opening of the corridor, homes closer to the corridor sold for less than expected. The gap between sale price and expected sale price narrows for homes located further from the corridor both before and after the opening, which fits with the idea that the impact of the rail traffic should die off with distance. The similar price-distance pattern for homes sold before and after indicates that prices in the corridor area were negatively impacted before the corridor opened. With an infrastructure project of this scale, it is not surprising at all that prospective home buyers and sellers in the area were aware of the potential impact. The fact that the pattern persisted even after the opening suggests that the negative impact of the rail traffic was not completely capitalized into home prices beforehand.

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5.2 Basic Model Results

The regression results for the first two models described earlier are summarized in Table 3. The units of the rail density measure in these regressions are hundred millions of gross ton miles per mile. In Panel A, the first column does not include zone or seasonal dummy variables or any housing characteristics, only the density change of the nearest rail interacted with the indicator for which zone in which the home is located. Column I shows a strong negative effect of an increase in the rail density for the homes within 1/3 of a mile of a rail. This indicates that for these homes, an increase in rail density of 100 million gross ton miles per mile will cause home prices in the area to fall by -0.6 percent. While this may seem small, the re-routing of traffic due to the Alameda Corridor increased traffic in the corridor zone by 50 to 90 million gross ton miles per mile. The negative effect of a density increase is lessened, but still statistically different from zero, for the next set of homes 1/3 to 2/3 of a mile from the rail. A one unit increase in rail density causes a -0.3 percent fall in the home price in this zone. Finally, for homes between 2/3 of a mile and one mile from the track the negative effect disappears. The coefficient for this last group is small and positive, but not significant. Column II includes zone indicators for all homes, seasonal dummies, and housing characteristics. All coefficients move towards zero and the standard errors are larger, but the overall pattern where the impact diminishes with distance remains.

Column III introduces indicators for proximity to a rail crossing interacted with the rail density change. The coefficient on density change for homes nearest an intersection (within 500 ft) is considerably more negative than for the rest of the zone but is not statistically significant. The period under study can be considered to be anomalous as the growth and subsequent popping of the real estate bubble characterizes the second half of the housing data. As a robustness check, Column IV restricts the data set to homes sold before the crash in housing prices. Truncation of the data pushes the coefficient on density change for homes nearest a crossing further negative. Since traffic was falling at these intersections we can interpret this result to mean the housing bubble

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likely sapped some of the price boost felt by homes in this area.

Thus far it has been implicitly assumed that homebuyers and sellers are myopic about the impact of the Alameda Corridor on home values. This assumption is especially strong for homes near the corridor itself, as construction spanned several years and was by no means a minor project. Ideally it would be possible to use a timeline of the corridor's construction or news stories about the planning of the corridor as the points in time when agents became aware of the potential home price impacts. Unfortunately, the housing data available for this paper begin in 1995 and planning for the corridor began in the early 1980s. Instead I exclude homes that were sold during the construction period of the corridor and report the results in Panel B of Table 3. Despite the reduction in observations, the coefficients do not change much and are more precisely estimated.

5.3 Heterogeneous Effects

The regressions above were re-run to allow the coefficients on rail density to differ for corridor and non-corridor traffic. We see in Table 4 the pattern of negative impacts dissipating with distance persists, but the coefficients for corridor traffic are larger and more precisely estimated. For homes in the zone closest to the non-corridor rails, a 10 MGTM/mi increase in density causes a -0.5 percent decline in home prices. However, rail traffic in these areas fell so homes were appreciating at a faster pace than expected. The impact of a density change in the next zone around non-corridor rails is negative, but only statistically different from zero if the housing crash is excluded. In the corridor zone a 10 MGTM/mi increase in density causes a -0.8 percentage point lower growth than expected. This translates to a 4 percent lower home price growth when rail traffic increased by 50 MGTM/mi.

It should be noted that, while they are not statistically different, it is somewhat unexpected that the coefficient on corridor traffic is larger in absolute value. My expectation was that the coefficient would be smaller, capturing the concavity created by diminishing effect of greater amounts of traffic

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Table 3: Impact of Rail Traffic on Home Prices

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Any	-0.062	-0.050	-0.032	-0.024	-0.062	-0.049	-0.016	-0.008
	(0.010)***	(0.022)**	(0.026)	(0.039)	(0.015)***	(0.018)***	(0.020)	(0.027)
1/3 - 2/3 mi. from Any	-0.035	-0.044	-0.051	-0.086	-0.039	-0.051	-0.063	-0.111
	(0.012)***	(0.020)**	(0.018)***	(0.019)***	(0.014)***	(0.020)**	(0.022)***	(0.027)***
2/3 - 1 mi. from Any	0.019	0.010	0.004	-0.020	0.025	0.018	0.006	-0.029
	(0.018)	(0.011)	(0.026)	(0.023)	(0.014)*	(0.015)	(0.014)	(0.020)
500 ft from Crossing			-0.248	-0.298			-0.286	-0.353
			(0.169)	(0.121)**			(0.105)***	(0.107)***
1000 ft from Crossing			-0.015	-0.010			-0.067	-0.076
			(0.059)	(0.071)			(0.066)	(0.074)
1500ft from Crossing			-0.040	-0.082			-0.079	-0.122
			(0.076)	(0.080)			(0.070)	(0.077)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	28586	28586	28586	20578	24833	24833	24833	17675
R-squared	0.8518	0.8536	0.8537	0.8283	0.8339	0.8358	0.8358	0.8058

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

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- a hypothesis that will be tested later. One possible explanation is that homeowners and sellers surrounding the non-corridor rail were better informed as to the impact of the rails, they could have acted on this information prior to the redirection of traffic, dampening the total effect. Under this circumstance, excluding the construction period should bring the estimates for each zone closer together, which we can see in Panel B is the case.

Once construction period homes are excluded, we find that rail density changes have similar impacts for homes in the first two zones around corridor and non-corridor rails. While the impact of density changes for the first two zones are similar, the effect dies out faster for non-corridor homes. Homes located between 2/3 of a mile and one mile from the Alameda Corridor still felt a negative impact, falling -0.2 percent for each additional 10 MGTM/mi. However, homes that are the same distance from non-corridor rails do not experience a measurable impact from a rail change. Whether using Panel A or B, the strength of the density effect is greatly magnified for homes in the immediate vicinity of rail road crossings. Rail density in this area fell from about 30 MGTM/mi to 2.5 MGTM/mi meaning homes nearest the rail grew about 8.3 percent above the expected price.

When the non-corridor traffic is disaggregated even further (Table 5), separating the rail west of the corridor from the rail to the east, we find that the effect of the rail density change is concentrated around the railroad crossings and is stronger in the west. In fact, there is no effect for homes around the east railroad unless located near an intersection. The coefficient on density change for homes nearest to an east intersection should be disregarded as very few homes are located in this zone and even fewer (16) have sale pairs spanning a density change. These coefficients for rail crossing homes are negative, but only significant if we consider home sales before the housing bust, suggesting that any stronger growth felt in the area was given back when housing prices began falling. There are two possible explanations for the weaker results along the east rail. First, if container traffic from the port does not leave on rail, it leaves on trucks. Interstate 710 is the major truck route leaving

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Table 4: Impact of Rail Traffic on Home Prices: Heterogeneous Impacts

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor	-0.050	-0.037	0.005	0.000	-0.068	-0.058	-0.006	-0.007
	(0.029)*	(0.023)	(0.030)	(0.046)	(0.027)**	(0.024)**	(0.036)	(0.045)
1/3 - 2/3 mi. from Non-Corridor	-0.023	-0.033	-0.032	-0.073	-0.042	-0.056	-0.056	-0.108
	(0.019)	(0.026)	(0.032)	(0.026)***	(0.028)	(0.027)**	(0.029)*	(0.038)***
2/3 - 1 mi. from Non-Corridor	0.032	0.022	0.022	-0.007	0.023	0.013	0.013	-0.025
	(0.017)*	(0.019)	(0.024)	(0.025)	(0.020)	(0.021)	(0.020)	(0.031)
0 - 1/3 mi. from Corridor	-0.080	-0.088	-0.088	-0.138	-0.071	-0.076	-0.076	-0.148
	(0.016)***	(0.013)***	(0.024)***	(0.036)***	(0.015)***	(0.022)***	(0.022)***	(0.030)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.056	-0.056	-0.056	-0.068	-0.063	-0.063	-0.059
	(0.014)***	(0.020)***	(0.018)***	(0.024)**	(0.014)***	(0.014)***	(0.022)***	(0.021)***
2/3 - 1 mi. from Corridor	-0.035	-0.033	-0.033	-0.062	-0.024	-0.027	-0.027	-0.040
	(0.013)***	(0.016)**	(0.016)**	(0.020)***	(0.013)*	(0.017)	(0.020)	(0.022)*
500 ft from Crossing			-0.276	-0.314			-0.290	-0.349
			(0.122)**	(0.183)*			(0.113)***	(0.111)***
1000 ft from Crossing			-0.044	-0.026			-0.072	-0.071
			(0.069)	(0.083)			(0.058)	(0.065)
1500 ft from Crossing			-0.069	-0.098			-0.084	-0.117
			(0.044)	(0.084)			(0.066)	(0.083)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	No
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	No
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	No
Observations	28586	28586	28586	20578	24833	24833	24833	24833
R-squared	0.8520	0.8537	0.8538	0.8283	0.8341	0.8359	0.8359	0.8059

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

the port and cuts directly through the east rail, so it is possible that rail traffic has been substituted for truck traffic in this area; something that could be explored further. Additionally, the homes in the most densely populated area of the east rail zone are also located adjacent to the rail yards where idling train have created a health risk for neighboring communities (ARB 2007). For the west rail, the coefficients are comparable to the earlier estimates, but the precision is reduced. If the construction period is excluded, we get the familiar pattern of a strong negative effect of rail density that diminishes as you move further from the rail.

5.4 Convexity of Costs

The nature of traffic shift that occurred due to the Alameda Corridor offers an opportunity to explore how homeowners react to differing levels of an externality. Homeowners along the corridor were faced with sharp increases in rail traffic near their homes, while homes in other areas experienced a sharp decline in traffic. This tandem upward and downward shift allows us to gain some insight into the marginal cost structure associated with the intensity of this externality. If the marginal cost of an increase in traffic is different in absolute value than the marginal cost of a decline in traffic the welfare implications of rail traffic will hinge on where these burdens are borne. Consider a situation where two equally populated neighborhoods each had a track running through. If the marginal cost of traffic were increasing total welfare would be largest with an equal distribution of traffic. However, if the marginal cost were diminishing an argument could be made that one of the neighborhoods should carry the traffic and could be compensated in some way by the other. If the marginal cost were constant, distribution of the traffic would be less important as it does not impact the magnitude of the welfare impact.

The test we perform to determine whether marginal costs are increasing or decreasing is to use a approximation to the marginal cost and compare the regression coefficients for a change in density in the corridor zone versus the non-corridor zone. Because the the areas have different

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Table 5: Impact of Rail Traffic on Home Prices: Disaggregated Zones

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III		I	II	III	
Δ Rail Traffic :	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor West	-0.069	-0.063	-0.027	-0.030	-0.098	-0.088	-0.046	-0.050
	(0.039)*	(0.038)*	(0.045)	(0.060)	(0.040)**	(0.041)**	(0.064)	(0.066)
1/3 - 2/3 mi. from Non-Corridor West	-0.035	-0.051	-0.051	-0.102	-0.063	-0.079	-0.078	-0.155
	(0.030)	(0.029)*	(0.039)	(0.048)**	(0.032)**	(0.040)*	(0.033)**	(0.042)***
2/3 - 1 mi. from Non-Corridor West	0.022	0.014	0.015	0.000	0.016	0.012	0.012	-0.024
	(0.029)	(0.024)	(0.031)	(0.035)	(0.033)	(0.041)	(0.032)	(0.045)
0 - 1/3 mi. from Non-Corridor East	-0.012	0.009	0.034	0.021	-0.009	0.011	0.045	0.040
	(0.050)	(0.031)	(0.050)	(0.069)	(0.052)	(0.033)	(0.042)	(0.049)
1/3 - 2/3 mi. from Non-Corridor East	0.004	0.000	-0.000	-0.028	0.005	0.001	0.000	-0.019
	(0.038)	(0.037)	(0.047)	(0.037)	(0.059)	(0.042)	(0.043)	(0.040)
2/3 - 1 mi. from Non-Corridor East	0.051	0.035	0.035	-0.026	0.043	0.032	0.032	-0.020
	(0.036)	(0.036)	(0.039)	(0.024)	(0.044)	(0.031)	(0.035)	(0.050)
0 - 1/3 mi. from Corridor	-0.080	-0.087	-0.087	-0.139	-0.070	-0.071	-0.071	-0.147
	(0.015)***	(0.013)***	(0.025)***	(0.035)***	(0.017)***	(0.023)***	(0.022)***	(0.028)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.055	-0.055	-0.058	-0.067	-0.059	-0.059	-0.057
	(0.015)***	(0.019)***	(0.019)***	(0.026)**	(0.018)***	(0.016)***	(0.021)***	(0.022)**
2/3 - 1 mi. from Corridor	-0.035	-0.032	-0.032	-0.063	-0.022	-0.022	-0.022	-0.039
	(0.016)**	(0.017)*	(0.016)**	(0.020)***	(0.010)**	(0.018)	(0.019)	(0.023)*
500 ft from West Crossing			-0.275	-0.325			-0.275	-0.344
			(0.137)**	(0.228)			(0.143)*	(0.138)**
1000 ft from West Crossing			0.004	0.045			-0.015	0.009
			(0.090)	(0.096)			(0.066)	(0.088)
1500 ft from West Crossing			-0.050	-0.047			-0.055	-0.059
			(0.071)	(0.110)			(0.083)	(0.099)
500 ft from East Crossing			-0.120	0.123			-0.129	0.091
			(0.232)	(0.483)			(0.273)	(0.480)
1000ft from East Crossing			-0.124	-0.219			-0.151	-0.251
			(0.136)	(0.116)*			(0.168)	(0.144)*
1500 ft from East Crossing			-0.061	-0.184			-0.084	-0.197
			(0.085)	(0.064)***			(0.087)	(0.100)**
R-squared	0.8520	0.8537	0.8539	0.8283	0.8341	0.8359	0.8361	0.805
Observations	28586	28586	28586	20578	24833	24833	24833	17675

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

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home values we will need to incorporate this difference into the test in order to find the marginal dollar cost. Additionally, to test convexity of the cost structure some stronger assumptions have to be made. I am forced to assume that an increase in rail traffic in each area causes the same level of negative impact and that the difference in how it is capitalized into home prices is due to individuals preferences over these impacts. This may be a difficult assumption to accept as the Alameda Corridor was constructed such that trains would no longer cross streets at surface level. Removing traffic from surface level interactions is likely to reduce the impact that homeowners perceive, so our test is possibly biased towards accepting the hypothesis that marginal costs are diminishing. The hypothesis test is as follows:

$$\begin{aligned} H_0 &: \psi_1 AvgPrice_{NonCorridor1} = \theta_1 AvgPrice_{Corridor} \\ H_1 &: \psi_1 AvgPrice_{NonCorridor1} > \theta_1 AvgPrice_{Corridor} \end{aligned} \tag{5}$$

Using estimates from Table 4 we fail to reject the null hypothesis that marginal costs are constant. The coefficients on density change are similar or higher in the corridor zone, but the average home value is higher in the non-corridor zone. A change of 10 MGTM/mi in rail density causes a change in home value of $1,180 in the western non-corridor zone, $863 in east rail zone, and a $832 change in home value in the corridor zone. The difference between these estimates is not statistically significant at any conventional level. While this test is imperfect due to the strong, and possibly invalid, assumptions required, it does still provide some evidence against diminishing marginal cost of the externality as the test is biased in the direction of finding diminishing marginal costs, but finds no evidence of this. Performing a joint test of the hypothesis that the marginal effects for each distance band are the same between corridor and non-corridor rails brings us to the same conclusion.

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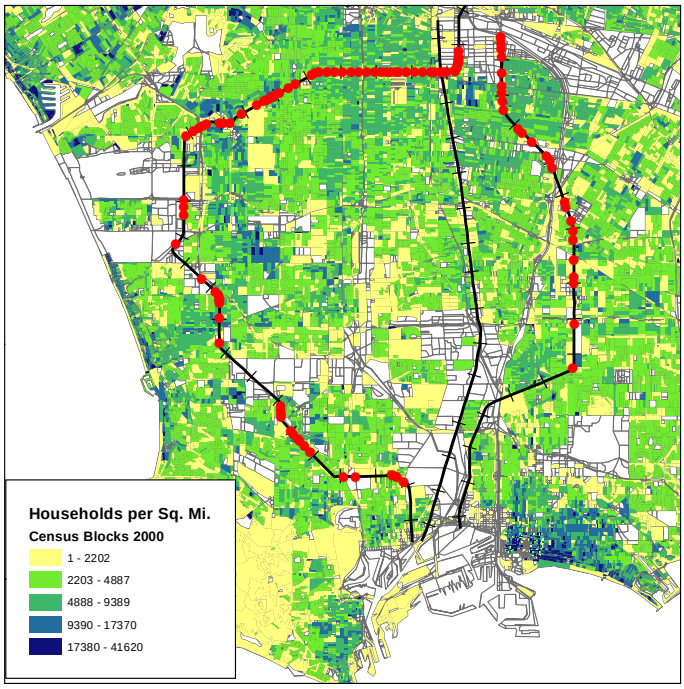
Figure 7: Household Density



5.5 Aggregating Impact

If the population density and distance of each affected line were identical we would only need the marginal effect and density change to determine whether the net effect capitalized into home prices was positive or negative. As can be seen in Figure 7, the population density is not constant along each line and, in fact, there are very few homes near the lower section of the central Alameda Corridor. In addition to changing population densities, the length of each line differs. To understand how this affects the overall impact of the rail shift, we must tabulate the number of homes and the average price in each zone. Using Census 2000 data we find the number of housing units in each Census block and using our housing data we find the average pre-treatment price. Using this information and the marginal effects calculated in the earlier regressions we can add up the total impact capitalized into home prices. Figure 8 displays number of housing units affected on the x-axis, sorted by distance to a rail, and the cumulative impact on the y-axis with the negative and positive impacts plotted separately. In panel (a) we use the regression coefficients from Panel B Column II of Table 5 to estimate the total effect on housing, finding the positive impact to be

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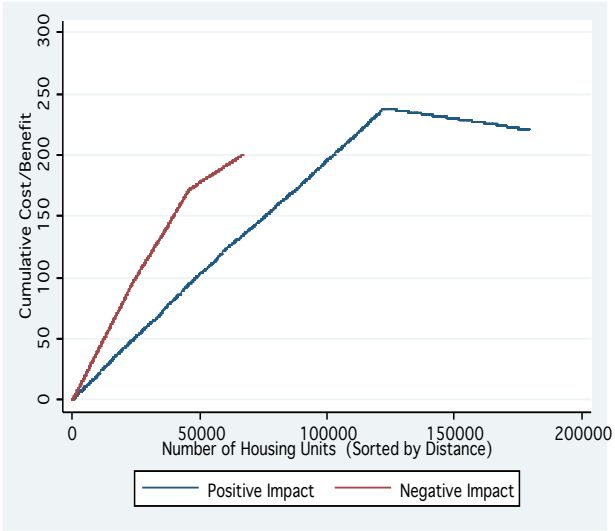
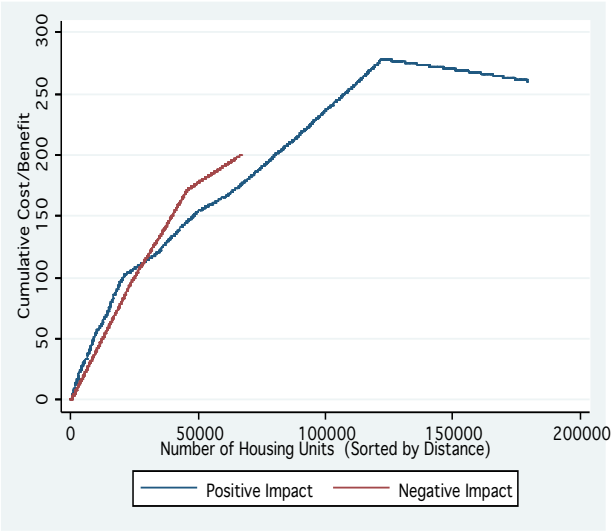
Figure 8: Cumulative Impact of Rail Shift

(a) Disaggregated Impacts



(b) Intersections



roughly $23 million greater than the negative impact. It should be noted that line for the negative impact is more steeply sloped, not because of a difference in the marginal effect, but because the change in rail traffic was greater on the Alameda Corridor than on the individual non-corridor rails. Finally, when we use the most detailed specification including the effect on homes around the railroad crossings we see in panel (b) that the positive impact is now steeper initially due to the magnified effect around the rail crossings and that the gap between the positive impact and negative impact is wider. Considering the magnitude of the housing value in the one-mile zone around the rails totaled $36 billion in 1997, the small total positive impact is negligible. While the net impact may be negligible, there has been a significant transfer of housing value from the communities surrounding the Alameda Corridor, which tend to be predominantly minority and lower income, to higher income neighborhoods surrounding the non-corridor rails.

6 Conclusion

This paper exploited a natural experiment to measure the positive and negative impacts of rail traffic on neighboring homes. I find strong evidence negative spillovers from local rail traffic nega-

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tively impact home values. Additionally, the case for concentration of a negative externality is not supported as I did not find evidence of concavity or convexity of the cost of rail traffic on homes. Therefore a zero-sum redistribution of traffic would be expected to have no impact. In this case, there was a small positive impact on housing values as a result of the more direct routing of traffic. Because the Alameda Corridor saw a larger increase in absolute value than the decrease on the other lines, the negative impact felt by a home along the Alameda Corridor was greater in absolute value than the positive impact received by a home along a rail where traffic was reduced. However, there were many more homes along the non-corridor rails leading to the small net positive effect. The positive gain was muted by the narrowly focused impact felt around the eastern non-corridor rail. Because of the confounding effect of the 710 interstate and nearby inter-modal railyards, the positive benefit was confined to the homes near rail crossings.

The rail traffic setting explored here is ideal for investigating the negative externality effects of infrastructure expansions with little interference from demand side effects. If the re-routing experiment had been for highway or airport traffic the negative impacts would have been more difficult to measure as the positive effects of proximity to airports or reduced commute times would have likely influenced home values. The use of freight rail traffic allowed for cleaner estimation of this impact. The most likely source of this type of demand side impact from freight rail would be from greater employment opportunities during construction, though the longer window of data available allows this issue to be circumvented.

Infrastructure expansions are often touted as local job creators, but there are also costs borne by the localities. Understanding the spatial dispersion of the costs and whether there are convexities is necessary when evaluating these projects. From this paper, the lack of evidence of diminishing marginal cost suggests that concentrating the negative impacts of an infrastructure project yield no reduction in the welfare costs. The fact that we uncover a relatively linear marginal damage curve for winners and losers from this infrastructural redistribution indicates that there are no complex

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welfare dynamics at work, at least as revealed by home prices. This would indicate that planners considering future projects will maximize welfare simply by making transportation infrastructure as direct and efficient as possible when local impacts are unavoidable.

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Attachment K
Exhibit 4012-000030-CWF
Columbia Waterfront LLC

Impacts Of Rail Transit On Property Values

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ABSTRACT

Introducing rail transit into a region often creates expectations about the impact of the rail project on property values. Information on the impact of rail on property values is often incomplete and limited to anecdotal evidence, leaving regions planning for rail investments without a firm basis to judge the future impact of such an investment. In addition, this lack of complete information limits the extent to which transit agencies can develop strategies to maximize positive property value impacts. This paper summarizes a comprehensive survey of recent research on the impact of rail transit and property values. The impact of twelve rail projects (including both heavy rail and light rail) throughout North America is compared to develop general conclusions about the impact of rail on property values. In general, proximity to rail is shown to have positive impacts on property values. This conclusion is based on several measures of property value such as sales prices of single-family homes, apartment rents, and median home value. This survey of recent experience also reveals that the relative impact of rail transit is affected by a number of factors. The relative increase in accessibility provided by the new transit investment is the primary factor in increasing property values. In addition, some studies show that such factors as proximity to industrial uses or to highway facilities may limit the extent to which property values are increased. These conclusions suggest a number of strategies that transit agencies can undertake to ensure maximum property value benefit for land along future rail alignments.

INTRODUCTION

The introduction of a rail transit investment brings benefits to the transportation system and to the accessibility of the population to employment, retail, and recreation activities. Rail transit investments also introduce a variety of impacts to the area around the rail alignment. One of the most significant impacts of a rail transit project is the impact on property values. Numerous accounts of recent experiences with the impact of rail transit on property values have surfaced within the past two decades with varied results and general conclusions based on the local conditions of the rail transit systems studied. These numerous accounts often appear as isolated anecdotes in documenting the impact of rail transit on property values.

This paper presents a summary of the recent studies that examine the impact of rail transit on property values. It synthesizes the research in order to draw general conclusions and to place the various experiences in the context of one another. The summary begins with an enumeration of impacts of rail on single family homes. It continues with a discussion of additional studies that suggest that there are disparate property value effects based upon other factors. This discussion identifies various variables associated with a rail transit investment that contribute to positive and negative changes in property values. Finally, the summary ends with a suggestion that the primary positive impact of rail on property values is the impact due to accessibility.

The latter half of the paper speaks generally about another way that rail transit can affect property values, through new development. Because the documentation on the actual value increase is not as well documented as the value difference due to accessibility differences, the discussion focuses on general principles associated with the increased ability to develop land and the factors that contribute to intensification and changes in use. The paper concludes with a general discussion of strategies transit agencies can take to ensure maximum property value benefit.

IMPACTS ON PROPERTY VALUES

Positive Impacts of Rail on Residential Property

One of the more prominent ways that people understand the value of property is through the price or value of a home that they own or in the rent that they pay. Generally, individuals working in an office building or

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purchasing goods in a retail store do not readily know the rents charged for office space or retail space. In addition, the amount of space devoted to residential property is generally greater than that devoted to other uses. Given that the number of residential property owners or of residential renters is greater that the number of consumers of other types of real estate, the effects of rail transit on rail transit are most acutely felt in the residential sector. For these reasons, much of the research performed on the impact of rail transit on property values focuses on the impact on residential property values.

The analysis of residential property impacts begins with a study on apartment rentals around stations on the Bay Area Rapid Transit (BART) system. The Bay Area Rapid Transit system in the San Francisco Bay Area is a transit system with the most well-documented impacts in the United States. Recent studies associated with the twentieth anniversary of the regional heavy rail system have detailed the impact of BART on property values. In a study to examine the potential for housing near transit, comparisons were made between the property values of new housing developments around several transit stations (many of them newly constructed) and developments well outside of BART station areas. Rental housing units near BART were found to enjoy higher rents over those away from the BART system. For example, one bedroom apartment units within a quarter-mile of the Pleasant Hill BART station in suburban Contra Costa County, east of San Francisco, rented for approximately 10% more per square foot than one bedroom units away from BART. Following a similar pattern, two bedroom units near the station rented at approximately 16% more per square foot than comparable units in the same general area but farther from BART. Another suburban area encompassing the cities of Union City and Freemont experienced a similar pattern of higher rents for transit-proximal locations.

This pattern was not widely felt, however, throughout the BART service area. For example, in northern Alameda County area encompassing the communities of Albany, El Cerrito, and Richmond, apartment unit rents exhibited no significant difference based on the distance from the BART station. This helps to highlight that different communities experience property value benefits differently. In some communities, transit options and transit accessibility play a larger role in housing prices than in others. Examining the difference even further with tests that hold other variables constant, such as the number of bedrooms, the age of the unit, and the presence of amenities such as playgrounds or weight rooms on the site of the housing complex, the rent premium for being within one quarter-mile of BART was found to be $34 more per month. (1)

A separate study of the impacts of the BART system examined the impact on home values. Statistical models developed to analyze the impact of proximity to rail on property values showed that for every meter a house in Alameda County was located closer to the nearest BART station, its sales price in 1990 increased by $2.29. For every meter a house was closer to the nearest BART station in Contra Costa County, the sales price increased $1.96. According to the models, a house immediately adjacent to BART would sell for close to 38% more than an identical house not near any BART service (35 kilometers away). (2) Effectively, this comparison may represent the difference between the sales price of the home near a station of a mature rail system and the sales price of a home in a region without a mature rail system.

Another heavy rail system experienced mixed results with respect to the impact on property values. An analysis of single family home prices near the 21-mile heavy rail Metrorail system in Miami-Dade County, Florida revealed mixed results. In an analysis of comparing home price sales from 1971 (13 years before the 1984 opening of the heavy rail line) to 1990 (6 years after opening), property values near Metrorail stations experienced at most a 5% higher rate of appreciation in sales value compared to the rest of the City of Miami. The Miami study also found varying effects of proximity to rail. Housing prices in some neighborhoods also varied. Interestingly, the study attributed these variations to neighborhood type. For example, the introduction of Metrorail weakly increased the value of existing properties near transit stations in higher priced neighborhoods experiencing growth. Properties in neighborhoods experiencing decline showed almost no relative benefit to property values.(3)

An examination of areas near commuter rail systems in suburban Philadelphia confirms that there is a similar effect associated with commuter rail service. For two separate commuter rail systems, there are proven premiums for being near commuter rail. In suburban New Jersey, for example, the median home price for census tracts immediately served by the rail line operated by PATCO was generally 10% higher that the median home price in census tracts located away from the rail line. This differential was evident in the same direction for the Philadelphia suburbs within Pennsylvania. The average median home price for census tracts served by SEPTA commuter rail enjoy a 3.8% premium over the average median home price for census tracts not directly served by commuter rail.(4)

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The Potential for Negative Impacts

Given the positive nature of the correlation between rail transit service and property values, is there any potential for negative effects caused by new transit infrastructure? Can factors such as noise, traffic, safety, or aesthetics negatively affect property values? Two recent experiences – one with light rail and one with heavy rail – place the potentially negative effects in perspective.

A 1993 study of the Eastside Metropolitan Area Express (MAX) light rail transit line reviewed the impacts of rail transit to property values in suburban Portland. In general, Portland's experience is generally consistent with the results of the studies in other areas. Within the 2 years after the 1986 beginning of operation of the rail line, residential properties in the East Burnside area within 500 meters of the transit were, on average, 10.6% greater in value than homes outside of 500 meters. Properties within the 500 meter walking distance generally experienced higher property values the closer a property was to the station. Within the immediate station area, however, nuisance effects such as noise and increased traffic reduce the potential property value impacts of those properties closest to the station area. Nevertheless, that there is a net benefit shows that, at least in the case of this particular area within metropolitan Portland, the benefit of rail transit overshadows the nuisance effects.(5)

In Atlanta, the impacts of rail transit were tested in an area of DeKalb County along the East Line of the Metropolitan Atlanta Rapid Transit Authority. This study area was chosen because the neighborhood types served by the line to the north and south of the line are dramatically different enough to demonstrate if there are relative differences due to neighborhood types. The east line follows the right of way of freight railroad tracks stretching to the east from downtown Atlanta. As such, industrial uses lie on both sides of the rail transit line, generally adjacent to the right-of-way. These industrial uses, the railroads, and the MARTA East Line form a buffer between the neighborhoods to the north and south of the right-of-way. The areas to the north of the line comprised predominantly middle class neighborhoods with some prominent affluent sections. The areas to the south of the line are predominantly lower income, lower middle class neighborhoods. In 1980, the average value of housing on the north side of the tracks were more than twice the value on the south side of the tracks. At the same time, the mean family income on the north was close to twice that on the south side. The fact that these two dramatically different neighborhood types were served by the same transit line presented the opportunity to examine if the impacts of rail transit on property values depend upon the characteristics of the neighborhood.

Examination of the effects of proximity to rail transit for these two neighborhoods showed that proximity to rail showed a positive effect on property values on the south side, but a negative effect in the neighborhood on the north side. In the neighborhood on the south side, property values increased close to $1045 for every 100 feet a property was closer to the East Line. The opposite occurred on the north side. For every 100 feet a property was closer to the East Line, property values dropped by $965. This negative effect may be due to such factors as noise, perceptions of crime, and visual intrusion. The pattern of rising property values as one travels to the north of rail tracks may also have to do with the general pattern of rising incomes as one travels to the north. In addition, proximity to the industrial uses and the freight railroad right-of-way were may also be deterrents to high property values. In the case of the south side, the value of accessibility provided by the rail line more than compensated for these nuisance effects. On the north side, the value accessibility was not enough to compensate for the nuisance effects. (6)

While the Atlanta experience appears to demonstrate the opposite effect of that shown in Miami, these differences can be explained by the assertion that rail transit imparts value to residential property in districts where the population values the access provided by that transit service the most, regardless of the income of the district. In Miami, higher growth, higher priced neighborhoods experienced a greater positive effect than stagnant, lower priced neighborhoods. In Atlanta, it appears that the opposite may be the case. The higher income neighborhoods did not appear to show value associated with being near rail while lower income neighborhoods did show positive value with that association. While this may appear to be a contradiction, these facts highlight one of the primary reasons why rail transit imparts value to properties. Rail transit shows positive correlation to property values to areas where the access provided by the transit service is valued. This is the case for both the high growth, higher valued districts in Miami and the lower income groups in suburban Atlanta.

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Factors Affecting The Magnitude Of Property Value

Impact

Access to Employment

These studies all suggest that there are generally positive impacts of proximity to rail transit on property values, although some experience more pronounced increases than others. This leads to the following question. What is it about a rail transit system increases the value of property? And why do property values increase more in some cases than in others? The comparison of the Atlanta experience and the Miami experience highlight that the value of accessibility provided by rail transit accounts for a significant part of the impact on property values. The experience around the Philadelphia to Lindenwold High Speed Line supports this notion. In studying the impacts around this heavy rail connection between Philadelphia and suburbs in Southern New Jersey, is was found that there was an increase in value of $149 (in 1971 dollars) in the price of a single family home for each dollar value of time savings to the Philadelphia central business district.(7) A similar effect was felt in the Toronto area. The average premium for the average home served by the new Spadina heavy rail line was found to be C$2,237. Commute time savings contributed most to these premiums. (8) Effectively, individuals are capitalizing the time savings they receive by a lower priced commute into a higher priced home purchase.

Another study conducted in the Philadelphia area, examined the impact of commuter rail service on property values. Regional census tracts with commuter rail services averaged 12% more of their residents working in downtown Philadelphia than surrounding census tracts. Census tracts in suburban Philadelphia near Southeastern Pennsylvania Transportation Authority commuter rail lines generally had a median home price 3.8% above the median home price of census tracts not near commuter rail. Census tracts in Philadelphia suburbs in New Jersey near commuter rail lines operated by the Port Authority Transit Corporation (PATCO) demonstrated a median home price of 10% above those not near commuter rail. (4)

This experience suggests that the primary advantage of properties near rail over those not near rail transit is the additional accessibility that the rail transit line brings to those properties near transit. The added convenience of accessibility manifests itself to different types of properties. Residential properties become more attractive because residents near rail more convenient access to regional employment, retail, and cultural opportunities. Properties holding employment uses such as offices and industrial sites experience higher property values because such properties have increased access to a larger labor market. In fact, office properties demonstrate a larger property value increase compared to industrial sites because office buildings tend to cluster in more dense concentrations, allowing for the benefit of rail to be more acutely felt. Finally, retail properties often benefit from the fact that rail transit contributes to the concentration of activity and increases in pedestrian traffic in transit-accessible, pedestrian-oriented districts.

Pedestrian Accessibility

Most of the tests of the impact of rail on property values showed that the positive effects of rail transit on property values were most prominently felt within a very limited distance from transit stations. This distance is determined by the distance of a reasonable walk from the station, generally one quarter mile to one-half mile. Beyond this zone, the effect of the proximity to rail on property values is neglible. Easier automobile access to stations, therefore, has limited appreciable effects on property values. This highlights the importance of creating more the pedestrian connections to rail transit stations and the enhancing the pedestrian environment around stations.

Market Penetration

The extent of property value increase appears to be affected by the market penetration of transit in the respective area. A comparison of various California rail systems confirms this. Statistical analyses compared 5 rail systems in California – the CalTrain commuter rail line connecting San Mateo County to San Francisco and San Jose, BART in the San Francisco Bay Area, the light rail systems Sacramento, San Jose, and San Diego. The study confirmed that the that those systems with the highest rates of ridership and that reached more locations within their respective regions, such as BART and the San Diego Trolley experienced the most significant association between distance from transit stations and property values. Property values in the regions these systems serve increased more than $2 per meter the closer the property was to the transit alignment. This effect was stronger and more significant

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in some portions of these regions than in others. Proximity to the CalTrain commuter rail service, and the Sacramento light rail system and the San Jose light rail transit system exhibited a negative relationship between proximity to the line and property values. The study suggested, however, that this negative effect may have been due to proximity to heavy industry and freeways near the light rail tracks. (9) This comparison suggests that rail systems that enjoy the highest rates of usage enjoy the greatest property value increases. This reinforces the notion that rail transit accessibility is one of the strongest determinants of property value increases.

Development Impacts

As the summary of studies shows, research on the impact of rail on property values has focused primarily on comparing the effect of distance from the rail system on property values. As just mentioned, this comparison suggests that the primary influence on property values is the improvement in regional accessibility that a rail transit investment brings. However, measuring the effect of proximity to rail at one point in time fails to capture the second major effect of rail on property values. Rail transit may make locations near transit more valuable as sites for potential development, thus increasing the value of property at those locations.

Second, rail transit can make a property a more attractive site for a higher level of development. Often, property owners decide they can develop their vacant parcels in order to capitalize on the proximity to transit. In other cases, an existing low density use can be converted to a higher density use or another type of use altogether. The conversion of properties from previously vacant sites to developed sites imparts additional value to the property. An informal survey of properties in Hillsborough County in Florida suggested that the average appraised value of developed parcels within the urbanized core was approximately $19,000 greater per acre than that of undeveloped parcels in the same urbanized core. A review of the BART system 20 years after the beginning of revenue operation revealed that there were more significant changes in land use and density around the rail transit stations than near nearby highway intersections. Such change, however, has depended on the willingness of local jursidictions to accommodate such development growth. (Cervero and Landis 1995, unpublished)

Policies to Maximize Positive Impacts of Rail on Property Values

Given that there are proven positive impacts of rail on property values because of new accessibility and the because of the ability to attract new and more intense development, how best can transit agency maximize the potential for a property value increase? This section presents several strategies that transit agencies can undertake to maximize the positive impact on property values of a rail transit investment. As discussed earlier, there are two primary ways that property values can increase due to a rail transit investment. This section, therefore, groups the strategies into ways to improve accessibility and ways to improve the possibility of new development. In addition, this section briefly mentions strategies to minimize the potential negative impacts of a rail transit system.

Improving Accessibility

Plan for Regional Accessibility

Improving accessibility provided by rail requires that the rail line or rail system be planned to reach regional accessibility centers quickly. When planning rail transit alignments, it is important, therefore, to place the rail line within a reasonable walking distance of current and planned regional employment centers, cultural centers, and retail opportunities. In fact, locations with high levels of employment accessibility, either through highways or through transit, generally have higher housing prices and rents that locations with less employment accessibility. (10) Any factor that increases the length of travel time to other locations near the rail system will unnecessarily reduce the accessibility provided by the rail transit investment. This reduction in the value of rail transit will result in lower than potential property value increases. Placing a rail transit station at locations far from strong centers of development will limit the accessibility provided by rail transit and therefore limit the impact on property values.

Maximizing the accessibility provided by the rail is also impacted by the plan for operations. Strategies to increase speed such as providing separate right-of-way to improve running speeds can reduce travel time to locations along the line. Increasing frequencies also increases the level of service provided by a rail line. In addition, providing some limited service by skipping stops at times of the day or by building fewer stops can improve accessibility in the region.

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Table 1: SUMMARY OF THE IMPACT OF RAIL TRANSIT FACILITIES ON PROPERTY VALUES

AUTHORS	RAIL MODE	LOCATION (TRANSIT FACILITY)	EXTENT OF PROPERTY VALUE IMPACT	MAJOR CONCLUSIONS
Boyce, David et al. (1972)	Heavy Rail	Southern New Jersey (Philadelphia – Lindenwold High Speed Line)	positive increase of $149 (1971 $) in the price of a home for each dollar of value in time savings	• Property values incorporate travel time to major employmen centers.
Bajic, Vladimir (1983)	Heavy Rail	Toronto (Spadina Line)	$2,237 premium for the average home	• Commute time savings contributes most to home value premiums
Voith (1991)	Commuter Rail	Southern New Jersey (PATCO) Suburban Philadelphia (SEPTA)	+10% premium for median home price in census tracts served by rail line +3.8% premium for median home price in census tracts served by rail line	• Proximity to commuter rail service has some minor positive median home values
Nelson, Arthur (1992)	Heavy Rail	Atlanta, Georgia (MARTA East Line)	+$1,000 on home prices for each 100 feet a house is closer to a rail station in low-income transit adjacent census tracts; a slight negative effect in high income tracts (although this may be due to proximity to industrial uses or to low income neighborhoods)	• For lower income neighborhoods, the benefit effects of accessibility more than offset any nuisance effects. • Higher value homes may be more sensitive to nuisance effe than by improvements in accessibility.
Al-Mosaind, Musaad, et al. (1993)	Light Rail	Portland, Oregon (MAX Eastside line)	+10.6% for homes within 500 meters	• Where transit plays a minor role, transit's impact on propert values is minimal. • Positive effects of accessibility are stronger than the negati nuisance effects.
Gatzlaff, Dean and Smith Marc (1993)	Heavy Rail	Dade County, Florida (Miami Metrorail)	at most a 5% higher rate of appreciation in real estate sales value compared to the rest of the City of Miami	• Residential values were, at most, only weakly impacted by t announcement of the new rail system • Higher priced neighborhoods have experienced greater increases in property values near Metrorail stations while declining ones have not
Landis, John et al. (1994)	Heavy Rail, Light Rail, and Commuter Rail	San Mateo County (CalTrain) San Francisco Bay Area (BART) Sacramento (Light Rail) San Jose (Light Rail) San Diego (The Trolley)	negative effect on proximity to Caltrain +$2.29 per meter closer to BART in Alameda Co.; +$1.96 per meter in Contra Costa Co. no discernable positive or negative impact -$1.97 per meter closer to light rail (but negative effect may be due to proximity to industrial and commercial uses) +$2.72 per meter closer to the Trolley	• The extent to which a rail system captures ridership from its market area affects the extent to which property values are increased • Frequency of service and regional accessibility affect the amenity of a rail system
Cervero, Robert (1996)	Heavy Rail	San Francisco Bay Area (Bay Area Rapid Transit)	+10-15% in rent for rental units within 1/4 mile of BART	• Units within a quarter-mile of the Pleasant Hill Bart station rented for around $34 more per month than comparable uni farther away.

Improve Pedestrian Station Accessibility

Positive property value impacts are primarily felt within a limited zone around transit stations, generally a reasonable walking distance of up to one-quarter or one-half mile. Enhancing pedestrian accessibility from the station to the surrounding area can thus increase the likelihood that properties will fall within a reasonable walking distance of the station and therefore experience a benefit to the their value. Improvements to station area accessibility can take the form of increasing the density of streets and pedestrian paths, improving safety, lighting, and other pedestrian amenities, and by providing additional station entrances and portals to allow direct access to the station from more locations.

Minimize Negative Impacts of the Rail Investment

Although the exact impact of nuisance variables such as noise, and visual obstruction caused by at-grade and elevated rail guideways has not been extensively reviewed, several studies at least suggest that such nuisances do lessen the amount of property value benefit that properties near the rail alignment and rail stations experience (6). Rail investment planning thus should seek to mitigate these types of effects through effective design and engineering.

The examination of the impact of proximity to the MARTA east line in Atlanta may have also suggested that proximity to industrial uses often has a negative effect on property values. Because the most available railroad rights-of-way for developing rail transit investments often occur in industrial districts, it is important to plan for a conversion of uses to more transit-compatible uses. Transit agencies can help local municipalities and jurisdictions plan for appropriate buffer uses between the remaining industrial land and the transit station area. In the longer term, plans can potentially incorporate the eventual conversion of uses to more transit-compatible ones such as housing or commercial space. Recent experiences with joint development indicates that industrial sites often provide for attractive opportunities for redevelopment.

Improving Potential for New Development

Assemble Development Sites

Transit agencies are often left with surplus sites after completion of a rail transit investment. Often, these sites are no longer necessary for the operation of the transit system. Surplus sites, however, are often characterized by irregular shapes and small size. These constraints limit the attractiveness of these properties as locations for development. Partnerships with adjacent property owners and with local jurisdictions can, however, enable the assembly of these sites can facilitate the assembly of these sites into larger, more flexible sites that allow for a broader range of development options. The federal government has historically allowed lease of property to private developers as long as revenues were used for transit purposes. Recently, the federal legislation has permitted the sale of property for limited purposes.

Introduce Incentives and Reduce Regulation for Development Near Stations

Often, developers are hesitant to be the first to enter a particular market niche. Development to capitalize on rail transit is often a new phenomenon to read estate developers in a given region because rail is often new to certain regions. Therefore, assorted incentives, both with increased financial incentives and decreased regulation may provide the jump start necessary to attract more developers to take advantage of transit-adjacent sites. Such incentives may include low-cost financing, mortgage guarantees, waivers or reductions in impact fees, and incentives to promote mixed uses.(11)

Support Joint Development

Developers in cities with new rail transit systems often have little experience with developing around transit stations. Transit agencies can perform a role as a catalyst by partnering with private developers to jointly develop property adjacent to transit stations. Activities that support joint development can include providing information on available sites for development, by establishing a process to receive, evaluate, and approve development proposals, and by providing assistance in the public outreach during the development review process. Joint development also has the additional benefit of increasing the attractiveness of the station area. Coordinated planning around stations for property around station

CONCLUSIONS

Rail transit investments have proven positive effects on property values. In fact, the effect of a new fixed guideway transit investment is two-fold. First, transit investments improve the convenience of accessing other parts of a region from station locations. Second, rail transit accessibility enhances the attractiveness of property, increasing the likelihood that the property can be developed

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or redeveloped to a more valuable and more intense use. Documentation of the impact of rail transit on property values primarily focuses on the first effect. Property value premiums due to increases in accessibility range between 3% and 40%. Property value premiums due to increases in the ability to develop or redevelop property depend on the land use and amount of development allowed on the property. Slight negative impacts of rail on property values are generally attributed to noise, visual intrusion, and the association of the rail right-of-way with industrial uses.

Transit agencies can undertake a number of strategies to increase the potential to increase property values with fixed guideway investments. To increase the effect of improved accessibility, transit agencies can plan rail lines to be serve the most prominent existing and planned development clusters. It can also orient the operating plan to provide for the maximum accessibility benefit by limiting the number of stops and planning for higher speed services. In addition, a transit agency can work with local jurisdictions to enhance pedestrian accessibility in station areas. Enhancements such as increased density of streets and walkways and safety improvements, and can make the positive impacts of rail transit on adjacent properties more apparent. To increase the positive impact of rail transit through new development, transit agencies can work to assemble development sites and undertake joint development activities. It can also work to enable development and redevelopment of station sites through support of development incentives and enhanced zoning.

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Attachment G
Exhibit 4008-000008-CWF
Columbia Waterfront LLC

Potential Fishing Impacts and Natural Resource Damages from Worst-Case Discharges of Oil on the Columbia River

Report in the Matter of Application No. 2013-01
Vancouver Energy Distribution Terminal
EFSEC Case Number 15-001

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May 12, 2016
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List of Acronyms and Abbreviations

Abt	Abt Associates
ADIOS2	Automated Data Inquiry for Oil Spills 2
API	American Petroleum Institute
BTEX	benzene, toluene, ethylbenzene, and xylenes
DEIS	Draft Environmental Impact Statement
DEM	digital elevation model
dilbit	diluted bitumen
DSAY	discounted service acre-year
DWH	*Deepwater Horizon*
EFSEC	Energy Facility Site Evaluation Council
ELS	early-life-stage
GIS	geographic information system
HEA	habitat equivalency analysis
LCR	lower Columbia River
MHHW	mean higher high water
MLLW	mean lower low water
NOAA	National Oceanic and Atmospheric Administration
NRDA	natural resource damage assessment
NWI	National Wetlands Inventory
ODFW	Oregon Department of Fish and Wildlife
OPA	Oil Pollution Act
PAH	polycyclic aromatic hydrocarbon
RDA	Resource Damage Assessment
REA	resource equivalency analysis
RM	river mile
SIMAP	Spill Impact Model Application Package
Tesoro	Tesoro Savage Petroleum Terminal LLC
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UV	ultraviolet

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Vancouver Terminal	Vancouver Energy Distribution Terminal Facility
WCD	worst-case discharge
WDFW	Washington Department of Fish and Wildlife

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S. Executive Summary

The Tesoro Savage Petroleum Terminal LLC has submitted an Application for Site Certification to the Washington State Energy Facility Site Evaluation Council (EFSEC) to construct and operate the Vancouver Energy Distribution Terminal Facility at the Port of Vancouver in Vancouver, Washington. Abt Associates and Bear Peak Economics were tasked with estimating potential economic impacts to fisheries and potential natural resource damages from an effective worst-case oil spill based on a tanker grounding in the Columbia River near Vancouver, Washington. In addition, we examined potential natural resource damages from a train derailment near the Bonneville Dam.

The scope of this task was restricted to assessing the impacts in the Columbia River from these two scenarios; we did not evaluate potential impacts in the Pacific Ocean or along the Pacific Coast. We also did not separately assess how the public or Indian Tribes would value the potential losses to natural resources if either of these spills were to occur, although these values may be at least partly accounted for in the methods we used. Thus, we expect that we are underestimating the potential impacts to fisheries and the potential natural resource damages from these spill scenarios.

The “effective worst-case discharge” for a tanker grounding in the lower Columbia River is a spill of 189,845 bbls (about 8 million gallons) of Bakken crude oil (EFSEC, 2015). Based on data from a 1984 oil spill in the river as well as models presented in the Draft Environmental Impact Statement (DEIS; EFSEC, 2015), we concluded that oil spilled near Vancouver would reach Longview (approximately 40 miles downstream) in 1 day, then travel slowly through the estuary, reaching the mouth after an additional 4 days. In the reach from Vancouver to Longview (Reach 2), we estimated that most of the oil would be on the surface, based on the physical properties of Bakken crude and the oil transport models presented in the DEIS. However, even a small percentage of 8 million gallons mixing into the water column could create concentrations of polycyclic aromatic hydrocarbons (PAHs) potentially toxic to exposed fish. In the lower reach from Longview to the mouth (Reach 1), tides cause diurnal current reversals, and the model from the DEIS predicts that a higher percentage of surface oil will disperse into the water column.

The worst-case discharge for a train derailment is a spill of 20,000 bbls (840,000 gallons) of Bakken crude oil (EFSEC, 2015). The worst-case scenario would be for the oil spill to occur immediately upstream of the Bonneville Dam, with most of the oil going through the spillway. In this highly turbulent environment, much of the oil would be mixed into the water column, potentially exposing white sturgeon to highly elevated PAH concentrations in their protected spawning grounds immediately downstream of the Bonneville Dam (Reach 4), in addition to exposing adult salmon migrating upstream to spawn and juvenile salmon (smolts) migrating downstream to the Pacific Ocean. The oil would move downstream, exposing river habitat both upstream of Vancouver (Reaches 4 and 3) and downstream of Vancouver (Reaches 2 and 1) to the oil.

Economic Impacts to Fisheries

We evaluated the potential economic impacts related to commercial and recreational fisheries for the tanker grounding scenario only. A tanker grounding that discharges 8 million gallons of Bakken crude oil into the river environment would have a substantial impact on commercial and

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recreational fishing. While past spills at other sites throughout the country have not always resulted in fishing closures, some spills have resulted in closures lasting from several months to almost a full year. Given the large amount of oil discharged under this scenario and the confined river environment of the potential spill, we estimate that a 6-month closure of all fishing on the lower Columbia River is a likely outcome.

Impacts to recreational fishing are likely to continue even after a closure is lifted. In past spills, recreation impacts have usually lasted for a period of several months to a year or more. For the spill under consideration, we have assumed that impacts to recreational fishing last a full year. The first 6 months involve a 100% loss of trips during the closure, and the remaining 6 months involve losses that decline linearly to zero at the end of a year.

For the specific values estimated below, we assumed the spill would occur in May and would affect the highly valued summer and fall fishing seasons. We calculated three different types of fishing losses:

- ***Lost revenue from commercial landings***: $4.7 million. This is a measure of the economic losses to commercial fishermen. Lost revenue may differ from total losses because commercial fishermen may recoup some costs while the fishery is closed, or may continue to incur losses after the fishery is reopened due to public perceptions about fish harvested from the river.
- ***Decline in expenditures by recreational anglers****:* $14.4 million. This is a measure of the potential disruption to local economic activity, with the most direct impacts on local businesses, such as bait shops and marinas. If anglers make up for lost trips on the Columbia River by taking additional trips to other sites nearby, some of these expenditures may not be diverted from the local area.
- ***Decline in the value of recreational fishing***: $17.8 million. This is the monetary quantification of lost enjoyment by recreational anglers whose preferred fishing opportunities are degraded or eliminated by the spill.

Because each of these losses is measuring something conceptually different, these values may not be strictly additive.

Natural Resource Damages

To estimate potential natural resource damages from these oil spill scenarios in the lower Columbia River, we used a habitat equivalency analysis (HEA). This is a commonly used technique where damages are based on the cost to restore habitat and natural resource services equivalent to those that were harmed by the oil. We estimated the service loss from oil exposure based on available data and knowledge from other spills, noting that in the event of an actual spill, federal and state natural resource Trustees would use data collected during the spill to estimate lost habitat services. In addition, we again note that we have not accounted for impacts in the Pacific Ocean and along the coast, and we have not separately assessed potential losses in the value of natural resources to the public or to Tribes, and thus these estimates are not comprehensive.

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Our HEA generally followed methods developed for natural resource damage assessments in Puget Sound (Commencement Bay/Hylebos Waterway, Elliot Bay/Duwamish River). The assumed restoration is estuarine marsh habitat. If oil caused harm (injury) to natural resources in other habitats, those service losses were converted to an amount of marsh habitat that provides equivalent services. In this analysis, we estimated service loss to estuarine and freshwater marsh habitats both in the river channel and in the floodplain adjacent to the river channel; these wetland habitats were assumed to provide the same services as a restored estuarine marsh. We also estimated service loss to riverine, subtidal, and other habitats in the river channel; these habitats were assumed to provide 10% of the services of an estuarine marsh.

In a HEA model, future service losses from the lingering effects of the spill and future service gains from habitat restoration are discounted to a base year using a 3% discount rate to reflect consumer time preference. The discounted losses and gains in each year are summed, creating an estimate of total natural resource injuries in units of discounted service acre-years (DSAYs), and an estimate of total restoration benefits in DSAYs per acre. Dividing the total injuries (DSAYs) by the benefits of restoration (DSAYs per acre) provides an estimate of the number of acres of marsh habitat restoration required to make the public whole.

For these scenarios, we assumed that the spill occurs in the spring of 2016 (present year, for discounting purposes), and that most of the service losses occur in 2016 and 2017. Complete recovery to pre-spill conditions occurs slowly thereafter until 2025. We assumed that the marsh restoration required to offset these impacts would be completed in 2021, it would take 15 years for the marsh to become fully established and provide 100% of marsh habitat services (Commencement Bay Natural Resource Trustees, 2002), and those restored services would be provided for 100 years. This provides 20.5 DSAYs of restoration “credit” per acre restored.

We found a wide range of costs for restoring estuarine marsh habitat; some projects restored hundreds of acres of habitat by breaching a dike and flooding former fields, at a cost of a few thousand dollars per acre. Other projects, including those in Commencement Bay, required land purchase, waste removal, and a complicated engineering design to restore the habitat; these projects cost over $1 million per acre. We used the recent Fir Island restoration in the Skagit Valley (WDFW, 2014) as the basis for cost estimates. This project restored 130 acres of marsh habitat supporting Chinook salmon and snow geese at a cost of $110,000 per acre.

Tanker Grounding

An 8-million-gallon oil spill in the Columbia River near Vancouver would expose fish, birds, pinnipeds, and other biota (and their supporting habitats) to oil, with the largest impacts most likely to result if the spill occurs in the spring (mid-April to mid-May). Potential natural resource impacts from this oil spill include:

- ***Birds***: There are four wildlife refuges between Vancouver and the mouth of the river, with many thousands of birds potentially exposed to oil. In 2007, approximately 140 bald eagles were known to reside and breed along the river. Data from the literature suggest that most birds exposed to oil are impaired and may die from symptoms ranging from hemolytic anemia to hypothermia to heart failure. Oiled eggs rarely produce offspring, and oiled feathers impact flight behavior, which could lead to increased predation and decreased hunting and migration success.

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- ***Pinnipeds***: Hundreds of Steller sea lions, California sea lions, and harbor seals are in the estuary in the spring; sea lions can be found throughout the lower Columbia River, including at the base of the Bonneville Dam. Data from other spills suggest adverse health effects on marine mammals exposed to oil.
- ***Adult salmon***: We calculated the potential exposure of salmon to oil from this scenario based on fish count data from the Bonneville Dam. Data from the literature suggest that adult salmon swimming upstream take up to 3 weeks to reach the dam; about 2 weeks' worth of adult salmon would intersect the oil slick as it moved downstream from Vancouver. We estimated 45,000 to 70,000 adult salmon would be exposed to the oil in Reach 1, and an additional 20,000 to 60,000 adult salmon would be exposed in Reach 2. Recent literature suggests that PAH exposure reduces the physical fitness of fish, which could affect the ability of adult salmon to reach their spawning grounds.
- ***Juvenile salmon***: Salmon smolts migrate downstream in the spring. The literature suggests that smolts migrate with the current until they reach the estuary, where they linger for several days before swimming out to sea. We assume that one daily cohort of smolts would follow the oil downstream, and several additional daily cohorts would then intersect the oil in the estuary. In total, we estimate 1.4 million to 1.6 million smolts would be exposed to the oil in the river over the approximately 5 days that the oil is primarily in the river before discharging into the Pacific Ocean. Although few studies have exposed juvenile fish oil, the literature suggests that the concentrations of PAHs expected in the Columbia River from this spill scenario would exceed thresholds for multiple toxic endpoints in early life-stage fish.

To determine the appropriate compensation for the impacts of oil exposure, we calculated the total area of the river channel from Vancouver to the mouth (Reaches 1 and 2, extending nearly 100 river miles). Using bathymetric and National Wetlands Inventory (NWI) data in a geographic information system (GIS), we calculated 16,152 acres of wetland habitat and 91,579 acres of riverine/subtidal habitat would be oiled in the river channel. We estimated a 90% loss of habitat services in Reach 2 and a 75% loss in Reach 1 in 2016, recovering to a 10% service loss by the end of 2017, and reaching pre-spill conditions by 2025. This results in 21,276 DSAYs of natural resource injury (HEA "debit").

With a total calculated debit of 21,276 DSAYs, and using a credit of 20.5 DSAYs per acre of restored wetland calculated above, the total the total quantity of restoration required to offset the injuries in Reach 1 and Reach 2 of the river channel is 1,040 acres. At a cost of $110,000 per acre, the total damages for injuries to the river channel habitats would be about $114.4 million (Table S.1).

Table S.1. Estimated cost to restore marsh habitat sufficient to offset injuries to river channel habitats in the lower Columbia River downstream of Vancouver

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
21,276	20.5	1,040	$110,000	$114.4 million

To capture likely natural resource injuries to birds that are exposed to oil in the river but are found in adjacent floodplain habitats, we estimated habitat service loss in wetlands in the 100-year floodplain but outside of the area designated as river channel. These wetlands could be

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directly exposed to oil if the river stage is high, they could have stranded oil on the margins, and the birds residing in the wetlands could be exposed to oil on the river channel.

Using NWI data in a GIS, we calculated 29,867 acres of floodplain wetlands in Reaches 1 and 2 downstream of Vancouver. We estimated a 25% loss in Reaches 1 and 2 in 2016, recovering to a 5% service loss by the end of 2017, and reaching pre-spill conditions by 2025. For the 29,867 acres of floodplain wetland habitat, the total HEA debit is 10,580 DSAYs.

With a total calculated debit of 10,580 DSAYs and a credit of 20.5 DSAYs per acre, the total quantity of restoration required to offset the injuries to refuge habitat and biota is 517 acres. At a cost of $110,000 per acre, the total damages would be about $56.9 million (Table S.2).

Table S.2. Estimated cost to restore marsh habitat sufficient to offset injuries to floodplain wetland habitat in the lower Columbia River downstream of Vancouver

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
10,580	20.5	517	$110,000	$56.9 million

Train Derailment

Although the worst-case train derailment scenario is a spill of roughly 10% of the oil spilled in a worst-case tanker grounding, it will expose a greater area of the lower Columbia River to oil. Assuming most of the oil goes through the Bonneville Dam spillway, it will be mixed into the water column and expose fish in the 4.8-mile reach below the dam (Reach 4) to highly elevated PAH concentrations. This oil will then continue downstream, exposing biota in Reach 3 (which extends downstream to Vancouver) and, to a lesser degree, biota in Reaches 2 and 1 downstream of Vancouver. In total, this is approximately 140 river miles of potential oil exposure.

Natural resource damages are not scalable based on the quantity of oil spilled; therefore, we would not expect damages from this spill scenario to be 10% of the damages from the previous scenario. Although the quantity of oil is less and the oil exposure will decrease with distance from the dam, the amount of exposed habitat in the lower Columbia River is greater than in the tanker scenario. In addition, as noted previously, we would expect a large quantity of oil in the tanker scenario to be discharged into the ocean and deposited on the coastline. We have not quantified damages in those habitats.

Similar to the previous scenario, an 840,000-gallon oil spill in the Columbia River just upstream of the Bonneville Dam would expose fish, birds, pinnipeds, and other biota (and their supporting habitats) to oil, with the largest impacts most likely to result if the spill occurs in the spring (mid-April to mid-May). Potential natural resources exposed to the oil include:

- ***Birds***: There are seven wildlife refuges (and one small game management area) between the Bonneville Dam and the mouth of the river. As described previously, these refuges are home to thousands of birds that would potentially be exposed to the oil, and the oil directly or indirectly would cause mortality for many of these exposed birds.

- ***Pinnipeds***: Sea lions congregating at the base of the Bonneville Dam would be exposed to highly elevated oil concentrations. Other pinnipeds would be exposed to lower concentrations of oil in the estuary (Reach 1).

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- ***Adult salmon***: For this scenario, we only calculated the number of salmon exposed at the base of the dam (Reach 4). The number of adult salmon per day counted at the Bonneville Dam in mid-May from 2011 to 2015 ranged from 2,000 to 9,000, with an average of 4,000. The daily cohort present at the base of the dam when the spill occurs would be exposed to highly elevated PAH concentrations. As mentioned previously, it takes adult salmon approximately 3 weeks to travel from the mouth of the river to the dam; each of those daily cohorts would be exposed to the oil as well, at lesser concentrations with distance downstream.

- ***Juvenile salmon***: The number of salmon smolts per day counted at the Bonneville Dam in mid-May between 2011 and 2015 ranged from 27,000 to 220,000, with an average of 112,000. This daily cohort would be exposed to highly elevated PAH concentrations near the dam, and their exposure would likely continue for several days as they traveled downstream with the oil plume. Additional daily cohorts of smolts would be exposed in the estuary before swimming out to sea.

Using the same methods described for the tanker grounding scenario, we calculated the total area of the river channel from the Bonneville Dam to the mouth (Reaches 1 through 4, extending nearly 140 river miles). Using bathymetric and NWI data in a GIS, we calculated that 16,687 acres of wetland habitat (primarily in the estuary, Reach 1) and 110,316 acres of riverine/subtidal habitat would be oiled in the river channel. Because 866 acres of riverine habitat in Reach 4 is protected white sturgeon spawning habitat, we assumed this reach provides the equivalent of 100% of estuarine marsh habitat services, rather than the 10% estimate that we used for all other riverine habitat.

We estimated a 90% loss of habitat services in Reach 4, a 50% loss in Reach 3, and a 15% loss in Reaches 2 and 1 in 2016. Reaches 4 and 3 would recover to a 10% service loss by the end of 2017 and to pre-spill conditions by 2025. Reaches 2 and 1 would recover to a 5% service loss by the end of 2017 and to pre-spill conditions by 2025. This results in 10,135 DSAYs of natural resource injury (HEA debit).

With a total calculated debit of 10,135 DSAYs and a credit of 20.5 DSAYs per acre, the total quantity of marsh restoration required to offset the injuries to river channel habitats is 495 acres. At a cost of $110,000 per acre, the total damages would be about $54.5 million (Table S.3).

Table S.3. Estimated cost to restore marsh habitat sufficient to offset injuries to river channel habitats in the lower Columbia River downstream of the Bonneville Dam

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
10,135	20.5	495	$110,000	$54.5 million

To capture likely natural resource injuries to birds that are exposed to oil in the river but are found in adjacent floodplain habitats, we again estimated habitat service loss in wetlands in the 100-year floodplain but outside of the area designated as river channel. Using NWI data in a GIS, we calculated 32,055 acres of floodplain wetlands downstream of the Bonneville Dam.

We estimated a 75% loss of habitat services in Reach 4, a 25% loss in Reach 3, and a 10% loss in Reaches 2 and 1 in 2016. Reach 4 would recover to a 25% service loss by the end of 2017 and

to pre-spill conditions by 2025. Reach 3 would recover to a 10% service loss by the end of 2017 and to pre-spill conditions by 2025. Reaches 2 and 1 would recover to a 2% service loss by the end of 2017 and to pre-spill conditions by 2025. This results in 5,643 DSAYs of natural resource injury (HEA debit).

With a total calculated debit of 5,643 DSAYs and a credit of 20.5 DSAYs per acre, the total quantity of marsh restoration required to offset the injuries to floodplain wetland habitat and biota is 276 acres. At a cost of $110,000 per acre, the total damages would be about $30.4 million (Table S.4).

Table S.4. Estimated cost to restore marsh habitat sufficient to offset injuries to floodplain wetland habitat in the lower Columbia River downstream of the Bonneville Dam

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
5,643	20.5	276	$110,000	$30.4 million

Conclusions

We examined potential impacts to commercial and recreational fisheries from a tanker grounding near Vancouver, and we estimated potential natural resource damages from both the tanker grounding scenario near Vancouver and a train derailment scenario near the Bonneville Dam. The scope of this work was restricted to impacts in the Columbia River. Though oil in the Columbia River (particularly from a tanker grounding near Vancouver) would be discharged to the Pacific Ocean and would impact natural resources along many miles of coastline, we have not quantified those impacts.

To estimate natural resource damages, we used a HEA model that calculates damages based on the cost to restore habitat equivalent to what the oil injured. If a major spill were to occur in the Columbia River, Trustees would incorporate laboratory and field data to calculate the habitat losses. Trustees might also choose to estimate damages based on values that humans place on natural resources, including Tribal cultural values. A damages estimate incorporating these values could be substantially higher than the restoration-based calculations in this analysis.

The estimated fisheries impacts from a tanker grounding near Vancouver include a 6-month fisheries closure, plus lingering effects on recreational fishing for an additional 6 months, range from $4.7 million to $17.8 million (Table S.5). As noted previously, these losses are not strictly additive.

Table S.5. Summary of estimated losses to fisheries from a worst-case vessel grounding near Vancouver

Type of loss	Value
Lost revenue from commercial landings	$4.7 million
Decline in expenditures by recreational anglers	$14.4 million
Decline in value of recreational fishing	$17.8 million

The estimated damages to Columbia River habitats from a worst-case vessel grounding in Vancouver is $171.3 million, including $114.4 million for injured habitats in the river channel and $56.9 million for injuries to floodplain wetlands adjacent to the river (Table S.6).

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Table S.6. Summary of estimated restoration-based damages to Columbia River habitats from a worst-case vessel grounding near Vancouver

Habitat	Damages
Wetland and non-wetland (riverine, subtidal) habitats in the lower Columbia River channel downstream of Vancouver	$114.4 million
Wetland habitat in the 100-year floodplain adjacent to the lower Columbia River channel downstream of Vancouver	$56.9 million
Total	$171.3 million

The estimated damages to Columbia River habitats from a worst-case train derailment near the Bonneville Dam is $84.9 million, including $54.5 million for injured habitats in the river channel and $30.4 million for injuries to floodplain wetlands adjacent to the river (Table S.7).

Table S.7. Summary of estimated restoration-based damages to Columbia River habitats from worst-case train derailment near the Bonneville Dam

Habitat	Damages
Wetland and non-wetland (riverine, subtidal) habitats in the lower Columbia River channel downstream of the Bonneville Dam	$54.5 million
Wetland habitat in the 100-year floodplain adjacent to the lower Columbia River channel downstream of the Bonneville Dam	$30.4 million
Total	$84.9 million

These estimates are considerably less than major oil spill settlements such as *Exxon Valdez* or *Deepwater Horizon*. Although damages are not scalable based on the volume of oil discharged, such calculations can provide useful context. Summarizing data from multiple incidents, the range of damages from other oil spill incidents scaled by the volume of oil spilled in the Columbia River scenarios is $232 million to $1.16 billion for the tanker grounding, and $24.4 million to $122 million for the train derailment. The restoration-based damages estimate of $171.3 million calculated for the vessel grounding is below this range; the damages estimate of $84.9 million calculated for the train derailment is within this range. These estimates do not include damages from oil discharged to the ocean, which, if considered, would result in substantially higher estimated damages.

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WDFW. 2014. Skagit Wildlife Area, Fir Island Farms Reserve Unit: Fir Island Farms Final Design Project. Washington Department of Fish and Wildlife. Available: http://wdfw.wa.gov/lands/wildlife_areas/skagit/final_restoration_study.php. Accessed 5/2/2016.

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1. Introduction

The Tesoro Savage Petroleum Terminal LLC (Tesoro) has submitted an Application for Site Certification to the Washington State Energy Facility Site Evaluation Council (EFSEC) to construct and operate the Vancouver Energy Distribution Terminal Facility (Vancouver Terminal) at the Port of Vancouver in Vancouver, Washington (Figure 1.1).

The Washington Attorney General's Office retained Abt Associates (Abt) to evaluate potential fisheries impacts and natural resource damages if a worst-case oil spill were to occur in the Columbia River. This report evaluates selected categories of potential environmental and economic impacts for a hypothetical oil spill resulting from an incident related to Vancouver Terminal operations, including the potential economic impacts of a closure of the lower Columbia River (LCR) to commercial and recreational fishing, as well as a restoration-based approach to quantifying potential damages to natural resources in the LCR.

1.1 Scope of the Report

The object of this report is to provide approximate estimates of potential fisheries impacts and natural resource damages that could be associated with hypothetical oil spill scenarios, based on a rapid review of readily available data. It is not intended to be a comprehensive examination of these topics. Some of the limitations of the scope of the analysis presented herein include the following:

- ***Geographic scope***. This analysis includes impacts solely to the LCR. A major oil spill in the LCR could lead to a substantial amount of oil exposure in the Pacific Ocean, and could potentially result in the deposition of oil along many miles of coastline. Depending on winds and tides, the oil could also move up the Willamette River into Portland Harbor. Consequently, our analysis likely underestimates the geographic extent of impacts to natural resources, perhaps by a substantial degree, and we may also be underestimating the impacts on commercial and recreational fisheries.

- ***Trustee scope***. This analysis of natural resource damages does not include cultural impacts to Tribes. Tribes are Trustees of natural resources. Any oil-related diminution of the cultural value that Tribes place on natural resources is compensable as damages. A large oil spill in the LCR would likely impact Tribal cultural values; we have not incorporated those losses in this analysis.

- ***Methodological scope***. For these hypothetical spill scenarios, we use a common method of calculating damages based on the cost to restore natural resources similar to those harmed during the spill. We can make a reasonable approximation of the impacts of the spill and the amount of restoration that might be required based on existing data. However, Trustees have multiple options for assessing damages, including natural resource valuation methods that incorporate the value that the public places on natural resources. Trustees may elect to design a survey that asks the public what they are willing to pay to prevent a recurrence of this size of oil spill in the LCR, or how much restoration they think is appropriate to offset the impacts from the oil spill. Such a survey of public opinion could lead to an estimate of damages considerably higher than the estimates provided herein.

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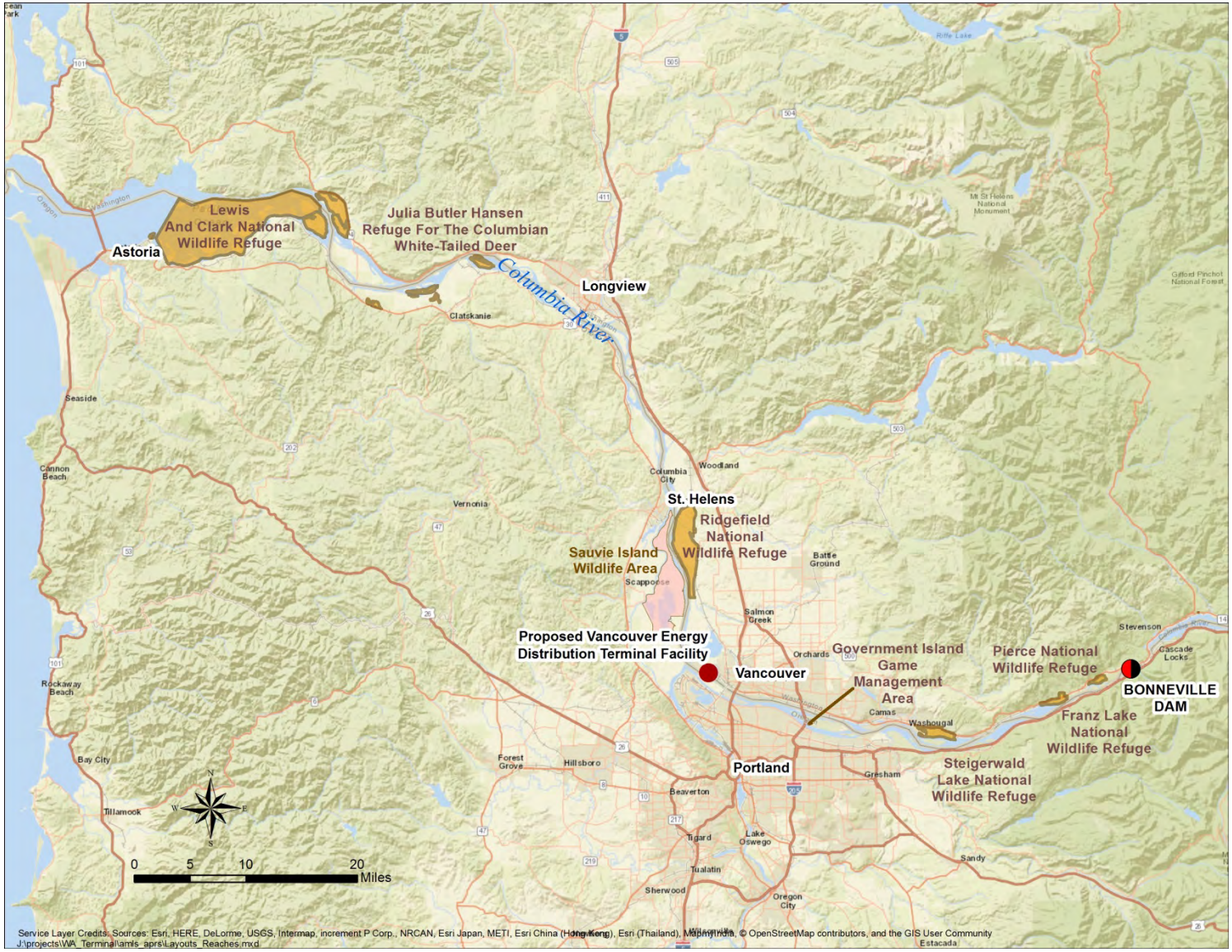
Figure 1.1. Location of proposed the Vancouver Terminal and surrounding Columbia River environment.



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- ***Volumetric scope***. We evaluated only the impacts of the effective worst-case scenarios discussed in the Draft Environmental Impact Statement (DEIS) for the Vancouver Terminal (EFSEC, 2015). For a tanker grounding near Vancouver, this is a spill of over 189,845 bbls, and for a train derailment near the Bonneville Dam, 20,000 bbls. These worst-case spill scenarios are unlikely. However, the estimates of fisheries closures and natural resource damages that we provide in this report are applicable to spills that are not nearly as large. Such estimates are not linearly scalable; the fisheries impacts and natural resource damages presented in this report may be nearly the same even if only 10% of the volume of oil from the worst-case scenario spilled into the LCR.

- ***Oil source scope***. We evaluated only the potential impacts of a Bakken crude oil spill on the LCR. The proposed Vancouver Terminal would also handle diluted bitumen (dilbit), which would likely behave quite differently if discharged to the river. Dilbit is a heavier oil and would have a higher potential to sink to the river bottom. This could have profound effects on the types and timing of natural resource damages as well as the timing of fishery closures.

In addition to the limitations on the scope of our evaluations, there are limitations on the available data that we can use to predict the impacts of a hypothetical spill. Although a large body of literature exists that describes oil fate and transport and the toxicity of oil on biota, existing models and literature do not enable comprehensive prediction of oil exposure and resulting adverse effects on natural resources without actual data. Thus, none of the damages estimates in this report should be considered definitive; if a large spill were to occur in the LCR, the Trustees would likely collect both field and laboratory data to assess oil exposure and the adverse impacts of the exposure on natural resources.

Existing literature that allows us to make this initial estimate of potential impacts of a large oil spill in the LCR includes literature on the natural resources of the LCR; on potential oil fate and transport processes; and on the effects of oil on biota such as fish, birds, and invertebrates. Resource officials have long been concerned about oil spills in the LCR; the latest *Lower Columbia River Geographic Response Plan* (ODEQ et al., 2015) includes detailed summaries of natural resources and habitats likely to be exposed to oil if a major spill were to occur. In this report, we provide summary information (e.g., wildlife refuges shown on Figure 1.1) but generally refer the reader to existing literature without reproducing the information in detail.

1.2 Report Organization

The remainder of this report is organized as follows. Chapter 2 describes two worst-case discharge (WCD) scenarios: a tanker grounding in the LCR near Vancouver (Section 2.1) and a train derailment downstream of The Dalles Dam and upstream of the Bonneville Dam (Section 2.2). These scenarios are based on information that EFSEC published in the DEIS for the Vancouver Terminal (EFSEC, 2015).

The remaining chapters discuss the potential impacts from these oil spill scenarios. Specifically, Chapter 3 discusses the potential economic impacts of commercial and recreational fishery closures; and Chapter 4 discusses potential natural resource damages in the LCR after the WCD from a tanker grounding. Chapter 5 discusses potential natural resource damages after the WCD from a train derailment upstream of the Bonneville Dam (Figure 1.1).

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References

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2. Worst-Case Discharge Scenarios

As background context for the oil spill scenarios, we first summarize the *MobilOil* tanker spill that occurred in the Columbia River in 1984, and then presents two separate potential future scenarios: a WCD from a tanker grounding near Vancouver in the LCR, and a WCD from a train derailment. These two scenarios are based on WCD analyses presented in Chapter 4 (EFSEC, 2015) and Appendices E (Etkin et al., 2015) and (Etkin and Moore, 2015) of the Tesoro Vancouver Terminal DEIS. The *MobilOil* spill was substantially smaller than the WCD spills from the DEIS, but it provides some information on the fate and transport of oil in the Columbia River.

2.1 *MobilOil* Spill of 1984

The tanker *MobilOil* grounded in the Columbia River near St. Helens, Oregon [river mile (RM) 88], shortly after midnight on March 19, 1984. Damage to the tanks resulted in a spill of approximately 3,925 bbl (165,000 gals) of heavy residual oil, number six fuel oil, and an industrial fuel oil (Kennedy and Baca, 1984). This spill occurred near St. Helens, approximately 15 mi downstream of the proposed Vancouver Terminal in Vancouver; the total discharge was about 2% of the effective WCD for a tanker grounding (see next section).

At the time of the tanker grounding, the calculated discharge in the Columbia River at the Bonneville Dam was 239,300 cfs. Over the next several days, the discharged oil ranged from about 215,000 to 273,000 cfs (USACE, 2016).

According to Kennedy and Baca (1984), the U.S. Army Corps of Engineers (USACE) estimated that the Columbia River discharge downstream of the Willamette River confluence (more than 40 miles downstream of Bonneville Dam) was approximately 320,000 cfs at the time of the spill. The average downstream current was 2 kts, or 2.3 mph, ranging from about 2.5 kts (2.9 mph) at the low, outgoing tide to 1.5 kts (1.7 mph) at the high, incoming tide (Kennedy and Baca, 1984). By the morning of March 19, 1984, the leading edge of the oil slick was over 20 mi downstream, near Longview, Washington, at RM 65. The following morning (March 20), the oil slick had progressed to RM 35. This is downstream of where the river current reverses diurnally with slow tides (Kennedy and Baca, 1984), and thus the net progression downstream was substantial.

The oil reached the mouth of the river and entered the Pacific Ocean within 2 to 3 days after being discharged from the damaged tanker. By March 25, 1984, the oil had spread about 50 mi northward up the Washington Coast to Ocean Shores. Lesser amounts of oil spread southward along the Oregon Coast, with oil reported as far south as Cannon Beach, about 25 mi south of the river mouth (Figure 2.1; Speich and Thompson, 1987).

The oil discharged from the ship settled to the river bottom in an eddy, before eventually entering the main flow of the river as oil droplets in the water column, or as a slow-moving oil plume along the river bottom. Oil was stranded on the river banks, pushed higher up the banks at high tide, and stranded as the tide dropped. Some of the stranded oil was washed back into the river; however, stranded oil in marshes and sloughs may have remained for a considerable amount of time, as oil does not readily rewash into the river from these habitats, and the spill occurred during a spring tide cycle when the high tide was particularly elevated (Kennedy and Baca, 1984).

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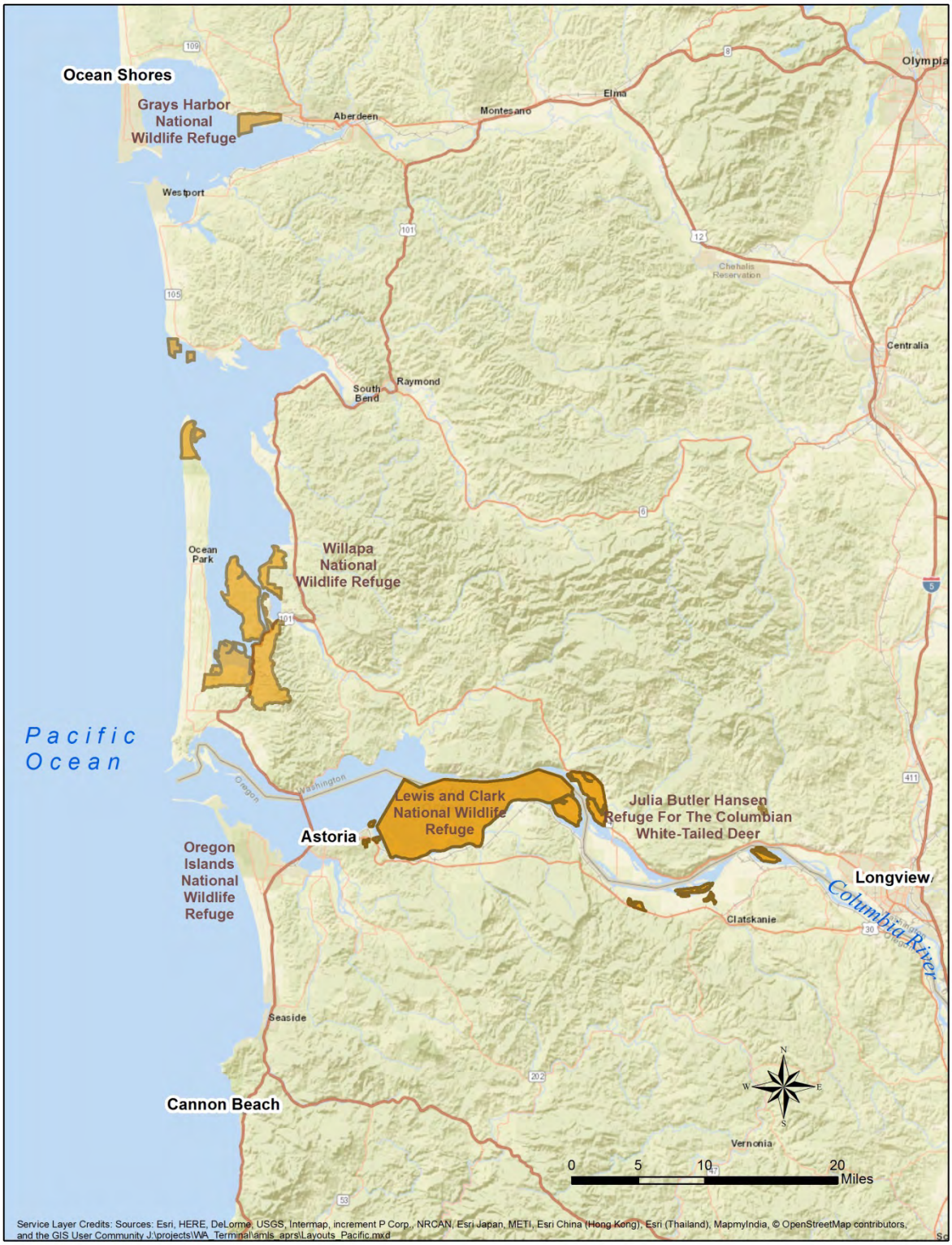
Figure 2.1. Oil from the *MobilOil* in 1984 discharged from the Columbia River to the Pacific Ocean and washed ashore from Cannon Beach, Oregon, to Ocean Shores, Washington.



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Although they did not discuss their methods, Kennedy and Baca (1984, p. 36) estimated that surface oil reached the mouth of the river in "a few days," oil in the water column reached the mouth of the river in about 1 week, oil near the river bottom may have remained for several weeks, and stranded oil may have remained even longer. This information helps to inform estimates of oil fate and transport for future oil spills (see next section); Chapter 4 contains summaries of the reported adverse environmental effects of this spill.

2.2 WCD from a Tanker Grounding in the LCR near Vancouver

The WCD in the Columbia River is based on a hypothetical grounding of a large tanker in the vicinity of Vancouver. Although the proposed Vancouver Terminal will handle both Bakken crude and dilbit, we focused solely on the potential impacts of Bakken crude. Exposure and injury of natural resources during an oil spill depend on the type of oil discharged and its physical and chemical properties; the toxicity of the oil; processes influencing fate and transport of oil in the environment; and the potential impacts of the oil on terrestrial, freshwater, and estuarine/marine environments (EFSEC, 2015). In this chapter, we consider these factors for the WCD scenario.

2.2.1 Physical Properties of Bakken Crude

Bakken crude oil is considered a light crude with physical characteristics similar to other light crude oils, with relatively low viscosity, low sulfur content, low density, and an American Petroleum Institute (API) gravity between 40 and 43 (EFSEC, 2015). As noted in the DEIS, Bakken crude has a reputation for being highly volatile, in part from the Lac Megantic disaster in 2013. However, Bakken crude is similar to other light crudes as described in Auers et al. (2014), including the crude oil that was released during the *Deepwater Horizon* (DWH) oil spill. For example, the profiles of volatile components [e.g., benzene, toluene, ethylbenzene, and xylenes (BTEX)] and polycyclic aromatic hydrocarbons (PAHs) in Bakken and DWH crude oil are very similar (Figure 2.2). Thus, the extensive recent literature on the mobility and toxicity of the MC252 crude is relevant and applicable to the evaluation of potential impacts resulting from a Bakken crude oil spill.

2.2.2 Weathering of Bakken Crude

As described in the DEIS, "When oil is released into the environment, it is altered by various chemical and biological processes that are collectively referred to as 'weathering,' including spreading/dispersion, evaporation, dissolution, emulsification, photo-oxidation, adsorption/ sedimentation, and biodegradation" (EFSEC, 2015, p. 4-36). Thus, the spatial and temporal impact of a WCD event will be influenced by dispersal and weathering of the crude after the spill.

Chemically, within 5 days, the Bakken crude will have lost its volatile components, BTEX will be gone, and most naphthalenes (i.e., lighter PAHs) will be lost as well. Heavier PAHs will remain, and the oil can become increasingly tarry, more difficult to capture, and may eventually become heavier than water and sink. Abt scientists and collaborators conducted numerous studies on weathering of DWH oil, which is similar to Bakken crude. Based on these studies, we can estimate oil weathering in terms of loss of PAHs for up to 36 days (Figure 2.3; Johnson et al., 2016). We calculated that samples of fresh Bakken crude have a fraction PAH of 1.12%,

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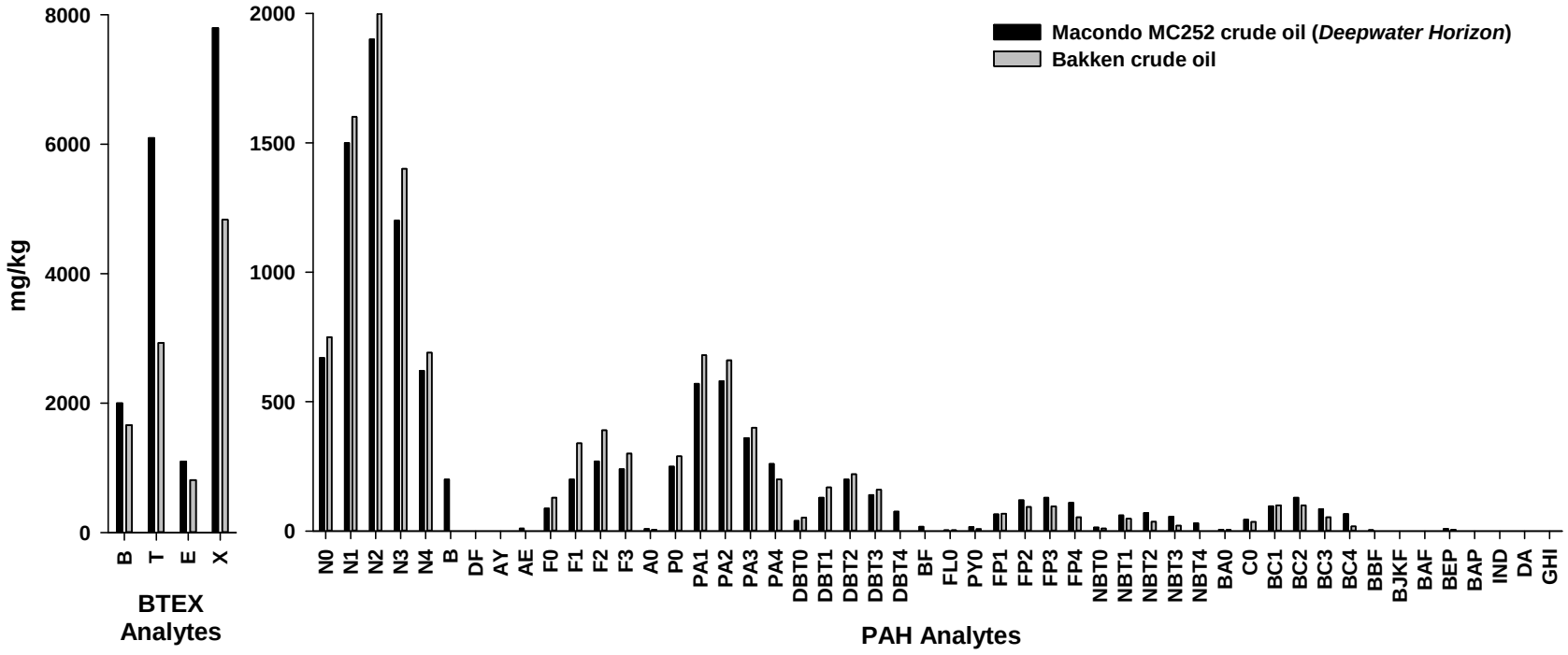
Figure 2.2. Comparison of concentrations of volatile compounds such as BTEX and PAHs in Bakken crude oil and DWH crude oil collected from the riser of the Macondo well during the DWH oil spill.



Sources: Etkin and Moore, 2015, Tables 45–46 (Bakken); Forth et al., 2015 (DWH).

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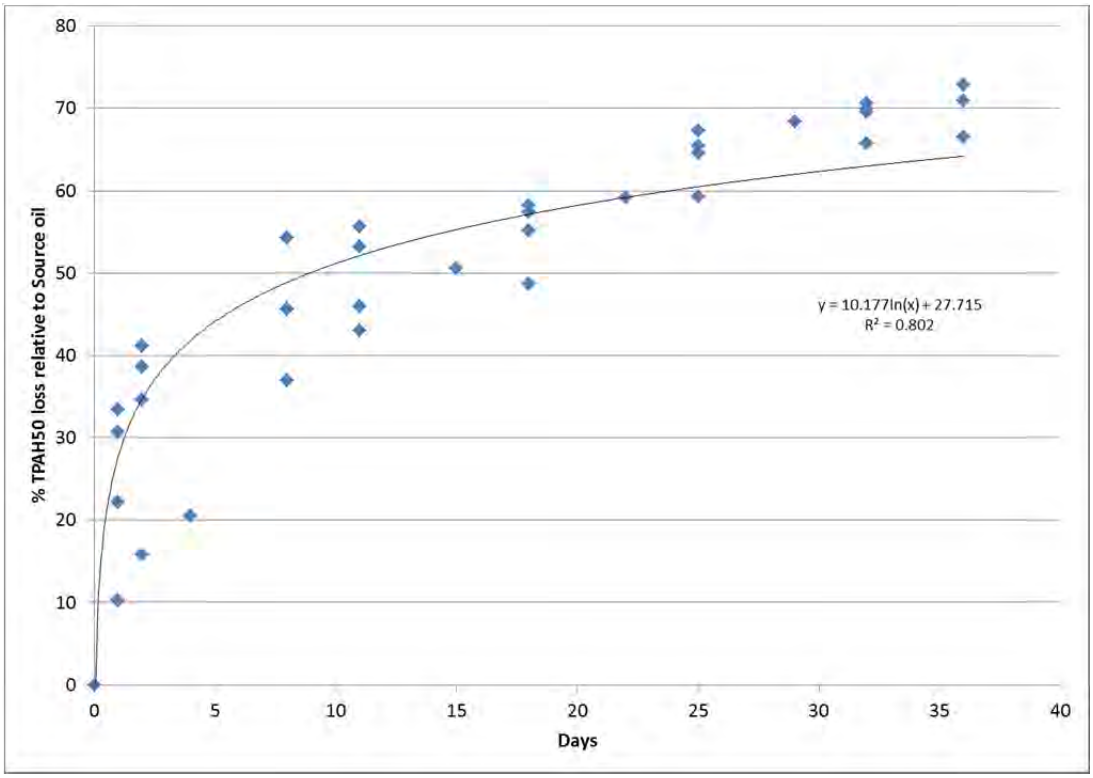
Figure 2.3. Total PAH depletion in fresh DWH oil weathered in outdoor chambers that simulated natural weathering conditions. The depletion rate presented here was used to estimate total PAH depletion in Bakken crude oil over 5 days.



Source: Johnson et al., 2016.

using data presented in Appendix J, Table 46, of the DEIS (Etkin and Moore, 2015). Using weathering data from DWH oil, we estimated that the PAH fraction of spilled Bakken crude will decrease to 0.6% over 5 days.

DWH oil skimmed off the ocean surface many days after being discharged was naturally weathered and was similar to samples we weathered under our controlled outdoor weathering process for 22–36 days (Forth et al., 2015; Johnson et al., 2016). Thus, during the DWH oil spill, substantial quantities of oil remained in the system after days or even weeks of weathering; this highly weathered oil was still toxic to aquatic organisms (Morris et al., 2015). A discharge of Bakken crude into the Columbia River might likewise remain in the environment and be toxic to aquatic organisms for days or weeks after a spill.

2.2.3 Effective WCD

To the extent possible, the WCD scenarios we evaluated are based on those presented in Chapter 4 and Appendix J of the DEIS. The DEIS includes multiple, low-probability WCD scenarios, based primarily on groundings or collisions of various tankers. EFSEC defined the "effective" WCD as "the most credible or realistic volume for a WCD based on the amount of oil that would effectively be released in the event of a tanker impact accident (collision or grounding) based on maximum possible outflow as determin[ed] by modeling" (EFSEC, 2015, p. 4-26). The WCD varies based on tanker type and other assumptions. In our analysis, we used

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the scenario presented in the DEIS involving a grounding of an Aframax tanker carrying Bakken crude, with an effective WCD of 189,845 bbls (EFSEC, 2015) or about 8 million gallons. For comparison, the oil released from the *Exxon Valdez* was 257,000 bbls (11 million gallons) (NOAA, 2001). As discussed in subsequent chapters, we assumed that the spill occurs in the spring (between mid-April and mid-May), corresponding with peak salmon populations in the LCR.

2.2.4 Oil Fate and Transport

Although a tanker spill could occur downstream of the proposed Vancouver Terminal or along the coast, for our analysis we assumed that the WCD would occur in the Columbia River near Vancouver.

The fate and transport of oil discharged to the Columbia River will depend on the chemical and physical properties of the oil spilled, the nature of release, and the environmental conditions present at the time of the discharge, including river and tidal currents, winds, and temperature. Because we are evaluating a hypothetical spill, we must develop a reasonable set of conditions. To estimate the fate and transport of the oil discharged under this effective WCD scenario, we reviewed information from the 1984 *MobilOil* spill, the modeling studies cited in the DEIS (EFSEC, 2015), and other available information.

Unquantified impacts: Spatial domain of analysis

A WCD in the Columbia River could result in crude oil reaching the mouth of the river and discharging into the Pacific Ocean, particularly if the tanker accident occurred downstream of Vancouver. It is also likely that a spill of this magnitude could result in oil moving up the Willamette River and into Portland Harbor. We have not attempted to quantify fisheries impacts or natural resource damages to the Pacific Coast or the Willamette River in this analysis.

For our analysis, we divided the LCR into four reaches (Figure 2.4) based on river hydrodynamics and habitat. Reach 1 extends from the mouth of the Columbia River to just downstream of Longview. This portion of the river has diurnal reversals in flow direction based on tides. Reach 2 extends from Longview to Vancouver, the location of the proposed Vancouver Terminal. Reach 3 extends from Vancouver to a point about 5.5 mi downstream of the Bonneville Dam. Reach 4 extends to the dam and comprises protected sturgeon spawning habitat.

River Currents

Transport of oil spilled in the Columbia River will depend on the river and tidal currents at the time of the spill, as well as on other factors, including winds. As discussed previously, oil discharged during the *MobilOil* spill flowed downstream at 1.7 to 2.9 mph, reaching the mouth of the river in 2 to 3 days. The river flow dominated the movement of oil from this spill, with the wind acting as a secondary influence on the movement of floating oil (Kennedy and Baca, 1984).

A recent evaluation of the average surface water velocity for the LCR indicated slower velocities than those reported during the *MobilOil* spill. The oil spill response plan (NAC, 2015, ODEQ et al., 2015) states that velocities at Vancouver are 1 to 1.5 kts (1.2 to 1.7 mph) downstream. Surface water velocity in the LCR at low summer/fall flow depends on the tide, and averages 0.5 kts (0.6 mph) upstream on an incoming high tide, and 1.0 kts (1.2 mph) downstream on an outgoing low tide (NAC, 2015).

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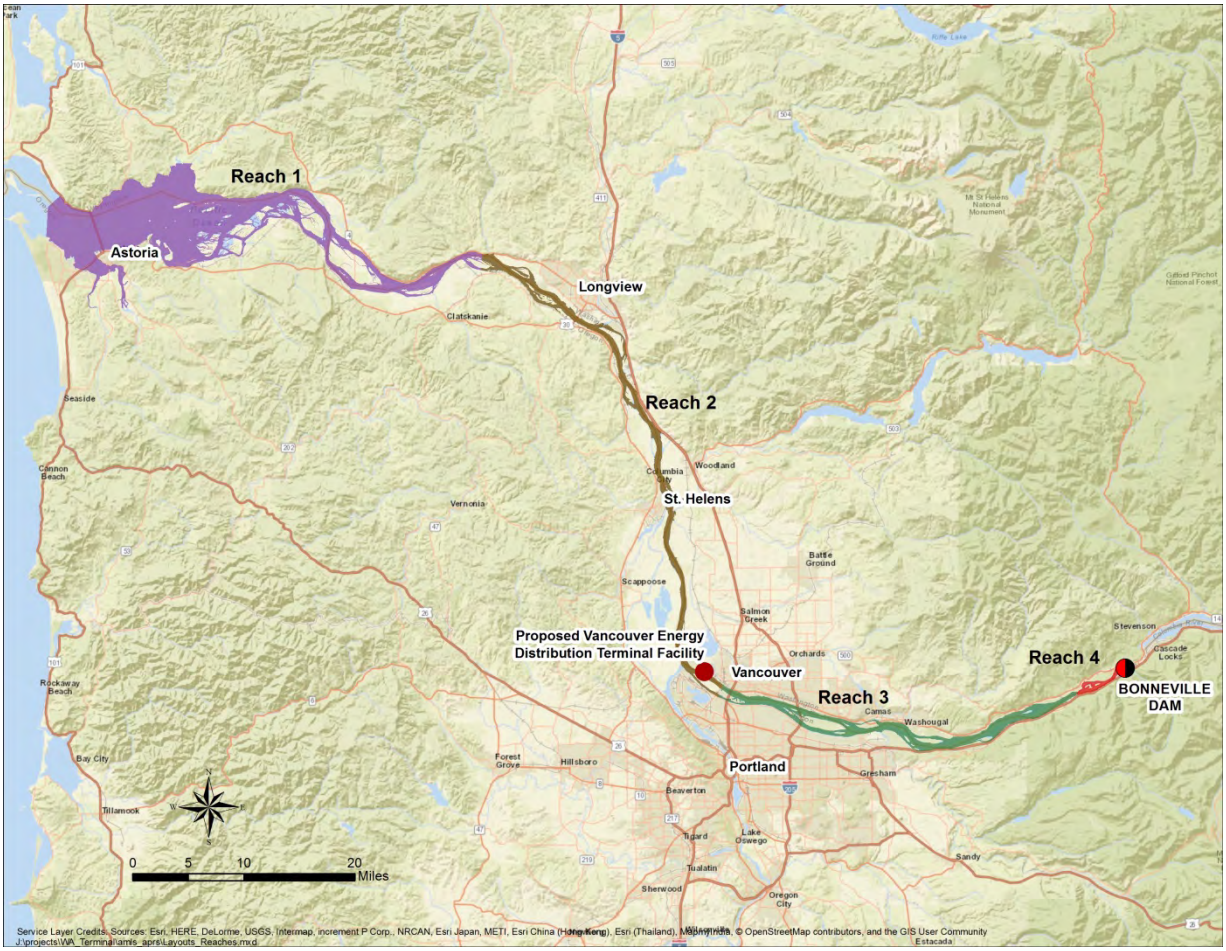
Figure 2.4. LCR reaches defined for this analysis.



In addition, for Reach 1 we estimated the average current speed from station-specific Tidal Current Predictions data computed by the National Oceanic and Atmospheric Administration's (NOAA's) Center for Operational Oceanographic Products and Services (NOAA, 2016a). Station predictions are available in approximately 3.5-hour time steps for 2014–2016. We computed averages at select stations (Figure 2.4, Table 2.1) for mid-May, 2014–2016, and found the data to be highly variable between stations. Average net downstream currents ranged from less than 0.1 mph to up to 0.5 mph. Flow velocities predicted for these tidally influenced current stations are at considerable depth rather than at the surface of the river, and may not represent the currents at the surface that would influence floating oil. In particular, the NOAA-predicted currents likely underestimate downstream surface velocities within the lower 18 mi of the river, where density differences between fresh river water and saline seawater result in a two-layered flow system. In this region, currents at depth may move in the opposite direction at the surface, because freshwater surface currents move downstream and saline water moves upstream (NAC, 2015; ODEQ et al., 2015).

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Table 2.1. Tidal current stations average net velocity downstream (toward the ocean) within Reach 1

Station identification	Station name	Approximate depth (ft)	Average May current (mph)
1171	Chinook Pt	14	0.1
1191	Woody Island Channel (off Seal Island)	12	0.2
1216	Hunting Island	20	0.2
1231	Cathlamet Channel	19	0.5

For our WCD tanker oil spill scenario, we estimated average surface water velocities and travel times below Vancouver for two reaches (Figure 2.4), extending about 100 mi downstream from the proposed Vancouver Terminal to the river mouth (Figure 2.5). We assumed that the average current in the first reach is 0.5 mph or 12 mi/day, for a transit time within Reach 1 of approximately 4 days. For Reach 2, we assumed a velocity on the high end of the range reported by NAC (2015) of 1.7 mi/hr. The distance from Vancouver to Longview is approximately 40 RM, so at this velocity the water transit time in this reach is approximately 1 day. This estimate is consistent with the modeling cited in the DEIS, which indicated that oil would be transported this distance in 24 hrs (French McCay et al., 2006; Etkin and Moore, 2015). It is also consistent with Kennedy and Baca (1984, p. 36), who estimated that the residence time of oil in the Columbia River from the *MobilOil* spill ranged from “a few days” for surface oil to about 1 week for oil in the water column, several weeks for oil near the river bottom, and longer still for stranded oil.

Water Volume

We estimated the volume of water within the four reaches we defined within the LCR. We used the channel area of each reach to estimate the water surface area. We obtained channel boundaries from the U.S. Geological Survey (USGS) National Hydrographic Dataset (USGS, 2012), based on the “perennial, Stream/River” feature code within the attribute table of the geographic information system (GIS) data. We obtained bathymetric data in the form of a 30-m digital elevation model (DEM; NOAA, 1998) from the mouth of the Columbia River to the Bonneville Dam.[1] Table 2.2 presents the estimated volume, surface area (derived from the bathymetric data footprint), and approximate start and end mile for the four reaches below the Bonneville Dam.

1. The DEM was generated from 306,711 soundings dating from 1935 to 1958 with depths relative to the local tidal datum which, according to the metadata from NOAA, is typically the mean lower low water (MLLW) datum. We derived volumetric estimates by reach within a GIS by calculating the volume below a reference plane that we defined using either the average great diurnal tide range [mean higher high water (MHHW) minus MLLW from the tide gauge information (NOAA, 2016b) within the reach (Reaches 1 and 2), or the highest value within the bathymetric layer (Reaches 3 and 4). In the latter case, this was expressed as positive values (i.e., values above the MLLW datum).

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Figure 2.5. Location of Bonneville Dam, tidal current stations and tide stations, and river miles on the LCR.

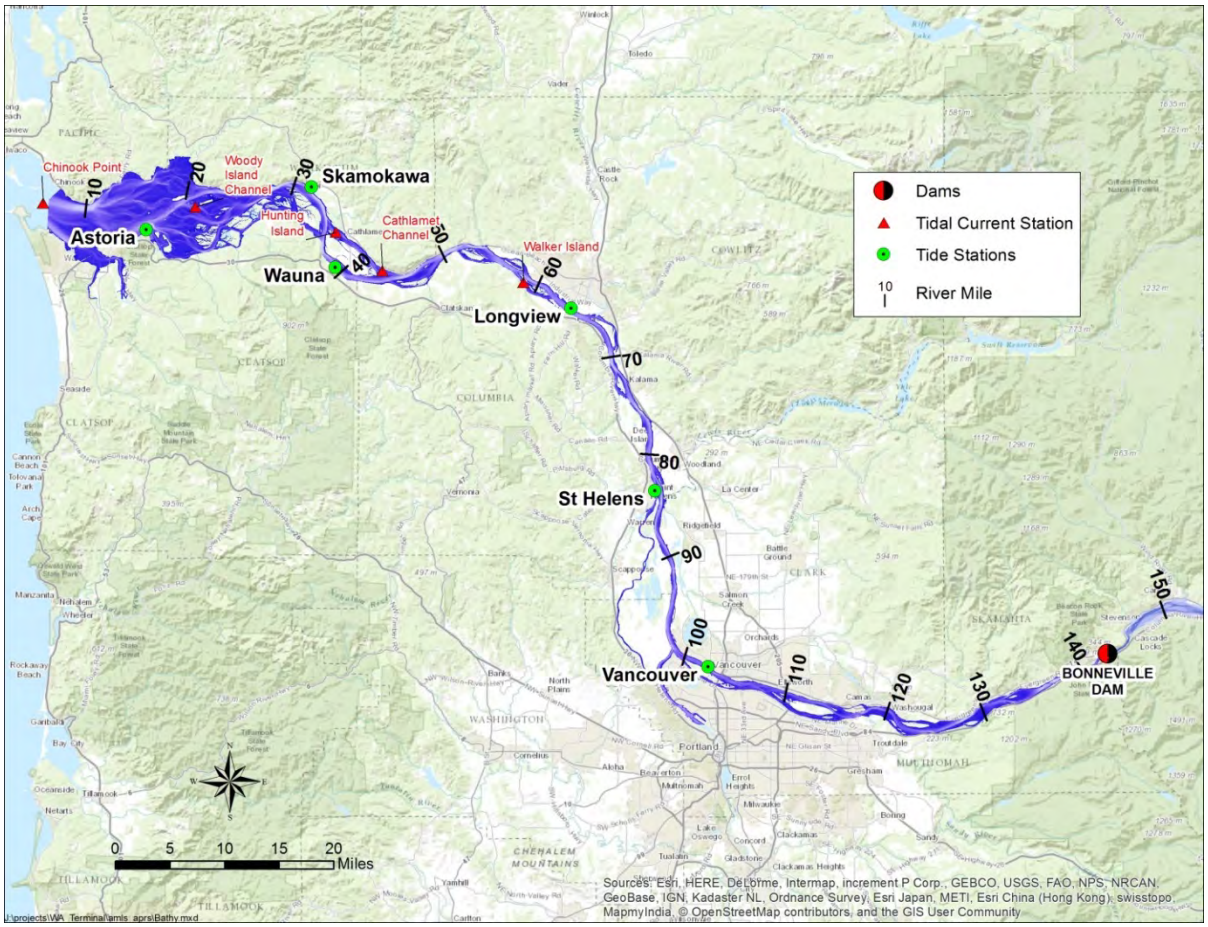

Table 2.2. Approximate volume, surface area, and river mile of reaches

Reach	Volume (ft^3)	Surface area (ft^2)	Average depth (ft)	Start of reach (RM)	End of reach (RM)
1	7.99E+10	3.66E+09	13.5	7	53
2	2.10E+10	8.29E+08	20.0	53	103
3	1.32E+10	7.60E+08	10.7	103	138
4	5.65E+08	3.30E+07	12.4	138	143

Automated Data Inquiry for Oil Spills 2

The Vessel Spill Risk Analysis (Etkin and Moore, 2015) provides results using the Automated Data Inquiry for Oil Spills 2 (ADIOS2) model, to simulate the fate of a large Bakken crude spill into an estuary. ADIOS2 is a NOAA model developed to predict the weathering processes and characteristics of oil slicks (Lehr et al., 2002). ADIOS2 uses information on the physical properties of the oil and environmental conditions, such as wind speed, to predict the fate of oil spilled onto water. It simulates the processes of oil spreading, evaporation, emulsification, and dispersion into the water column for up to 5 days following a spill (Lehr et al., 2002). As

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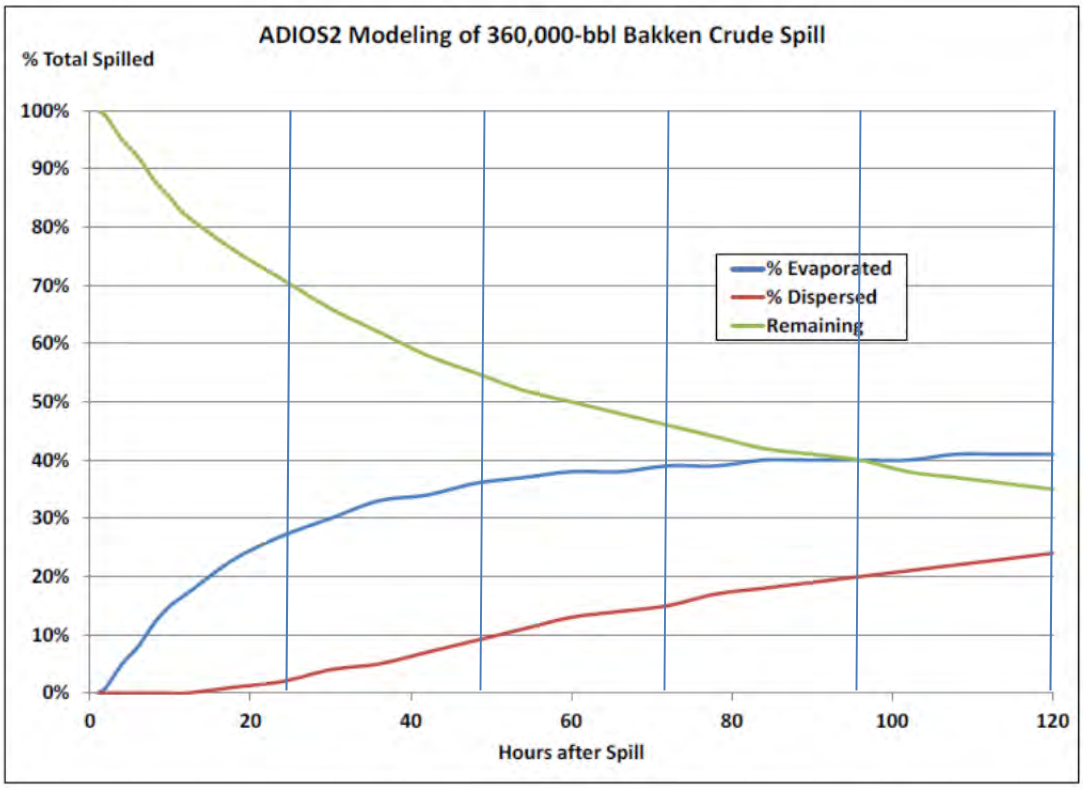
presented in the DEIS, the model was based on 360,000 bbls of Bakken crude spilling into 50°F estuarine waters with 8 mph winds, and the properties of the crude were based on "Lac Megantic samples with API of 41.8, density 0.827 g/cc at 50°F, viscosity 3.6 cSt at 50°F" (Etkin and Moore, 2015, p. 46).

The model predicts that after 1 day, approximately 4% of the oil will have dispersed into the water column, 29% of the oil will have evaporated, and about 67% of the oil will remain floating on the water surface. After 5 days, approximately 24% of the oil will have dispersed into the water column, 41% will have evaporated, and 35% of the spilled oil will still be on the surface (Figure 2.6). The ADIOS2 model does not simulate other effects of the fate of spilled oil, such as stranding of oil on the shoreline, biodegradation, or photo-oxidation.

Figure 2.6. ADIOS2 modeling of 360,000 bbl Bakken crude spill in estuary. Vertical lines added to indicate 1, 2, 3, 4, and 5 days post-spill.



Source: Etkin and Moore, 2015, Figure 14.

Spill Impact Model Application Package

French McCay et al. (2006) used the Spill Impact Model Application Package (SIMAP) to model a spill of 25,000 bbls of Bunker C fuel oil in a location between Longview and Vancouver, WA. This model scenario differs from the WCD scenario we evaluated in this report in many ways. For instance, Bunker C is a heavier and more viscous oil than Bakken crude, and 25,000 bbls is less than 15% of the effective WCD spill. French McCay et al. (2006) estimated that this considerably smaller spill would result in oil slicks traveling downstream to Longview, WA, within 24 hours (Figure 2.7).

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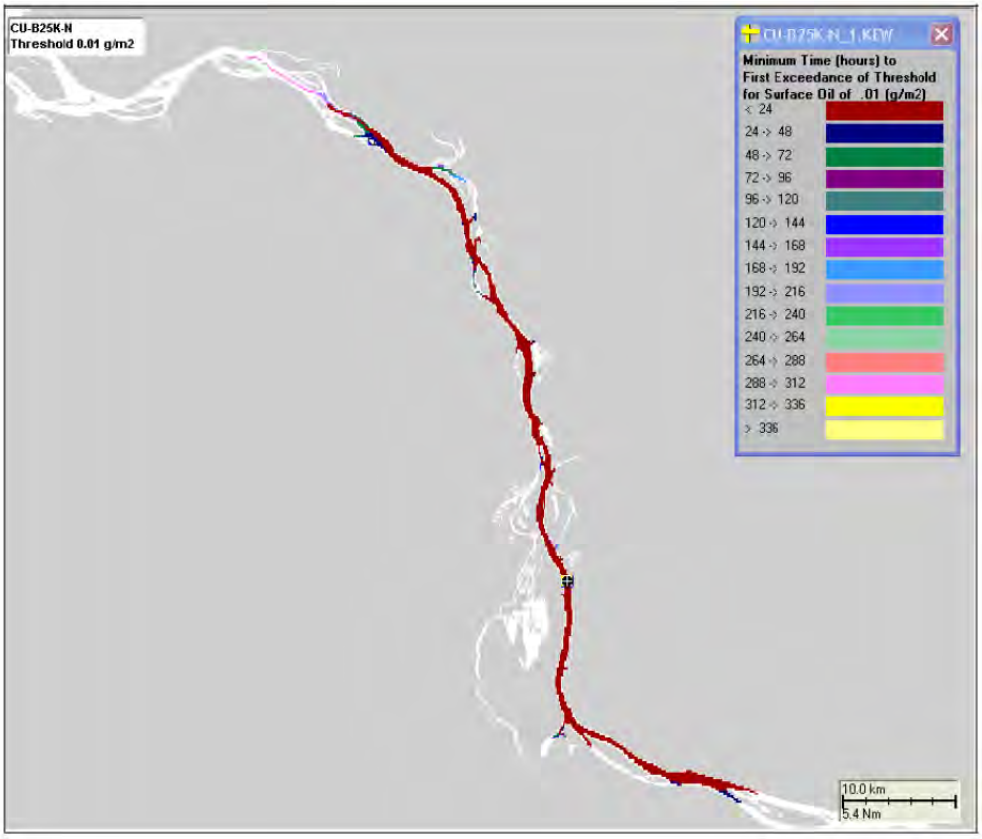
Figure 2.7. SIMAP model results showing the time after spill (hrs) when surface floating total hydrocarbons could first exceed 0.01 g/cm^2.



Source: French McCay et al., 2006, as cited in Etkin and Moore, 2015, Figure 11.

The fate and transport of the oil will depend on environmental conditions at the time of the spill, as well as the nature of the release of the oil. To bracket the release scenarios, we developed two WCD scenarios: one scenario assumes a rapid release from the tanker and all the oil is discharged within 2 hrs, and the other scenario assumes that the oil is discharged continuously for 24 hrs. The shorter timeframe results in more concentrated oil and less spreading over the river, while the longer timeframe results in a larger footprint of oil, but less oil within the contaminated surface area. As mentioned previously, we assumed this spill would occur in the spring (approximately mid-April to mid-May).

2-Hour Release of Oil

For our short timeframe discharge scenario, we assumed that the WCD of 189,845 barrels of Bakken crude is released over 2 hrs near the proposed Vancouver Terminal. Integrating the data from our data evaluation and the modeling efforts cited in the DEIS, we estimated the following:

Vancouver to Longview – Reach 2

- Within 1 day, the oil is estimated to travel from Vancouver to Longview, consistent with both the estimated transit time based on river velocity and the aforementioned modeling data. Some oil could also migrate upstream as the result of winds, but we did not consider upstream migration in this scenario.

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- Some of the oil could strand on the banks and floodplain habitat. Some of the stranded oil could be re-released during inundation with water during tidal fluctuations, but in other areas it could remain for days or weeks, or even longer. Sedimentation of oil could also result in contaminated sediments in more quiescent areas of the river. The ADIOS2 model results (Etkin and Moore, 2015) do not provide an estimate of the amount of oil lost from the water column by stranding and sedimentation.
- Biota could be exposed to stranded oil and oil in sediments.

Unquantified impacts: Upstream movement of oil

French McCay et al. (2006) predicted the oil would go both upstream and downstream. Other data suggest that while the river is tidally influenced as far upstream as the Bonneville Dam, it generally does not reverse flow upstream of Longview. It is possible that oil from a WCD would flow upstream as well as downstream, but we have not included the upstream reach in this analysis.

- Based on the ADIOS2 modeling, approximately 4% of the oil could disperse into the water column over the 1-day transit time. Using the estimated volume of water in Reach 2 (Table 2.2), and assuming this dispersed oil is evenly mixed laterally, vertically, and longitudinally within the Columbia River, we estimated the oil concentration in the water would be approximately 20,000 µg/L (Table 2.3). In an actual spill, the oil would not mix completely, and concentrations would be more patchy and variable.
- Assuming a percentage PAH percentage in the oil of 1.12% (Etkin and Moore, 2015, Table 46), the concentration of total PAHs[2] would be approximately 230 µg/L.
- Biota in the water column could be exposed to both the floating oil and oil dispersed into the water column.

Longview to Mouth of Columbia River – Reach 1

- Over the next few days, the oil could continue to flow downstream with the currents, as well as spread and disperse due to winds and waves.
- We estimated the transit time for the oil in Reach 1 to range from 3 days based on the 1984 *MobilOil* spill to 5 days based on the net velocity in this reach. For calculation purposes, we assumed the oil would be present on the water for 4 days before exiting the mouth of the Columbia River. We did not account for impacts to the ocean habitat or coastal areas in this analysis.
- Some of the oil could strand on river banks and floodplain habitat. Some of the stranded oil could be released again during inundation with water during tidal fluctuations, but in other areas it could remain for days to weeks, or even longer. Sedimentation of oil could also result in contaminated sediments in more quiescent areas of the river. The ADIOS2 model results (Etkin and Moore, 2015) do not provide an estimate of the amount of oil lost from the water column by stranding and sedimentation.
- Biota could be exposed to stranded oil and oil in sediments.

2. Total PAHs in this report refer to the sum of 50 commonly measured parent and alkylated PAHs; see Forth et al. (2015) for more information.

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Table 2.3. Estimated oil and PAH concentrations in the LCR for an effective WCD near Vancouver

Days since oil spill	Reach with floating and dispersed oil	Oil dispersed into water column (ADIOS2)	Estimated oil dispersed into the water column (gals)	Estimated percentage of total PAH in oil	2-hr release estimated oil in the water column (µg/L)	2-hr release estimated total PAH in water column (µg/L)	24-hour release estimated oil in the water column (µg/L)	24-hour release estimated total PAH in water column (µg/L)
1	2	4%	318,900	1.12%	20,000	230	2,000	20
2	1	9%	717,500	0.73%	48,000	350	4,000	30
3	1	15%	1,195,900	0.68%	80,000	540	7,000	50
4	1	20%	1,594,500	0.65%	110,000	690	9,000	60
5	1	24%	1,913,400	0.63%	130,000	800	11,000	70

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- Based on the ADIOS2 modeling results, oil would continue to disperse into the water column, with approximately 24% of the oil being dispersed into the water column within 5 days (Etkin and Moore, 2015).
- The ADIOS2 modeling predicts that at the end of 5 days, 35% of the oil would remain floating on the water.
- The floating oil would weather, resulting in a lower fraction of PAHs in the oil over time.
- We assumed that oil would cover one-quarter of Reach 1 each day as it migrates through the reach over 4 days.
- As above, we assumed that the available oil would be fully mixed within the water column.
- Using the estimated volume of water in Reach 1 (Table 2.2), and the amount of dispersed oil, we estimated oil concentrations could range from 48,000 to 130,000 µg/L in the water column beneath the floating oil slicks (Table 2.3).
- Assuming that total PAH is 1.12% of fresh oil and decreases to 0.63% after 5 days, the total PAH concentrations in the water column in Reach 1 could range from 350 to 800 µg/L (Table 2.3).
- Biota in the water column could be exposed to both the floating oil and oil dispersed into the water column.

24-Hour Oil Spill

If the oil is released over 24 hrs, the WCD of 8 million gallons of oil would be spread out over a much larger geographic area. We estimated that oil concentrations in the water could be as high as 2,000 µg/L in Reach 2, with total PAH concentrations of 20 µg/L (Table 2.3). As above, the ADIOS2 model results indicate that dispersion into the water column will increase over time, while weathering of the oil will reduce the fraction of PAH in the oil. Using the same assumptions described above, but with oil spread over a much larger spatial footprint, we estimated oil concentrations in the water in Reach 1 to range from 4,000 to 11,000 µg/L, with total PAH concentrations ranging from 30 to 70 µg/L.

Although these estimates of the fate and transport of a Bakken crude WCD into the Columbia River are uncertain, the scenarios described above provide a reasonable estimate of oil transport given available data.

2.3 WCD from Train Derailment into Columbia River Upstream of Bonneville Dam

In addition to estimating damages and economic impacts of fishery closures in the LCR, we also assessed potential damages from a train derailment upstream of the Bonneville Dam. The BNSF railroad carrying Bakken crude from North Dakota and Montana run on the bank of the river through that reach (Etkin et al., 2015).

The Rail Spill Risk Analysis in Appendix E of the DEIS (Etkin et al., 2015) provides an effective WCD of 20,000 bbls for a train wreck, based on the derailment of 28 full tank cars, each carrying 714 bbls of crude. The DEIS states, “This represents approximately the 99th percentile with

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respect to derailed cars assuming all of the cars release oil. This is the volume that is the most credible or realistic WCD with respect to the likelihood of the largest number of cars involved in a derailment and the likelihood of the cars releasing all of their contents" (Etkin et al., 2015, footnote 11, p. 14).

Crude oil trains can have as many as 120 rail cars, with a theoretical maximum discharge of 85,860 bbls (Etkin et al., 2015). However, the Rail Risk Spill Analysis states that this scenario is "extremely unlikely based on the very low probability of all of the cars derailing and the very low probability that all of the cars would release oil" (Etkin et al., 2015, p. 24). We used the effective WCD of 20,000 bbls cited in Table 4-14 of the DEIS (EFSEC, 2015), rather than the theoretical WCD of 85,860 bbls.

2.3.1 Fate and Transport

We evaluated a worst-case scenario of a train derailment near the Bonneville Dam, where spilled oil went over the spillway at the dam and entered the protected white sturgeon (*Acipenser transmontanus*) spawning area 4.5 miles downstream of the dam. For this scenario, we evaluated only natural resource damages, although it is likely a fishery closure would also be enforced as assumed in the tanker spill scenario described above. We have no existing models of oil fate and transport in this area, and developing our own model is beyond the scope of this analysis. We made some simple assumptions that likely underestimate potential natural resource exposure to a WCD scenario of Bakken crude oil spilled into this reach.

To evaluate potential natural resource damages from a WCD train derailment, we assumed that the oil spill occurred just upstream of the Bonneville Lock and Dam. All of the oil was discharged from the rail cars within 2 hours. Oil spread on the surface of the Bonneville Pool and was transported downstream toward the dam.

The Bonneville Dam has two powerhouses generating electricity, and a spillway to allow water to bypass the turbines (Figure 2.8; USACE, Undated). In the spring and summer, water is discharged over the spillway. In this WCD spill scenario, we assumed that the discharged oil passed over the spillway, turbulently mixing with Columbia River water.

The concentrations of oil in the river downstream of the Bonneville Dam would depend on the assumed volume of the oil discharged, the discharge in the Columbia River at the time of the spill, and the assumed time for the spilled oil to pass over the spillway. River discharge at The Dalles Dam, upstream of the Bonneville Dam, averages 270,000 cfs during the spring months, and decreases to an average of 140,000 cfs by August.[3] At the Bonneville Dam, water during the spring and summer is discharged over the Bonneville Dam spillway as well as through the turbines at the two powerhouses. USACE (2008) reported an average discharge over the spillway of 100,000 cfs in the spring and 85,000 cfs during the day in the summer. The percentage of the flow directed over the spillway and through the powerhouses varies with operational conditions. As an example, a fish-tagging study by Adams and Rondorf (2007) from April 29 to June 6, 2005, reported a mean river discharge at the Bonneville Dam of 216,400 cfs, with 47.3% of flow discharged at the second powerhouse, 40.3% at the spillway, and 12.4% at the first powerhouse.

3. USGS Station 14105700, average monthly mean discharge from 1985 to 2015.

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Figure 2.8. Bonneville Lock and Dam on the Columbia River. The photograph was taken looking upstream to the east. The spillway is in the center, the two powerhouses are on the left and right of the spillway, and the lock is on the far right.

Source: USACE, 2003.

Given the highly turbulent environment beneath the spillway, we assumed that the spilled oil mixed completely with water discharged over the spillway. Downstream of the dam, oil-contaminated water would be further mixed with water flowing through the powerhouses. Even with dilution, the result of mixing a WCD of oil with the water in the Columbia River results in substantial oil concentrations downstream of the Bonneville Dam. Using average mean May discharge (2005–2015) from the Bonneville Dam of 284,000 cfs (USACE, 2016), a density of the Bakken crude of 0.827 g/cm^3 (Etkin and Moore, 2015, p. 46), and assuming that all 20,000 bbls of discharged oil passed over the spillway within 2 hrs, we estimated the concentration of oil fully mixed downstream in the Columbia River would be 45,000 µg/L. Assuming PAHs are 1.12% of the oil (see previous section), we calculated a total PAH concentration of 500 µg/L.

Unquantified impacts: Effects of a spill on dam operations

A WCD either upstream or downstream of the Bonneville Dam could disrupt dam operations. If a major spill occurred downstream of the dam, one potential response action would be to spill enough water to create a downstream flood that would flush surface oil out to the sea. If a major spill occurred in the impoundment upstream of the dam, a possible response action would be to greatly reduce downstream flows (and power generation) to try to capture the oil before it went over the spillway, through the turbines or over the fish ladders. These potential impacts are not quantified in this analysis.

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It is possible that some of the oil may not pass over the spillway, perhaps getting trapped behind the dams and removed from the river before it can be mixed. Even if only 40% of the oil passed over the spillway in 2 hours, after full mixing, oil concentrations in the river would be approximately 18,000 µg/L and total PAH would be about 200 µg/L. These concentrations are sufficient to cause adverse effects on exposed biota (see Chapter 4).

This scenario would result in a pulse of highly contaminated water moving down the LCR. The spatial and temporal dimensions of the pulse would depend on the quantity of oil and the time for the discharged oil to spill over the spillway. Some of the oil droplets would rise to the surface of the river and form an oil slick, and other droplets would remain entrained in the water column. The oil would disperse as it migrated downstream and be diluted by tributary inflows, but the oil would continue to affect natural resources as it migrated approximately 140 miles downriver.

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3. Impacts to Commercial and Recreational Fishing

This chapter evaluates the potential economic impacts to commercial and recreational fishing from the hypothetical WCD in the LCR. This stretch of the river, from the Bonneville Dam to the Pacific Ocean, supports substantial commercial and recreational fishing throughout most of the year for species such as salmon, shad, and smelt. It does not include areas specifically devoted to Treaty fishing by Indian Tribes.

3.1 Commercial Fishing

Chinook salmon (*Oncorhynchus tshawytscha*) is the most prevalent species for commercial fishing in the LCR, with landings averaging 1.7 million pounds over the last 5 years, from 2011 to 2015. Landings of coho salmon (*Oncorhynchus kisutch*) averaged 653,000 pounds over the same period. Other commercial species include sockeye salmon (*Oncorhynchus nerka*), shad (*Alosa sapidissima*), smelt (*Thaleichthys pacificus*), and white sturgeon. Total landings of all species averaged 2.4 million pounds over the last 5 years. Data on commercial landings and prices in the Columbia River were provided by the Oregon Department of Fish and Wildlife (ODFW).[1]

Commercial fishing occurs over several seasons, defined in part by the spawning migrations of the primary species. The winter season includes January and February, with fishing for small amounts of Chinook salmon and white sturgeon. The spring season extends from March 1 to June 15, when Chinook salmon and shad are the primary species. The summer season extends from June 16 to July 31, and includes the harvest of Chinook salmon and sockeye salmon. The fall season extends from August 1 to October 31, when Chinook salmon and coho salmon are the primary species. Smelt are present in the river throughout the year, though the commercial harvest is sometimes limited to certain months.

The value of commercial landings can be estimated using ex-vessel prices, which represent the amount that commercial fishermen receive for their catch. Prices vary by species and season, ranging from about $6.00 per pound for spring Chinook salmon to less than $0.50 per pound for shad. Ex-vessel prices do not account for the value to consumers of fish harvested in the Columbia River, which can be difficult to estimate given that alternative sources of fish are available. Ex-vessel prices also may not accurately reflect losses to commercial fisherman when fishing is disrupted. A complete estimate of losses to commercial fisherman could be lower because of factors such as reductions in cost and effort when the commercial harvest is restricted, or could be higher because of oil damage to boats and fishing equipment or because of impacts to the public's perception of seafood harvested in the Columbia River even after closures are lifted.

1. Data were provided by personal communication from Douglas Case of the ODFW on April 16, 2016, and from the ODFW website at: http://www.dfw.state.or.us/fish/oscrp/crm/comm_fishery_updates_15.asp.

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3.1.1 Baseline Activity

Table 3.1 shows commercial landings and value by month for the 2011 to 2015 period. Value is calculated as landings in pounds multiplied by ex-vessel prices per pound. The average of landings and value over this five-year period represents an estimate of expected baseline activity in the event of a future spill. “Baseline” refers to the level of activity that would have occurred in the absence the spill and represents the amount of activity that could be impacted by the spill.

Based on the averages for 2011–2015, baseline landings are 2.4 million pounds per year and the baseline value is $5.1 million per year. The most significant baseline activity occurs in the fall season, with the monthly ex-vessel value exceeding $1 million for both August and September. Total baseline landings for the fall season are 2.2 million pounds.

3.1.2 Period of Impact

Many previous oil spills in the United States have led to closures of commercial fisheries. In some cases the closures lasted only a week or two. Often these short-term closures have been precautionary, imposed wherever oil is potentially present and lifted when testing does not find contamination in fish. For example, following the Chalk Point oil spill on a tributary to Chesapeake Bay in 2001, commercial fishing was closed for 2½ weeks while fish were tested for contamination. In other cases, contamination was detected and closures remained in effect until testing confirmed that fish were safe to eat. This was the case following the DWH oil spill in the Gulf of Mexico in 2010, when many areas were subject to fishing closures lasting between 3 months and 11 months, depending on proximity to the source of the spill.

Table 3.2 summarizes commercial fishing closures for selected past spills in the United States where reliable information on closures could be found. A more extensive list of oil spills since 1990, along with source documentation for information about closures, is provided in Appendix A.

As evident in Table 3.2, the amount of oil released can affect the period of a fishing closure, with larger spills often resulting in longer closures than smaller spills. The type of oil released can also be a factor, and the type of oil released in each spill is reported in the more extensive table in Appendix A. However, this factor was not deemed critical to this analysis because Bakken crude oil includes both light and heavy components. The area impacted can also affect the period of closure, because spills on the open ocean may dissipate more rapidly than spills in a confined bay or river. The type of fishing affected is also important. For example, shellfishing closures often last longer than closures for other types of fishing because shellfish are stationary on the sea or river bottom and can be heavily exposed to oil.

The most common oil spills have involved quantities of oil of less than 150,000 gallons and have resulted in relatively short fishing closures. For example, the Chalk Point spill, the Cosco Busan spill, and the Refugio spill were modest in size and led to fishing closures lasting from 2½ to 6 weeks. The North Cape spill on the coast of Rhode Island in 1996 involved a release of 828,000 gallons and led to a 3-month fishing closure. The Bouchard 120 spill in Buzzards Bay, Massachusetts, led to closures lasting 6 months or more despite the modest size of the spill (less than 100,000 gallons). However, the closure did not apply to finfish in the open water but to shellfish beds on the sea floor that are often slow to recover. The DWH oil spill occurred in the open ocean, involved an extremely large release, and led to closures for all fishing lasting up to 11 months in some areas.

Table 3.1. Commercial landings in pounds and value of landings, 2011–2015[a]

	2011		2012		2013		2014		2015		Average, 2011–2015	
Month	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
January	965	$2,718	1,098	$3,003	126	$407	–	–	–	–	730	$2,043
February	3,088	$15,415	962	$5,032	889	$3,886	16,750	$24,566	17,026	$23,464	7,743	$14,473
March	19,906	$118,794	2,786	$16,383	8,421	$56,541	8,268	$50,793	22,709	$145,937	12,418	$77,689
April	49,849	$299,743	103,081	$687,890	42,263	$314,747	30,107	$203,455	35,167	$228,581	52,094	$346,883
May	119,133	$685,593	48,080	$282,091	66,228	$382,080	46,083	$248,476	112,981	$735,148	78,501	$466,677
June	143,738	$386,960	81,502	$359,295	60,727	$288,526	46,110	$182,941	94,466	$461,194	85,309	$335,783
July	19,748	$61,022	14,432	$56,995	34,636	$140,882	46,340	$167,968	37,196	$128,869	30,470	$111,147
August	716,354	$1,397,382	638,944	$1,145,926	997,541	$2,365,051	599,342	$1,022,362	639,507	$1,368,035	718,337	$1,459,751
September	1,101,695	$1,890,787	412,952	$732,737	895,315	$1,760,385	2,576,664	$3,383,431	970,474	$1,730,747	1,191,420	$1,899,617
October	124,900	$228,780	82,209	$168,012	178,059	$338,963	701,404	$907,313	130,691	$248,290	243,453	$378,272
November	–	–	–	–	1,038	$2,005	–	–	–	–	1,038	$2,005
December	–	–	–	–	–	–	–	–	–	–	–	–
Total	2,299,377	$5,087,193	1,386,045	$3,457,364	2,285,243	$5,653,473	4,071,067	$6,191,304	2,060,217	$5,070,263	2,421,512	$5,094,341

a. Monthly data were available for landings by numbers of fish, but landings in pounds and value of landings were available only by fishing season. Development of monthly estimates of landings and value may have resulted in some approximations. Harvest of pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) were small and were excluded from the estimates.

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Table 3.2. Commercial fishing impacts in past U.S. oil spills

Name of spill	Year	Location	Quantity of oil (gallons)	Impact area	Impact period	Severity of impacts	Type of impacts
Bouchard 120	2003	MA	22,000–98,000	Coastline, variable extent (maximum = 65 mi)	6 months or more	Closure	Shellfishing
Chalk Point	2000	MD	140,000	20 RMs	2.5 weeks	Closure/ advisory	Shellfishing closure; fishing advisory
Cosco Busan	2007	CA	54,000	San Francisco Bay, plus 45 mi of coastline	3 weeks	Closure	All fishing
DWH	2010	Gulf of Mexico	134,000,000	Ocean, variable extent (maximum = 84,000 mi^2)	3–11 months	Closure	All fishing
North Cape	1996	RI	828,000	250 mi^2 of ocean	3 months	Closure	All fishing
Refugio	2015	CA	142,000	22 mi of coastline	6 weeks	Closure	All fishing
Selendang Ayu	2004	AK	321,000	166 mi^2 of ocean/bay	10 months	Closure	All fishing

The quantity of oil potentially released in the Columbia River, given the scenario under evaluation, is greater than the quantity released in many past spills. Though Bakken crude is a light oil with many components dissipating in a few weeks, the heavier components could remain in the river for many months. Also, the river environment may prevent oil from dissipating as quickly as spills in the open ocean. For the purposes of evaluating the impacts of an oil spill of 8 million gallons on the LCR, we assumed that the entire lower reach of the Columbia River, from the Bonneville Dam to the Pacific Ocean, would be closed to fishing for 6 months.

3.1.3 Economic Losses for Commercial Fishing

Following an oil spill in mid-spring (we use May 1 as the specific date), a 6-month closure would eliminate commercial fishing from May through the following October. Using the baseline estimates from the last two columns of Table 3.1, and summing across the appropriate months, would result in a loss of 2.3 million pounds of commercial landings, and a loss of $4.7 million in commercial fishing value.

3.2 Recreation Fishing

About 375,000 recreational fishing trips are taken annually to the LCR. A trip in this context is defined as any part of a day spent fishing. Species targeted by recreational anglers include Chinook salmon, coho salmon, steelhead trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), white sturgeon, shad, and walleye (*Sander vitreus*). Recreational fishing occurs by boat and from shore, with about 70% of recreational fishing trips by boat (Watts, 2009). The period from March to October is the most popular time of year for recreational fishing on the LCR. Data on the number of recreational fishing trips to the Columbia River were provided by the ODFW.[2]

2. Data were provided by personal communication from Kevleen Melcher of ODFW, April 14, 2016.

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3.2.1 Baseline Activity

Table 3.3 shows the number of recreational fishing trips by month for the most recent 5 years of available data. The average of these 5 years represents an estimate of baseline activity that could be impacted by a future spill.

Table 3.3. Recreational fishing trips, expenditures, and value

Month	Recreational fishing trips							
						Average, 2011–2015		
	2011	2012	2013	2014	2015	Trips	Expenditures[a]	Value[b]
January	1,405	722	1,119	–	–	649	$30,499	$37,654
February	7,231	11,066	6,520	3,452	5,170	6,688	$314,193	$387,892
March	61,502	41,123	42,222	25,435	41,044	42,265	$1,985,619	$2,451,382
April	51,111	58,541	30,882	60,457	50,545	50,307	$2,363,432	$2,917,818
May	26,701	24,853	28,106	40,426	42,427	32,503	$1,526,972	$1,885,151
June	73,238	70,095	78,494	58,370	43,875	64,814	$3,044,981	$3,759,235
July	64,266	60,139	26,080	31,015	33,012	42,902	$2,015,555	$2,488,339
August	70,829	56,326	67,996	53,877	43,642	58,534	$2,749,927	$3,394,972
September	69,127	65,386	63,889	74,072	70,086	68,512	$3,218,694	$3,973,696
October	25,883	8,212	9,982	16,439	18,274	15,758	$740,311	$913,964
November	3,399	–	–	–	–	680	$31,937	$39,428
December	1,890	–	–	–	–	378	$17,758	$21,924
Total	456,582	396,463	355,290	363,543	348,075	383,991	$18,039,878	$22,271,455

Notes: Totals may not sum due to rounding. Estimates of the total number of trips may be low due to incomplete sampling in winter months.

a. Average expenditures are the average number of trips mutliplied by $46.98 in expenditures per trip.

b. Average value is the average number of trips mutliplied by $58.00 in value per trip.

Table 3.3 also shows two types of value associated with recreational fishing trips. The first value is angler expenditures. Expenditures do not represent a loss to anglers, who recoup expenditures in the event that they cancel trips after an oil spill. However, the loss of spending by anglers can represent a disruption to local economic activity, particularly for businesses close to the affected areas and those businesses that provide services specifically for anglers, such as bait shops and marinas. The second value is the enjoyment value of fishing trips, or “consumer surplus.” This represents the amount anglers would be willing to pay, above what they actually pay, for the ability to take recreation trips to the Columbia River.

Expenditures were calculated by multiplying the number of fishing trips by $46.98 in estimated per-trip expenditures. This amount was calculated as the total angler trip-related expenditures in Washington and Oregon divided by the total angler trips in Washington and Oregon (USFWS and Census Bureau, 2014). Expenditures for anglers fishing on the Columbia River could differ from expenditures by anglers using sites throughout Washington and Oregon, but data specific to the Columbia River could not be obtained for this analysis.

The value of a fishing trip was taken from a report prepared for the Washington Department of Fish and Wildlife (WDFW) on the economic value of commercial and recreational fisheries in Washington State (TCW Economics, 2008). That report provided value estimates for several types of fishing, with a value of $58.00 per day for salmon fishing in Washington State. Salmon

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are the most popular species for recreation anglers on the Columbia River (Watts, 2009). For context, other related values include an estimate of $44.36 per trip for the value of Pacific Coast fishing (Loomis, 2005), calculated using a synthesis of values from 15 studies. A recent study of steelhead trout fishing on the Snake River in Idaho, a tributary of the Columbia River, found values ranging from $47.64 to $71.84 per trip (McKean et al., 2010).

3.2.2 Period of Impact

Following an oil spill, fishing closures may be imposed for several weeks or many months. However, the loss of recreational fishing depends as much on the behavioral response of anglers as any government-imposed closures. In some cases, such as the Athos oil spill on the Delaware River in Philadelphia, there was no fishing closure but angers avoided the spill area for many months (Athos/Delaware River Lost Use Technical Working Group, 2007). In other cases, such as the Chalk Point oil spill in Maryland, a closure was imposed and then lifted, but the level of recreational fishing activity did not return to normal until several months later (Byrd et al., 2001).

Table 3.4 summarizes the extent of impacts to recreational fishing for selected past oil spills in the United States. Additional information on the recreation impacts of past spills is included in Appendix A. The time period of impacts varies from a low end of 1 or 2 months to a high end of a year or more. The limited number of examples where impacts lasted a year or more includes two cases of an oil spill in a river (the Athos spill[3] and the Kalamazoo River spill); in these cases, the ability of oil to dissipate over a wider area was limited. In the Bouchard 120 spill, impacts lasted 2 years, but the impacts involved shellfishing for which prolonged impacts are more common than for other types of fishing. Investigators often find that impacts to boat-based fishing decline more quickly than shoreline fishing. This can be observed in Table 3.4 by comparing the boating assessments for the Bouchard 120 spill and the DWH spill to other activities assessed for those spills.

Overall, Table 3.4 illustrates that the severity of impacts from past spills typically varies from a 100% decline in trips during a fishing closure, to declines of approximately 10–60% when closures are not in place.

In evaluating a potential spill on the Columbia River, the potential release of 8 million gallons in the contained environment of a river suggests that significant impacts to recreational fishing would occur. While the lighter components of Bakken crude oil could dissipate quickly, significant amounts of heavier oil could remain for many months. In the previous section, we concluded that a fishing closure of the entire LCR could be in place for 6 months. In addition to affecting commercial fishing, a closure would also eliminate recreational fishing for that period. After the closure, evidence from past spills indicates that some recreational anglers would continue to avoid the spill area for some time. We assume that impacts to recreational fishing activity would decline linearly over the next 6 months, from 100% during the last month of the closure, to zero 1 year after the spill.

3. Impacts in the Athos spill were calculated over a period of 7 months, as shown in Table 3.4. However, the assessment of impacts did not begin until 5 months after the spill event because the spill occurred at the start of the winter season when little fishing occurred. The total elapsed time before impacts subsided was therefore a full year.

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Table 3.4. Recreational fishing impacts in past U.S. oil spills

Name of spill	Year	Location	Quantity of oil (gallons)	Impact area	Impact period	Severity of impacts	Type of impacts
American Trader	1990	CA	416,598	14 mi of coastline	7.5 weeks	85% decline in trips for first 5 weeks; 30% decline for next 2.5 weeks	Beach use, including some fishing
Athos	2004	DE	263,000	60 RMs	7 months	11% decline in trips	Fishing
Bouchard 120 (shoreline)	2003	MA	22,000–98,000	65 mi of coastline	2 months	9% decline in trips	Shoreline use, including some fishing
Bouchard 120 (shellfishing)	2003	MA	22,000–98,000	65 mi of coastline	2 years	59% decline in trips in first year; 11% decline in second year	Shellfishing
Bouchard 120 (boating)	2003	MA	22,000–98,000	65 mi of coastline	1 month	3% to 6% decline in trips	Boating, including fishing
Chalk Point	2000	MD	140,000	17 RMs	6 months	10% decline in trips	Shoreline use, including some fishing
Cosco Busan	2007	CA	54,000	San Francisco Bay, plus 45 mi of coastline	3 months	57% decline	Fishing, including boat and shore
DWH (shoreline)	2010	Gulf of Mexico	134,000,000	575 mi	11 months	Not available	Shore fishing
DWH (boating)	2010	Gulf of Mexico	134,000,000	575 mi	4 months	Not available	Boating, including fishing
Kalamazoo River (shoreline)	2010	MI	> 840,000	39 RMs	27 months	60% decline (initially 100% due to closure, declined over time)	Shoreline use, including fishing
Kalamazoo River (boating)	2010	MI	> 840,000	39 RMs	27 months	69% decline (initially 100% due to closure, declined over time)	Boating, including fishing

3.2.3 Economic Losses for Recreational Fishing

For this analysis, we assume that a large oil spill on the Columbia River would lead to a closure of the entire lower river to fishing for a period of 6 months. The closure would cause a 100% loss of recreational fishing from May, when the spill occurs, through October. Impacts over the next 6 months are assumed to decline following a linear trend. Specifically, in the seventh month (November) there is an 86% loss of trips; in the eighth month there is a 71% loss of trips; and the losses are 57%, 43%, 29%, and 14% for the remaining 4 months, respectively. Applying these percentage losses to the baseline amounts for the appropriate months in Table 3.3, the result is a total decline in recreational fishing on the Columbia River of 306,376 trips. This corresponds to a decline in trip-related expenditures of $14.4 million, and a decline in fishing value of $17.8 million.

3.3 Conclusions

A tanker accident on the LCR has the potential to release 8 million gallons of Bakken crude oil into the river environment (Etkin and Moore, 2015). An oil spill of this size would have a significant impact on commercial and recreational fishing. While past spills have not always

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resulted in fishing closures, some spills have resulted in closures lasting from several months to almost a full year. Given the large amount of the release under consideration and the confined river environment of the potential spill, a fishing closure of 6 months was determined to be a likely result.

Both commercial and recreational fishing would be affected by a fishing closure, but impacts to recreational fishing are likely to continue even after a closure is lifted. In past spills, recreation impacts have usually lasted for period of several months to a year or more. For the spill under consideration, we have assumed that impacts to recreational fishing last a full year. The first 6 months involve a 100% loss of trips during the closure, and the remaining 6 months involve losses that decline linearly to zero at the end of a year.

Although the impacts to fishing could affect areas of the Pacific Ocean as well as the Columbia River, we have evaluated impacts only down to the mouth of the river. Although upstream currents from ocean tides may not carry oil all the way to the Bonneville Dam, we have included the entire lower river up to the dam in our impact area. Given that the large majority of the lower river is downstream of the potential release, and given that fish spawning runs pass through oiled areas of the river, it is reasonable to include the entire lower river in the evaluation of spill impacts.

We calculated three different types of fishing losses: the loss in revenue from commercial landings, the decline in expenditures by recreational anglers, and the decline in the value of recreational fishing. Each of these values measures something conceptually different, and these values may not be strictly additive. For example, methods to calculate the value of fishing do not include angler expenditures, because anglers recoup their expenditures when they cannot fish. It would therefore be inappropriate to sum expenditures and angler values. Likewise, the loss in revenue from commercial landings is not a direct measure of economic loss, since commercial fishermen may recoup some costs, and may engage in other economic activities such as aiding in cleanup of the spill.

The loss in revenue from commercial landings is $4.7 million. This is a measure of the economic losses to commercial fishermen, although lost revenue does not directly represent total losses due to factors that are difficult to quantify, as noted above. The decline in expenditures by recreational anglers is $14.4 million. This should be viewed as a measure of the potential disruption to local economic activity, with the most direct impacts on local businesses, such as bait shops and marinas. If anglers make up for lost trips on the Columbia River by taking additional trips to other sites nearby, some of these expenditures may not be diverted from the local area.

The decline in the value of recreational fishing is $17.8 million. This is a monetary quantification of the loss of enjoyment by anglers whose preferred fishing opportunities are degraded or eliminated by the spill.

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A. Summary of Impacts to Recreational and Commercial Fishing from Past Oil Spills

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Table A.1. Impacts to recreational and commercial fishing from past oil spills

Spill incident	Year	Location	Quantity of oil	Type of oil	Type of environment	Recreational impacts				Commercial impacts				Sources
						Impact area	Impact period	Severity of impact	Type of impacts	Impact area	Impact period	Severity of impact	Type of impacts	
American Trader	1990	CA	416,598 gallons	Alaska North Slope crude	Ocean beaches	14 miles of coastline	7.5 weeks	85% decline for first 5 weeks; 30% decline for next 2.5 weeks	Beach use, including some fishing					Chapman and Hanneman (2001)
Athos	2004	DE	263,000 gallons	Heavy crude oil	River	60 RMs	7 months	11% decline in trips	Fishing, including boat and shore					Athos/Delaware River Lost Use Technical Working Group (2007); NOAA et al. (2009)
Berman	1994	PR	1.5 million gallons	#6 fuel oil	Ocean beaches	169 miles of coastline	2 months	30% decline in trips	Beach use, including some fishing					NOAA et al. (2002c); Tetra Tech (2006)
Bouchard 120 (shoreline)	2003	MA	22,000 to 98,000 gallons	#6 fuel oil	Bay/ocean beaches	65 miles of coastline	2 months	9% during first 2 months; 0.7% over next 3 months	Shoreline use, including some fishing					Bouchard B-120 Oil Spill Lost Use Technical Working Group (2009)
Bouchard 120 (shellfishing)	2003	MA	22,000 to 98,000 gallons	#6 fuel oil	Near-shore bay/ocean	65 miles of coastline	2 years	59% decline in first year; 11% decline in second year	Shellfishing	65 miles of coastline	6 months or more	Closure of some shellfishing areas	Shellfishing closure	Bouchard B-120 Oil Spill Lost Use Technical Working Group (2009)
Bouchard 120 (boating)	2003	MA	22,000 to 98,000 gallons	#6 fuel oil	Bay/ocean	65 miles of coastline	1 month	3% to 6% decline	Boating, including fishing					Bouchard B-120 Oil Spill Lost Use Technical Working Group (2009)
Chalk Point	2000	MD	140,000 gallons	#6 and #2 fuel oil	River, estuary	17 RMs	6 months	10% decline in trips	Shoreline use, including some fishing	20 RMs	2.5 weeks	Closure/advisory	Shellfish closure, fishing advisory	MDE (2000); U.S. EPA et al. (2000); Byrd et al. (2001); NOAA et al. (2002a)
Citgo Refinery/ Calcasieu River	2006	LA	2 million gallons	Waste oil	River and lake	67 square miles (Lake Calcasieu)	> 10 days	10-day closure, impacts could be longer	Fishing, boating					Associated Press (2006); Peck (2006)
Cosco Busan	2007	CA	54,000 gallons	Intermediate fuel oil	Ocean shoreline, near-shore ocean, estuary	San Francisco Bay, plus 45 miles of coastline	3 months	57% decline	Fishing, including boat and shore	San Francisco Bay, plus 45 miles of coastline	3 weeks	Closure	All fishing; $6 million in damages paid to 120 commercial fisherman	Leggett and Curry (2010); Bay City News (2011); CDFG et al. (2012)
Deepwater Horizon (fishing)	2010	Gulf of Mexico	134 million gallons	Louisiana sweet crude oil	Ocean shoreline	575 miles	11 months		Shore fishing					English and McConnell (2015)
Deepwater Horizon (boating)	2010	Gulf of Mexico	134 million gallons	Louisiana sweet crude oil	Ocean	575 miles	4 months		Boating, including fishing	Ocean, variable extent	3 to 11 months	Closure	Fishing closure	NOAA (2010a, 2010b, 2010c, 2010d, 2011); DWH NRDA Trustees (2015); English and McConnell (2015)

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Table A.1. Impacts to recreational and commercial fishing from past oil spills

Spill incident	Year	Location	Quantity of oil	Type of oil	Type of environment	Recreational impacts				Commercial impacts				Sources
						Impact area	Impact period	Severity of impact	Type of impacts	Impact area	Impact period	Severity of impact	Type of impacts	
Deepwater Horizon (shoreline)	2010	Gulf of Mexico	134 million gallons	Louisiana sweet crude oil	Ocean beaches	575 miles	19 months		Shoreline use, including fishing					English and McConnell (2015)
Ever Reach	2002	SC	12,500 gallons	#6 fuel oil	Near-shore ocean	Charleston Harbor	5 weeks	32% decline in trips	Shrimping					English (2004); SCDNR et al. (2012)
Julie N	1996	ME	170,000 gallons	#2 fuel oil	Bay/ocean	5 miles of coastline	1 month	100% decline (assumed)	Boat-based fishing					Clark et al. (1998)
Kalamazoo River (shoreline)	2010	MI	> 840,000 gallons	Crude tar-sands oil	River	39 RMs	27 months	60% decline (initially 100% due to closure, declined over time)	Shoreline use, including fishing					Mitchell (2015); USFWS et al. (2015)
Kalamazoo River (boating)	2010	MI	> 840,000 gallons	Crude tar-sands oil	River	39 RMs	27 months	69% decline (initially 100% due to closure, declined over time)	Boating, including fishing					Mitchell (2015); USFWS et al. (2015)
North Cape	1996	RI	828,000 gallons	#2 fuel oil	Bay/ocean	250 square miles of ocean	Several months	Closure	Charter fishing, recreational fishing	250 square miles of ocean	3 months	Closure	Fishing	Burroughs and Dyer (1996); NOAA et al. (2002b); RI DEM et al. (Undated)
Pearl Harbor	1996	HI	41,000 gallons	#6 fuel oil	Bay/ocean	Fishing closure for an unspecified period of time.				Fishing closure for an unspecified period of time.				Pearl Harbor Natural Resource Trustees (1999)
Refugio	2015	CA	142,000 gallons	medium to heavy crude oil	Near-shore ocean					138 square miles, 22 miles of coastline	6 weeks	Closure	All fishing; the primary focus of the fishery is sea urchin and crabs	Kacik (2015); NOAA (2015); Refugio Response Joint Information Center (2015)
Selendang Ayu	2004	AK	321,000 gallons	Viscous fuel oil (IFO 380 intermediate fuel oil)	Near-shore ocean	166 square miles of ocean/bay	10 months	Closure	All fishing	60 square miles of ocean/bay	10 months	Closure	All fishing	Alaska Department of Fish and Game (2005); Impact Assessment (2011); NOAA et al. (2015)

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4. Natural Resource Damages in Lower Columbia River

Natural resources in the Columbia River are held in trust for the public. The Trustees of natural resources in the LCR include the United States (Department of the Interior and NOAA), designated officials in agencies from the State of Washington and the State of Oregon, and numerous Tribes. The Oil Pollution Act (OPA) provides statutory authority for these Trustees to pursue damages (compensation) when oil pollution impacts natural resources.

As mentioned in Chapter 1, a comprehensive natural resource damage assessment (NRDA) for a major oil spill in the Columbia River could take years. In this chapter, we attempt to provide an approximate range of potential damages to specific natural resources, based on literature from other spills and on illustrative restoration-based "equivalency" analyses (see following section).

Trustees are entitled to compensation for direct losses to natural resources as well as lost use of natural resources. Recreational fishing losses are part of natural resource damages. The methods described in this chapter to estimate natural resource damages are likely to account in part but not entirely for recreational fishing losses. Therefore, the damages estimated in this section should not be added to the recreational fishing losses described in the previous chapter, but recreational fishing losses are not entirely subsumed in these estimates either.

The diminution of the cultural values that Tribes place on natural resources in the LCR would likely be an integral part of an NRDA for these oil spill scenarios. An evaluation of Tribal losses was not in the scope of the work presented here. As noted in the sidebar, Tribal losses from a catastrophic oil spill in the LCR could be considerable.

Unquantified impacts: Tribal losses

OPA provides Tribes with the authority to pursue damages for impacts to natural resources of particular significance to the Tribe. A large oil spill in the LCR could have considerable impacts on Tribal natural resources. This report does not include a calculation of these Tribal losses, and therefore may greatly underestimate natural resource damages from oil in the Columbia River.

4.1 NRDA Methods

NOAA has promulgated NRDA guidance under OPA [15 CFR Part 990]. The guidance provides methods for evaluating natural resource damages from an oil spill. Although not mandatory, the guidance presents three phases of oil spill assessment: a preassessment phase, where the Trustees determine that a full assessment is worthwhile; a restoration planning phase, in which the Trustees evaluate the impacts of the spill on natural resources and lost human uses and calculate the type and amount of restoration required to offset the impacts; and a restoration implementation phase.

Observable or measurable adverse changes to natural resources are defined as natural resource injuries [15 CFR § 990.30]. As part of the injury assessment process, Trustees quantify injuries over time and space. Trustees then develop restoration plans that describe the type and scale of restoration needed to compensate for the injuries to natural resources. A comprehensive examination of potential injuries from a worst-case oil spill and potential restoration projects to offset those injuries is well beyond the scope of this exercise. Rather, we present a commonly-used model to calculate an approximate amount and cost of habitat restoration that would offset potential injury scenarios.

One common approach to calculating natural resource damages is equivalency analysis, in which the Trustees calculate the amount and cost of restoration that will restore the equivalent to what

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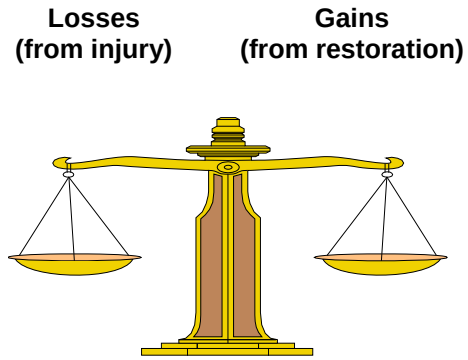
was injured as a result of the oil spill. Models used to make these calculations include the resource equivalency analysis (REA) and the habitat equivalency analysis (HEA), which is a variation of a REA with restoration based on units of habitat. Equivalency methods have been published in peer-reviewed literature, have been codified in NOAA's regulations for NRDA, have been accepted by U.S. Courts,[1] and are routinely performed at natural resource damage sites throughout the United States and overseas. Technical approaches for conducting equivalency analyses have been presented in published articles (e.g., Strange et al., 2002, 2004; Allen et al., 2005; Cacela et al., 2005; NOAA, 2006a).

Equivalency analyses are used to quantify impacts resulting from injuries to natural resources (i.e., the debit) as well as the expected benefits from restoration (i.e., the credit; Figure 4.1). Determining equivalency (scaling) between the debit and credit is conceptually simple:

- Sum the quantity of natural resource injuries over space and time
- Determine the amount and timing of natural resource benefits or services expected per unit of restoration
- Divide the total losses by the benefit per restored unit to calculate the quantity of required restoration.

Figure 4.1. HEA and REA are used to determine the type and amount of restoration needed to balance losses from natural resource injuries.



In this report, we perform equivalency analyses for different components of injury, including a HEA focused on aquatic habitat that could be injured in the LCR, and a HEA focused on floodplain habitat for birds that could be killed by the hypothetical spill. As mentioned previously, this report is not intended to replicate a detailed NRDA as spelled out in 15 CFR Part 990, but rather serves as illustration of the magnitude of potential natural resource damages that could occur.

To quantify potential natural resource injuries, we have estimated exposure of fish and birds to the oil, and then discussed the adverse effects that the oil exposure would have. This approach integrates data from other oil spills, including in particular the 1984 *MobilOil* spill that occurred in the LCR; and the DWH spill in the Gulf of Mexico, which led to a tremendous body of new literature on the effects of oil on fish and birds. Much of the DWH research is summarized in the Programmatic Damage Assessment and Restoration Plan that the DWH NRDA Trustees published recently (DWH NRDA Trustees, 2016). The Abt co-authors of this report managed the toxicity testing program for fish and birds on behalf of the Trustees.

1. United States v. Melvin A. Fisher et al., Case No. 92-10027-CIVIL-DAVIS (S.D Fla, 1992); United States v. Great Lakes Dredge and Dock Co., 259 F. 3d 1300, (11th Cir. 2001); In re: ASARCO LLC Chapter 11 Bankruptcy, Case No. 05-21207 (U.S. Bankruptcy Court, Southern District of Texas, Corpus Christi Division).

4.2 Natural Resource Exposure

To assess the magnitude of natural resource injuries from the oil spill, we first estimate the exposure of natural resources to oil. For this analysis, we include data from the 1984 *MobilOil* spill, and we summarize recent data on water bird and salmon presence in the LCR reaches. We compare the fate and exposure data from Chapter 2 with these estimates of salmon and water birds presence to estimate the exposure of these natural resources to oil from an effective WCD. This is obviously not a comprehensive estimate of natural resource exposure, but quantifying injuries and damages to these biota provides an initial estimate of the magnitude of damages that may occur from the WCD spill.

Unquantified impacts: Injuries caused by response actions

Trustees may seek natural resource damages for injuries that occur as a result of oil spill response actions. These may include dispersant application, skimming, burning, destruction of vegetation to access the river, destruction of bank habitat removing stranded oil, etc. This analysis does not include any estimates of damages for such activities.

4.2.1 Fish

The LCR system serves as a staging and rearing habitat and major migration portal for millions of anadromous fish each year. Major salmonid species include Chinook salmon, coho salmon, sockeye salmon), and steelhead trout. Additionally, the LCR serves as one of a few remaining intact habitats supporting white sturgeon populations in the United States. In 2010, Jones et al. (2011) estimated white sturgeon populations in the LCR to be as high as one million fish including juvenile, sub-adult, and adult life stages. However, the 2016 sturgeon fishing regulations for the LCR suggest that the population is highly stressed, as sturgeon angling is catch-and-release only and closed entirely from May 1 to August 31 from RM 82 to the Bonneville Dam (ODFW, 2016).

In the LCR Geographic Response Plan, ODEQ et al. (2015) list many of the fisheries resources in the LCR that would likely be exposed to oil during a major spill, including millions of juvenile and adult salmonids; other anadromous fish including green sturgeon (*Acipenser medirostris*), shad, and smelt; juvenile bottom-dwelling larval fish including several species of sole and flounder; numerous freshwater fish species in the more upstream reaches; and important shellfish such as Dungeness crab (*Metacarcinus magister*) in the estuary.

Unquantified impacts: Potentially injured natural resources

This estimate of natural resource damages is based on oil exposure to birds and salmonid fishes during the spill. Many other natural resources would also be exposed to oil, including other anadromous and resident fish species, marine mammals (particularly pinnipeds), benthic organisms, vegetation, etc. Estimates of damages here are based on costs to restore bird habitat and salmonids. While these restoration projects will restore more than just salmonids and birds, they are not going to restore all natural resources that are exposed to an oil spill of this magnitude.

Fish Exposure to Oil in the 1984 *MobilOil* Spill

The 1984 *MobilOil* spill, summarized in Chapter 2, released about 3,925 bbl of heavy fuel oil into the Columbia River at St. Helens, Oregon. This was about 2% of the effective WCD spill for this reach of the river. The natural resource exposure data from this spill are quite limited. There was no estimate of the number of fish that might have been exposed to oil. After the spill, a gill net pulled up 55 white sturgeon, of which 13 (24%) had visible signs of oil in their mouths. A commercial petrale sole (*Eopsetta jordani*) cannery discarded some fish with visible oil in their mouths, and some anglers turned in surf perch (family Embiotocidae) with evidence of oil exposure. Kennedy and Baca (1984) mention that pens in Rainier, Oregon, about 10 miles

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downstream from the spill site, were stocked with coho salmon on the day of the spill, but the fate and transport data (Chapter 2) suggest that most of the surface oil had passed Rainier by the time the pens could be stocked. The fish were apparently healthy 9 days after the spill, but it is not clear if they were exposed to the oil.

Estimating Exposure from Current Fish Counts

To provide an illustrative evaluation of potential natural resource injuries to fish in the LCR, we focus on potential injury to salmonids. Adult salmon and steelhead trout return to the LCR and begin migrating up river to natal spawning grounds beginning in late spring through early fall. Peak migration periods vary for different species and strains (Figure 4.2A).

Young salmon or smolts also migrate downstream to the mouth of the LCR during their first 1–2 years of life as they transition physiologically and behaviorally in preparation for their oceanic life stage. These runs occur roughly from March through October, with the majority of smolts migrating in late spring and early summer (Figure 4.2B). These migrations are taxing and stressful for both adult fish swimming upstream while undergoing major physiological changes in preparation for spawning, as well as for smolts that are also undergoing major physiological alterations that allow them to quickly transition from a freshwater to a marine environment.

We estimated adult and smolt salmon populations in different reaches in the LCR based on 5-year average adult and smolt passage data at the Bonneville Dam (Columbia Basin Research, 2016a, 2016b; Figure 4.2). Our estimate of the total number of adult salmon swimming upstream that would intersect the plume of oil coming downstream is based on data suggesting that it takes an adult salmon about 3 weeks to travel from the mouth of the river to the Bonneville Dam (Rub et al., 2012). To estimate the total number of smolts exposed to oil, we assumed that a daily cohort of smolts counted at the Bonneville Dam would be in Vancouver 1 day later (McMichael et al., 2013) and travel downstream with the oil plume. Once that daily cohort reaches the estuary near the mouth of the river, they typically remain for several days before migrating out to sea (McMichael et al., 2013). This could cause several more daily cohorts of smolts to intersect the oil near the mouth of the river in Reach 1.

Based on the data from the Bonneville Dam, we estimate that if a tanker spill occurred near the proposed Vancouver Terminal between mid-April and mid-May, between 45,000 and 70,000 adult salmon could be exposed in Reach 1 (approximately Longview, Washington to the mouth of the river; see Figure 2.4), and as many as 20,000–60,000 adult salmon could be exposed in Reach 2 (approximately Longview to Vancouver, Washington). Juvenile salmon (smolts) would be moving downstream with the oil and the river flow. We estimate that approximately 1,400,000–1,600,000 smolts would be exposed to the oil in the river; because both the oil and the smolts are moving downstream, we have assumed that the same fish would be exposed in Reach 2 and Reach 1.

Unquantified impacts: Geographic scope of salmon smolt evaluation

Our estimates of exposed salmon smolts are based on data from automated fish counters at the Bonneville Dam. The dam is about 40 miles upstream of the presumed location of the spill. We are not accounting for additional smolts entering the river from tributaries in that 40-mile stretch.

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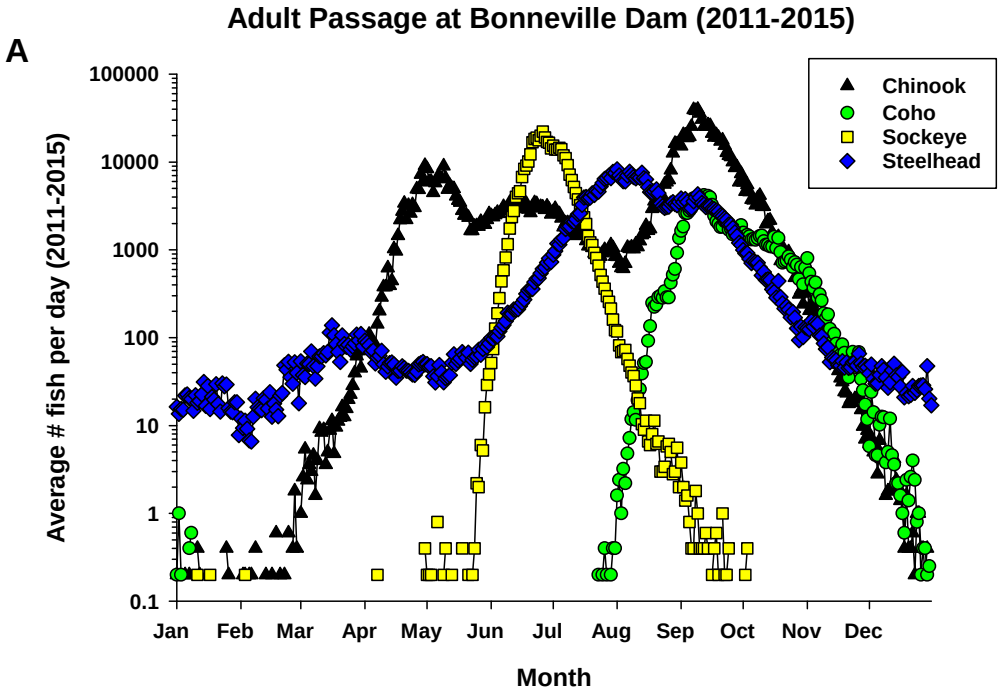
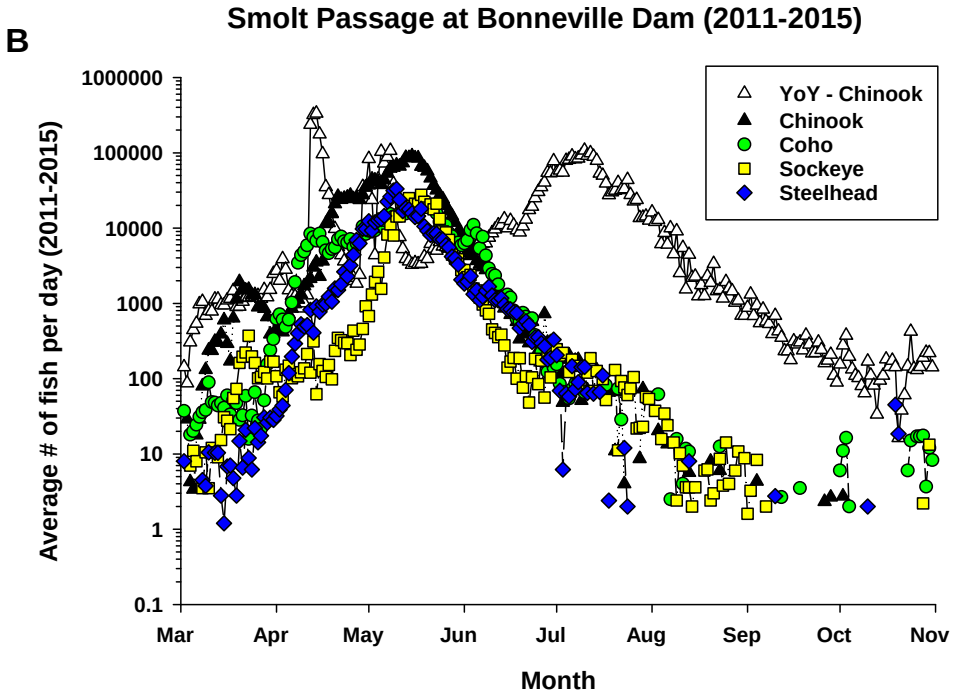
Figure 4.2. Average daily counts over 5 years (2011–2015) of adult salmon and steelhead moving upstream (A) and smolts moving downstream (B) at the Bonneville Dam.





Source: Columbia Basin Research, 2016a, 2016b.

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4.2.2 Birds

The LCR downstream of Vancouver includes four wildlife refuge areas with hundreds of bird species present at all times of year. The bird species most likely to be exposed to oil will be those that most heavily rely on water access to obtain food, including piscivores, dabbling and diving birds, shorebirds, and waders.

High-profile obligate piscivores like bald eagles (*Haliaeetus leucocephalus*), great blue herons (*Ardea herodias*), osprey (*Pandion haliaetus*), and belted kingfishers (*Megaceryle alcyon*) would likely be injured as a result of exposure to contaminated water caused by a spring/summer spill. These species, and many others, breed during this period, so adults and young could be impacted. Exposure of eggs and nestlings to oil occurs through transfer from contaminated food, nesting materials, and parental feathers. Impacts to adult bird health may in turn lead to nest abandonment and further loss.

Shorebirds and waders that rely on shorelines and marshy edges for foraging likely would also be affected by a spring/summer spill through lost food resources, habitat loss for both foraging and predator avoidance, and be exposed to toxic PAHs. Insectivorous birds, particularly those that rely on insects emerging from aquatic environments or that feed on invertebrates near shorelines, would likely be exposed to oil in shoreline habitats.

A major oil spill in the LCR would potentially expose a tremendous number of birds to oil. The LCR Geographic Response Plan (ODEQ et al., 2015) provides a summary of the bird species and habitats potentially exposed, including many threatened and endangered species. ODEQ et al. (2015) include the following when summarizing birds in the LCR:

- The Columbia River estuary is a shorebird site of world significance, supporting over 100,000 birds during peak migration periods. Tens of thousands of birds nest, feed, and/or roost throughout the lower 10 miles of the river during the spring and summer months. Some key species identified include Caspian terns (*Hydroprogne caspia*), double-crested cormorants (*Phalacrocorax auritus*), brown pelicans (*Pelecanus occidentalis*), and several species of gulls. In addition, seabirds such as marbled murrelets (*Brachyramphus marmoratus*) feed in the mouth of the estuary throughout the year.
- Bald eagles and great blue herons are nesting residents found throughout the region. Peregrine falcons (*Falco peregrinus*) are commonly found as winter and spring visitors to the lower estuary.
- Both resident and migratory songbirds heavily utilize riparian habitats year-round and are susceptible to oiling if riparian vegetation and shorelines become contaminated.

According to Collis et al. (1998), “Rice Island, a dredge material disposal island in the Columbia River estuary, supported the largest known caspian tern colony in North America (about 8,000 breeding pairs in 1998), and the only known breeding colony of this species in coastal Oregon and Washington. The colony of double-crested cormorants on East Sand Island in the estuary is the largest of its kind on the Pacific Coast of North America.” Both of these species nest in the estuary in the spring, typically laying eggs in late April or early May and incubating until early June. If the effective WCD spill occurred during these months, many of these birds

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would be exposed to oil while feeding in the river, and they would likely expose eggs to oil when incubating with oily feathers.

From 1978 to 2009, the number of nesting pairs of bald eagles along the LCR increased dramatically. In 1978, only 6 breeding pairs were found in Oregon, and 1 pair in Washington, in the Columbia River estuary. By 2007, 83 nesting pairs were in Oregon and 57 were in Washington (Isaacs and Anthony, 2011).

Bird Exposure to Oil in the 1984 *MobilOil* Spill

In response to the *MobilOil* spill, a bird rehabilitation facility was established at the Julia Butler Hansen Refuge for the Columbian White-tailed Deer (see Figure 1.1). Nearly 700 oiled birds, primarily western grebes (*Aechmophorus occidentalis*), common murres (*Uria aalge*), and scoters (*Melanitta* spp.) were brought to the facility. This includes birds oiled in the Columbia River and birds oiled along the Pacific Coast (Kennedy and Baca, 1984; Speich and Thompson, 1987). Kennedy and Baca (1984) include a list of 11 ducks, geese, and other waterfowl that they identified as target bird species most likely to have been exposed to the oil. No bald eagles were observed to have been exposed to oil (Kennedy and Baca, 1984), but very few bald eagles (9 nesting pairs on each side of the estuary) were present at that time (Isaacs and Anthony, 2011).

Estimating Bird Exposure

Unlike anadromous fish that are counted automatically at the Bonneville Dam, there are no automated bird counts for the LCR. The Audubon Society conducts Christmas bird counts annually, which provide brief snapshots of birds in specific small areas along the river. The data we examined were not at a sufficient scale over time and space to allow us to estimate the total number of birds (of any species, size, or guild). Thus, as discussed below, we used alternate methods for quantifying potential injuries to birds.

4.2.3 Pinnipeds

Harbor seals (*Phoca vitulina*), Steller sea lions (*Eumetopias jubatus*), and California sea lions (*Zalophus californianus*) can be found in the LCR and could be exposed to oil from a WCD spill. Seals and sea lions tend to congregate near the mouth of the river but are known to travel up the river all the way to the Bonneville Dam to feed on salmon and sturgeon (NOAA, 2006b; Wiles, 2015). The number of sea lions observed feeding near the bottom of the Bonneville Dam since 2002 has ranged from 85 to 111; more than 1,000 sea lions can be found in the LCR between the Bonneville Dam and the mouth (Norman, 2006).

NOAA (2014) estimates that the population of harbor seals in the LCR is approximately 5,700. Seals have their pups along the coast between mid-April and July (Seekins, 2009). Thus, it is possible the both adults and pups could be exposed to oil from the WCD spill.

The population of Steller sea lions in the LCR can range from 100 to 2,000 individuals (Wiles, 2015). During a typical day in May, there can be up to 3,000 harbor seals, 1,000 Steller sea lions, and 800 California sea lions on haul-outs in the Columbia River estuary (NOAA, 2006b).

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4.3 Natural Resource Injuries

This section presents evidence from other spills and studies, including limited data from the 1984 *MobilOil* spill, that show that natural resources are injured in large oil spills. As discussed previously, we focus on fish and birds, because these resources are more readily quantifiable.

4.3.1 Early-Life-Stage Fish

Developing early-life-stage (ELS) fish (i.e., embryos and larvae) are more sensitive to toxic components in crude oil than older life stages of fish. In particular, PAHs are highly toxic to ELS fish in concentrations in the low parts per billion range. For example, many ELS fish exposed to mixtures of DWH oil from the Macondo well in the Gulf of Mexico ("DWH oil") experienced mortality or severe cardiac impairment at concentrations ranging from 0.5 to 40 µg/L of total PAH and that subsequent exposure to ultraviolet (UV) light increased the toxicity of this oil by a factor of 10 to 100 (DWH NRDA Trustees, 2016, Chapter 4). Although PAHs are often used as the predominant quantitative metric to explain oil toxicity, it is important to remember that PAHs only comprise about 1% of the total mass of fresh crude oil, which contains thousands of additional compounds that may also elicit additional toxicity.

As described in Chapter 2, Bakken crude is also a light crude oil with a similar PAH profile to DWH oil. Therefore, it is reasonable to assume that the toxicity of Bakken crude will be similar to the toxicity of DWH oil.

4.3.2 Adult Anadromous Fish

Although ELS fish are typically more sensitive to oil than older life stages, juvenile and adult fish may also be adversely affected by oil exposure. The DWH NRDA Trustees (2016) developed a comprehensive toxicity testing program that included testing the effects of oil exposure on several juvenile and adult fish species. These tests focused on the effects of short-term oil exposure (1–7 days) on swim performance and immune function. These endpoints are relevant for migrating salmon that migrate from the mouth of the LCR to their natal spawning grounds, which could be hundreds of miles upstream. These fish need to be able to perform at a high level while undergoing major physiological and endocrinological changes in preparation for spawning, all of which can cause major stress to the fish.

Similarly, emigrating smolts may be more susceptible to immune challenges due to the stress of their migration and physiological changes taking place in preparation for the oceanic portion of their life history. Additional stress will compromise normal immune responses and make fish more susceptible to disease. Therefore, oil exposure can exacerbate natural stressors and increase mortality by decreasing swim performance and immune function in adult fish.

As part of the DWH NRDA, researchers determined that adult mahi-mahi (*Coryphaena hippurus*), a high-performing pelagic species, experienced significantly reduced swim performance at concentrations as low as 8 µg/L of total PAH (DWH NRDA Trustees, 2016; Stieglitz et al., 2016) after only 24 hours of exposure. The immune function of several juvenile fish species was compromised after PAH exposure, resulting in many adverse physiological effects including mortality. Effect levels and durations for these tests (Ortell et al., 2015) include:

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- Red snapper (*Lutjanus campechanus*; 16.5 µg/L of total PAH, 7 days)
- Atlantic croaker (*Micropogonias undulates*; 541 µg/L of total PAH, 4 days)
- Red drum (*Sciaenops ocellatus*; 245 µg/L of total PAH, 4 days).

Similar immunological effects have been observed with Pacific herring (*Clupea pallasi*) exposed to Alaska North Slope crude oil for 16–18 days, where Carls et al. (1998) observed immunosuppression and histopathologic abnormalities in adult fish exposed to oil-water mixtures with total PAH concentrations of about 25–60 µg/L.

In addition to sublethal effects on juvenile and adult fish, mortality has also been documented at relatively low oil exposure concentrations. For example, Birtwell et al. (1999) conducted yearly acute toxicity tests on juvenile pink salmon for 3 straight years and reported 96-hour LC50 (concentration lethal to 50% of the organisms in a test) values of 1.0 to 2.8 mg/L of total petroleum hydrocarbons. The estimated PAH values for these tests (assuming 1% of the total petroleum hydrocarbon content is PAH) would be 10 to 28 µg/L of total PAH.

Although controlled laboratory tests generate meaningful data that may help predict or explain adverse effects to fish in the wild, there are also observations of adverse effects to fish that occur after actual oil spills that we can use to assess possible injury. It may be difficult to quantify injuries to aquatic resources during and after these incidents because many dead fish will never be observed and counted and it is impossible to track survivors and monitor effects on their survival and reproductive success following exposure to oil. Therefore, actual observations of adverse effects in the field are underestimates of the full magnitude of injured resources.

Nonetheless, other oil spills in large rivers/estuaries have caused observable injuries to aquatic resources. For example, in August 2000, a pipeline rupture on the Pine River in British Columbia released approximately 6,200 barrels of light crude oil about 110 km (68 mi) upstream of the town of Chetwynd (BC Government, 2016). Reports indicate that 8% of the total oil spilled was not recovered from the water or soil, leaving about 500 barrels in the aquatic environment. Following the Pine River spill, surface sheen was reported 150 km (93 mi) downstream, major fish kills were observed downstream from the spill (BC Ministry of Environment, 2000), and the benthic invertebrate community was adversely impacted for up to 3 years following the spill (de Pennart et al., 2004). Although every incident will have unique characteristics, this example does suggest that a large oil spill in the LRC could adversely affect the aquatic community and cause major fish kills.

4.3.3 Birds

A tremendous amount of research has demonstrated that oil is toxic to birds. Studies have shown that oil on eggs affects reproductive success; ingested oil causes toxic responses such as anemia; and external oil damages feathers, causes hypothermia, and adversely affects flight. The DWH NRDA damage assessment report (DWH NRDA Trustees, 2016) and the supporting technical reports (e.g., Ziccardi and Drayer, 2015) include a review of much of the literature, and they summarize new findings that were discovered as part of the avian toxicity research during the NRDA process. Some of the highlights are included below; a more detailed review of oil toxicity to birds is beyond the scope of this document.

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Toxicity

Dozens of studies have shown that ingested oil is toxic to birds. The most prominent adverse effect of ingested oil is hemolytic anemia; studies as far back as the 1960s have shown this as a common response. Leighton (1993) provides a summary of the older studies. The DWH avian toxicity studies showed a direct link between oil ingestion and anemia endpoints (reduced packed cell volume, increased immature blood cells) in double-crested cormorants (DWH NRDA Trustees, 2016). Anemic animals lack sufficient functional red blood cells required for oxygen transport in the blood; eventually it is fatal, but anemic birds in the wild are subject to predation and less likely to be able to find sufficient food, which could result in mortality indirectly related to the oil.

Numerous studies have demonstrated that oil ingestion causes direct effects on the adrenal cortex that leads to cellular damage and an inability of the bird to respond to stress (e.g., Gorsline et al., 1982; see Leighton, 1993 for a review). Oil ingestion has also been shown to cause adverse effects to the immune system, including inflammation and infections (e.g., Newman et al., 2000). Finally, the DWH testing revealed that double-crested cormorants that ingested oil had reduced cardiac function and blood clotting dysfunction (DWH NRDA Trustees, 2016).

Reduced Reproductive Success

Studies decades ago demonstrated that minute amounts of oil on eggs can be sufficient to disrupt the developing embryo within. When avian eggs are exposed to even microliter volumes of oil during the first week of embryonic development, mortality and deformity rates are high (Albers, 1977, and many others; see Leighton, 1993 for review). The exposure can occur via oil transfer from contaminated nesting materials or from parental feathers. Additionally the reproductive success of adult females can be delayed and reduced following experimental oil ingestion (Cavanaugh and Holmes, 1982, 1987). Oiled birds are more likely to abandon nests and showed reduced parental care such as the 10-fold increase in nest abandonment observed in south polar skuas (*Stercorarius maccormicki*; Epply and Rubega, 1990).

Thermoregulation

Feathers provide birds with excellent insulation and waterproofing. Oil causes feathers to become matted, reducing both insulation and buoyancy. In cold waters, loss of buoyancy will compound thermoregulation issues from lack of insulation, which can rapidly causes hypothermia and death (O'Hara and Morandin, 2010).

Birds exposed to oil for only a few hours showed increases in heat production and thermal conductance even at room temperature (Erasmus et al., 1981; Dorr et al., 2015). The consequences of increased energetic demands to maintain body temperature, combined with behavioral changes such as increased time spent preening and changes in foraging patterns, have the potential to cause weight loss, interfere with reproduction, affect the immune response and prevent optimal body condition for migration.

Flight

Recent studies as part of the DWH avian toxicity work (see Ziccardi and Drayer, 2015) demonstrated that sublethal oil on feathers interferes with takeoff angles, reduces takeoff speed, and reduces flight endurance in western sandpipers (*Calidris mauri*). Homing pigeons (*Columba*

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livia domestica) with light to moderate oil on their feathers were significantly impaired, flying indirect routes at slower speeds with multiple elevation changes as they tried to fly home. It took an average of 58% longer to return, and the oiled feathers became frayed and brittle (DWH NRDA Trustees, 2016).

Thus, while the oil did not cause immediate obvious toxic effects or death, even the light amount of oiling greatly reduced the fitness of birds that depend on peak fitness in flight for survival. Birds with reduced fitness as a result of oil exposure are more vulnerable to predation, less likely to catch food if they are predators themselves, and less likely to reach their breeding grounds and reproduce if they are oiled while migrating. Delays of only 1 week can have negative consequences on their reproductive success such that a bird with even trace oiling could experience a 3–23% reduction in survival and a 19% decrease in reproductive output (DWH NRDA Trustees, 2016).

In summary, the large body of avian toxicity research investigating the effects of oil on birds strongly suggests that a bird exposed to oil will be stressed at a minimum, and many will die as a result of exposure. Nesting birds that roost with oil on their feathers are unlikely to successfully hatch and fledge their young. Birds that require peak metabolic performance (predators, migrators) may die from indirect oil effects if they do not die directly from oil exposure. Thus, most birds exposed to oil will be injured, and many will die directly or indirectly from the oil exposure.

4.4 Injury Quantification

A worst-case oil spill like the 8-million gallon scenario in the DEIS would have substantial ecological impacts in the LCR. Some of these impacts would be quantifiable, but many would not. The illustrative damage calculations presented in this analysis are qualitatively based on estimated adverse effects to fish and birds. As discussed previously, restoring habitat that will be increase the populations of the target species will also restore other natural resources that were injured but have not been explicitly quantified in this analysis, but would likely not comprehensively restore all injured natural resources.

4.4.1 Fish

The literature summarizing the 1984 *MobilOil* spill provides no direct evidence of injuries to salmonids. A 96-hour in situ bioassay conducted in Elochoman Slough (approximately RM 35) using Chinook salmon fingerlings found no significant mortality. The tests were designed to ensure that the state fish hatchery could release their fish without killing them; the timing of the test was not reported, nor was the actual exposure to oil, if any. Coho salmon fry stocked into a pen in Rainier, Oregon, on the day of the spill were alive and apparently not stressed 9 days later, but again, there was no quantification of oil exposure for these fish. It is unlikely that the fish in these tests were exposed to PAH concentrations representative of ambient conditions mid-river at the height of the spill.

As discussed in Chapter 2, the effective WCD scenario for the LCR is a spill from a tanker grounding, from which about 8 million gallons of Bakken crude spills into the LCR near Vancouver. A discharge of that magnitude occurring the spring (mid-April to mid-May) would likely expose fish to elevated PAH concentrations for the entire length of the river downstream of Vancouver (Reaches 2 and 1). If the oil spilled into the river over a 24-hour period, the

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estimated concentrations of total PAH could range from roughly 20 to 70 µg/L; if the grounded tanker broke apart and all the oil spilled into the river in a 2-hour period, the estimated concentrations of total PAH could range from approximately 230 to 800 µg/L (see Chapter 2). Summarized by reach, the anticipated concentrations in Reach 1 would be 30 to 800 µg/L (Figure 4.3a), and the anticipated concentrations in Reach 2 would be 20 to 230 µg/L (Figure 4.3b). These concentrations are well above concentrations known to cause toxicity in ELS and older life stage fish.

Although the data clearly suggest that the PAH concentrations in the water column would be sufficient to cause injury to fish, the magnitude of injury is uncertain. It is likely that some but not all exposed salmon smolt would be killed. For this analysis, we have included a range of mortality, from 25% to 75%. At 25% mortality, we estimate that about 5,000 adult salmon could be killed as a result of oil exposure in Reach 2 (approximately Vancouver to Longview), and 10,000 adult salmon could be killed as a result of oil exposure in Reach 1 (approximately Longview to the mouth). We also estimate that 350,000 smolts would perish as a result of oil exposure in the LCR.

At 75% mortality, we estimate that up to 50,000 adult salmon would perish in Reach 1 and up to 45,000 adult salmon would perish in Reach 2 (Table 4.1). In addition, at 75% mortality, an estimated 1,200,000 smolts would perish in the LCR as a result of oil exposure. The total range of estimated salmonid mortality (Reach 1 plus Reach 2) is from 15,000 adults and 350,000 smolts at 25% mortality up to 95,000 adults and 1.2 million smolts at 75% mortality (Table 4.1).

Table 4.1. Estimated range of salmonid mortality from the WCD oil spill in the LCR

Location	Mortality	Adults	Smolts	Mortality	Adults	Smolts
Reach 2 (Vancouver-Longview)	25%	5,000		75%	45,000	
Reach 1 (Longview mouth)	25%	10,000	350,000	75%	50,000	1,200,000
Total		15,000	350,000		95,000	1,200,000

4.4.2 Birds

We do not have an analogous model for estimating total numbers of potential dead birds resulting from oil exposure. While the avian toxicity data presented previously clearly demonstrates that most birds exposed to oil are likely to be injured and oiled eggs rarely develop into healthy birds, estimating a specific number of birds of different species that could be injured exceeds the scope of this analysis.

Quantifying Bird Mortality in the 1984 *MobilOil* Spill

Of the ~ 700 oiled birds recovered from the *MobilOil* spill, 475 were cleaned and released, and the remainder perished. Unfortunately, the released birds were not banded or tracked, and thus there are no data on how long those birds survived.

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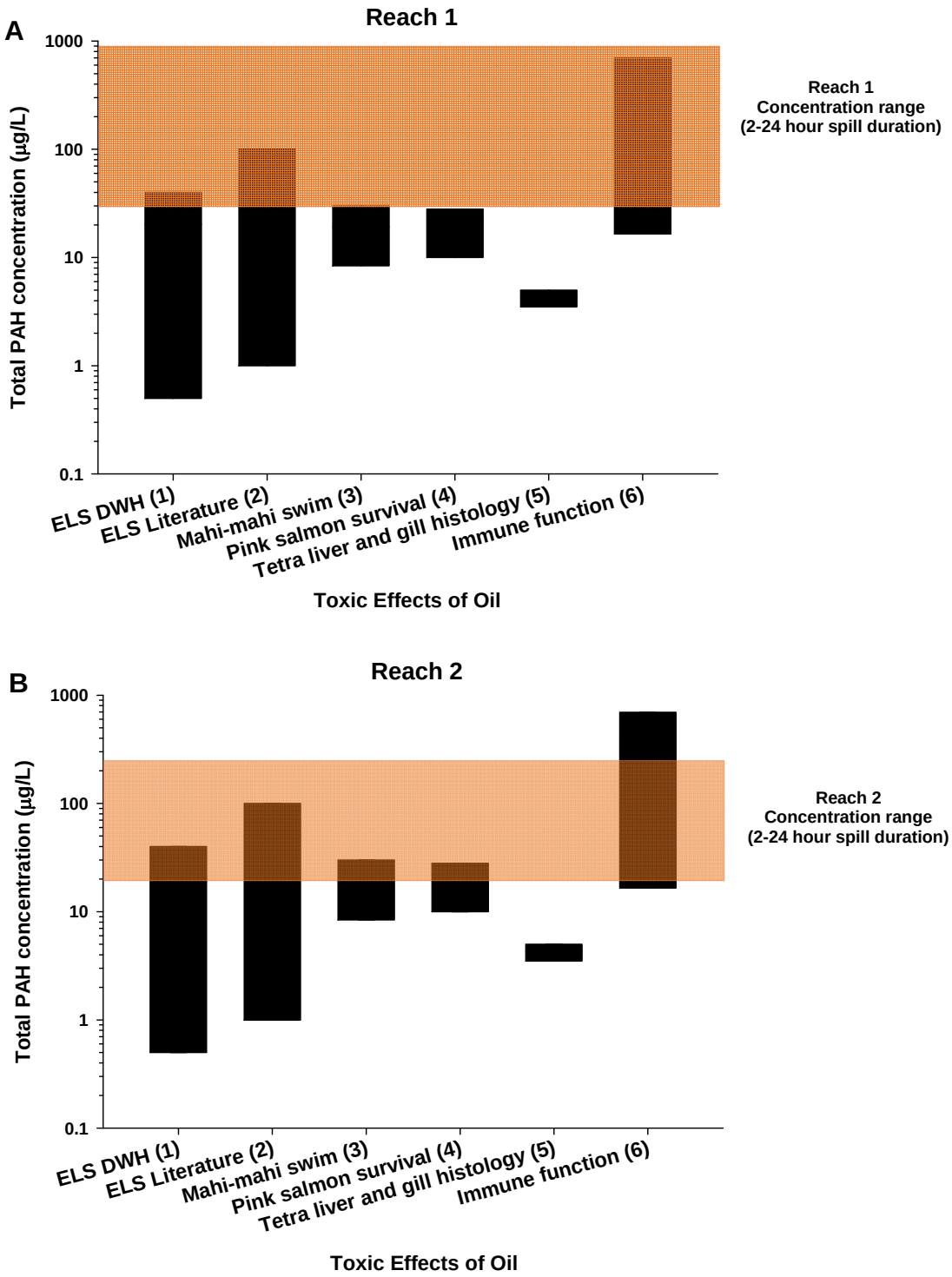
Figure 4.3. Ranges of published adverse effects levels of total PAH to ELS and older life stage fish (black bars) compared to the concentration ranges estimated for Reach 1 (A) and Reach 2 (B) given spill scenarios described in Chapter 2.



Sources: Carls et al., 1998; Birtwell et al., 1999; Akaishi et al., 2004; Lee et al., 2015a, 2015b; Ortell et al., 2015; DWH NRDA Trustees, 2016.

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It is important to note that dead birds recovered during an oil spill represent only a small portion of the total number of birds that died as a result of oil exposure. In fact, the likelihood that a dead bird in the estuary was recovered and brought to the facility is small. In many oil spill NRDAs such as the DWH spill (DWH NRDA Trustees, 2016), bird exposure estimates are adjusted to account for several factors, including:

- Carcass drift (i.e., the likelihood that a bird that dies on the water will drift to a bank or shoreline where a searcher can find it)
- Searcher efficiency (i.e., the likelihood that a person searching for bird carcasses will actually see it, based on carcass deposition studies)
- Carcass persistence (i.e., the length of time a stranded carcass can be found before it sinks or is scavenged).

Ford et al. (2001) and Ford and Zafonte (2009) conducted studies along the Oregon coast to quantify these factors. After the *New Carissa* oil spill in 1999, Ford et al. (2001) estimated that 2.75 large bird carcasses were not found for each one recovered on Oregon beaches, and 14.3 smaller bird carcasses were not found for each one recovered. They did not include a factor for birds exposed to oil but did not die until after flying away from the search area; this factor could increase the total estimated bird mortality by a substantial amount.

Similarly, for the *Nestucca* oil spill in 1988, resource agencies estimated that the total number of dead waterfowl was four to six times greater than the number of carcasses recovered (USFWS, 2004).

We could use these ratios to estimate the total number of dead waterfowl from the *MobilOil* spill, although it would primarily provide an estimate of dead oiled birds on beaches along the coast. It is likely that far more bird mortalities occurred in sloughs and wetlands in the estuary, and there are no available data because these carcasses would have been extremely difficult to find. It is also likely that some of the birds released from rehabilitation subsequently perished as a result of the oil exposure.

Thus, a very conservative estimate of the *MobilOil* bird mortality would be 223 recovered carcasses of large birds x 2.75 large birds not recovered for each one recovered = 613 large bird deaths.

At the higher multiplier range, 223 recovered carcasses x 6 birds not recovered for one recovered = 1,338 large bird deaths.

Although natural resource injuries are not scalable based solely on the quantity of oil discharged, scaling by volume can used as a range-finding exercise. The *MobilOil* was estimated to have discharged 3,925 bbls of oil, which is about 2.1% of effective WCD discharge of 189,845 bbl; if we scale the bird mortalities proportionally, the total waterfowl mortality would range from about 30,000 to 65,000 birds in coastal/beach habitat. Again, the *MobilOil* data likely includes few if any dead birds from estuarine habitat, where much of the bird injuries were likely to have occurred, but finding a carcass is extremely difficult.

Other Bird Mortality

As noted previously, Isaacs and Anthony (2011) reported 83 nesting pairs of bald eagles in Oregon and 57 in Washington as of 2007, for a total of 140 eagles (assuming each identified nesting site in fact had a pair of birds). Given the magnitude of the spill, it is highly likely that some bald eagles nesting along the Columbia River could get exposed to some oil and perish. Site-specific data would need to be collected during and after the spill to assess the impacts. It is likely that some bald eagles will die as a result of exposure to the oil.

Many thousands of songbirds living and nesting along the river would be exposed to oil and likely would die as well. For this analysis, we have not attempted to quantify songbird mortality, as we have little data on which to base an estimate.

4.4.3 Pinnipeds

Unquantified impacts: Pinnipeds

Despite hundreds of pinnipeds potentially exposed to oil, we have not quantified injuries to these animals.

Although we have estimates of the pinniped population in the LCR and number of seals and sea lions that NOAA (2006b) estimates will be present on a May day when a worst-case spill might occur, we do not have data to estimate the potential injuries to pinnipeds. Marine mammals are known to be sensitive to oil exposure; the overall health of common bottlenose dolphins (*Tursiops truncatus truncates*) exposed to DWH oil in Louisiana was substantially impaired (DWH NRDA Trustees, 2016). While it is likely that some pinnipeds would be injured in this WCD spill, we have not tried to quantify those injuries.

4.5 Damage Determination

As discussed previously, natural resource damages are frequently calculated based on the cost to restore equivalent resources or habitat. For this analysis, we present restoration-based damages for injuries to Columbia River habitat using a HEA model, where restoration is estuarine habitat restoration in Columbia River estuary. Generally, estuarine habitat is not equivalent to the oiled habitat in the middle of the river; therefore, we have used additional scaling factors to reflect the greater habitat services that estuarine habitat provides.

However, prior to presenting a restoration-based damages estimate, we first review other lines of data that can help provide an initial estimate of damages for a spill of this magnitude.

4.5.1 Washington State Oil Spill NRDA [WAC 173-183]

Washington State has a Resource Damage Assessment (RDA) Committee that determines appropriate methods for estimating damages from oil spills. The Committee uses a compensation schedule set out in WAC 173-183 to calculate appropriate damages for spills where restoration of injured resources is not technically feasible, damages are not quantifiable at a reasonable cost, or the responsible party proposes a restoration project that is insufficient to provide adequate compensation (Washington Department of Ecology, 2016).

WAC 173-183 contains a complicated multi-step method of calculating damages for spills in the Columbia River. Because the spill scenarios described here are unlikely to meet the criteria for using the compensation schedule, we did not undertake this endeavor.

WAC 173-183 also contains very simple methods of calculating damages: for spills less than 1,000 gallons, the range is $1 to $100 per gallon, and for spills of 1,000 gallons or more the range is $3 to $300 per gallon spilled. For an effective WCD spill of 8 million gallons, that scales to $24 million to $2.4 billion. This likely brackets natural resource damages for the WCD spill, but the two-orders-of-magnitude range is quite broad.

Washington Department of Ecology (2016) provides a spreadsheet of RDA oil spill incidents from 1991 through 2016. They report 50 spill incidents in the Columbia River or Columbia River Estuary for which damages have been calculated. The vast majority of the damages were calculated using the compensation schedule. None of these incidents is remotely of the magnitude discussed in these scenarios. In addition, as discussed previously, scaling compensable damages based solely on the volume of oil spilled is useful only to provide context for examining ranges of damage estimates. For the RDA incidents, a total of 20,385 gallons were discharged cumulatively from the 50 incidents, resulting in $594,000 in compensation to the State (in 2015 dollars).[2] This is an average of about $29 per gallon; an 8 million gallon spill at $29 per gallon is about $232 million in required compensation.

4.5.2 Damages from Other Spills

There are few historical oil spills that would be comparable to a catastrophe such as a spill of over 189,000 bbls of Bakken crude into the Columbia River. Again, damages from different spills in different locations are not scalable by volume spilled, but an examination of previous settlements can provide useful context. Here we examine natural resource damages from the *Exxon Valdez* in Alaska in 1989 and the DWH in the Gulf of Mexico in 2010, as well as the settlement from a smaller spill in Grays Harbor, Washington, in 1988.

The *Exxon Valdez* spilled approximately 257,000 bbls of oil into Prince William Sound in 1989. In 1991, Exxon reached a settlement with natural resource Trustees that included $900 million in natural resource damages (Rodgers et al., 2005). A $900 million settlement in 1991 dollars is approximately $1.56 billion in 2015 dollars. The unit cost in 2015 dollars is approximately $6,100 per bbl discharged (Table 4.2).

Table 4.2. Past damages settlements for two other major oil spills and one smaller spill near the Columbia River

Spill	Year settled	Spill volume (bbl)	Settlement ($)	$ (2015 dollars)	Cost/bbl
Exxon Valdez	1991	257,000	$900,000,000	$1,561,000,000	$6,100
Nestucca	1991	5,500	$7,480,000	$12,980,000	$2,400
DWH	2015	3,190,000	$8,800,000,000	$8,800,000,000	$2,800

The *Nestucca* spilled about 230,000 gallons (5,500 bbl) of No. 6 fuel oil into the Pacific Ocean near Grays Harbor, Washington, in 1988 (USFWS, 2004). In 1991, the United States and Canada reached settlements totaling $7.48 million for natural resource restoration (Helm et al., 2006). A $7.48 million settlement in 1991 dollars is approximately $13 million in 2015 dollars. The unit cost in 2015 dollars is approximately $2,400 per bbl discharged (Table 4.2).

2. See http://data.bls.gov/cgi-bin/surveymost?cu, U.S. All Items.

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The DWH spill discharged approximately 3.19 million bbls of oil into the Gulf of Mexico. Recently, BP reached a settlement with natural resource Trustees that included $8.8 billion in natural resource damages (DWH NRDA Trustees, 2016). The unit cost for this spill is approximately $2,800 per bbl spilled (Table 4.2).

The effective WCD for the LCR is 189,845 bbls (EFSEC, 2015). Using the cost per bbl spilled for these other spills (Table 4.2) as context, natural resource damages could be in the range of $456 million ($2,400/bbl) to $1.16 billion ($6,100/bbl).

4.5.3 Value of Lost Adult Salmon Fishery

Natural resource damages can be based on the economic value of the injured resources. Placing a value on lost recreational fishing is a common method of estimating damages to adult fish. If the public is less willing to go fishing after an oil spill, either because of a fishery closure or because of the perception that the fish are tainted, Trustees are entitled to damages commensurate with the lost fishing, regardless of the demonstrable adverse effects on the fish.

Our estimate of the value of lost recreational fishing in the LCR (see Chapter 3) is $17.8 million. This estimate is based on the average number of trips per month from 2011 to 2015, assuming that the fishery is closed for 6 months starting in May, and that recreational fishing slowly recovers for another 6 months (see Section 3.3). This value is not subsumed in a restoration-based damages estimate, because it captures some value of lost fishing that restoration projects will not restore. By the same token, this value should not be added to a restoration-based estimate, because restoration projects will restore salmon, and that will help to offset the lost fishing in future years.

4.5.4 Restoration-Based Damages: Columbia River Habitat

A tremendous amount of effort has been focused on estuarine habitat restoration in the Columbia River estuary and other estuaries in the Pacific Northwest. It is well beyond the scope of this report to provide a thorough review of restoration projects that have been designed and conducted in this area.

As discussed previously, restoration-based damages are based on the cost to restore natural resources that are equivalent to those that were injured from the discharge of oil. In this report, we are only assessing potential natural resource injuries in the Columbia River and adjacent impacted habitat. To calculate damages using HEA to estimate the quantity of estuarine habitat restoration that must be conducted to offset injuries, we calculate the net improvement in habitat services over time as a result of the restoration, and we calculate the unit cost (per acre) to perform the restoration.

Estuarine habitat restoration projects in this area often target human-made obstructions such as dikes, ditches, and culverts that restrict water and fish from accessing habitat. One recent example in the LCR is Steamboat Slough, in the Julia Butler Hansen Refuge at about RM 35. In the environmental assessment for the restoration project, the Columbia River Estuary Study Task Force (CRESTF, 2013, p. 8) noted the following:

> Tidal, estuarine wetlands are one of the most impacted habitats in the Lower Columbia River system, and are a priority for restoration, particularly for their high functional value to threatened and endangered salmonids that use these areas

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> as refugia, rearing and feeding before migrating to sea. Flood control measures, which include diking, filling, and ditching, have fragmented the estuary structure along the Columbia River and its tributaries. These actions limit and reduce the available habitat for juvenile salmonids throughout the greater Columbia River Basin.

In addition to simply opening habitat to juvenile salmonids, these restoration projects typically include construction or enhancement of wetland vegetation, regrading to provide complex multi-story habitat ranging from inundated wetland to occasionally inundated shrub/scrub to upland forest. While salmonids may be the target for restoration, many of these projects are restoring habitat for a wide range of biota, including waterfowl, songbirds, reptiles, amphibians, and invertebrates.

HEA Method

As discussed previously, the HEA method (NOAA, 2006a) requires estimating the total amount of natural resource injuries over time and space and the amount of natural resource improvement over time per unit (acre) of restoration. The quantity and cost of restoration required to offset the injury is then calculated.

The method requires calculating the total quantity of natural resource injury over space and time (debit). In a HEA, this debit calculation may also include an estimate of habitat service loss for each year of injury. This service loss factor is used to as a scaling factor, to balance services lost to injuries and services gained from restoration. Injuries in the future are discounted using a discount rate of 3% to account for the consumer time preference (i.e., habitat injured or restored today is worth more than the same amount of habitat injured or restored years in the future). The discounted service loss (in acres) of injured habitat in each year is summed to estimate a total debit, in units of discounted service acre-years (DSAYs).

The amount of restoration required to offset the debit is calculated similarly by estimating the service gain (in acres) of restored habitat each year multiplied by the discount rate and summed across all years to calculate the total amount of credit in DSAYs per unit of habitat restoration. The total debit (DSAYs) is divided by the total credit per unit of restoration (DSAYs per acre, in this case) to determine the total quantity of habitat restoration (acres) required to offset habitat injuries and make the public whole.

The specific HEA method that we use in this report is based on the methods described in the Commencement Bay NRDA (Commencement Bay Natural Resource Trustees, 2002, including appendices). For this settlement, the Trustees scaled all habitat injuries and restoration to a fully functioning estuarine marsh. Intertidal and subtidal habitats were assumed to provide 5% to 75% of estuarine marsh services for juvenile Chinook salmon and birds (Commencement Bay Natural Resource Trustees, 2002, Appendix C, Table 1). Service loss from exposure to contaminants was estimated based on sediment concentrations for multiple contaminant classes and toxicological dose-response curves for each class (see Cacela et al., 2005).

We use a similar scaling method to discount injured habitat that does not provide the equivalent services as estuarine marsh. However, for an oil spill that has yet to occur, we do not have sufficient data to use dose-response relationships as a service loss metric. Therefore, we estimate habitat service losses based on an overall integration of available data.

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Debit

We calculated the total area of Columbia River habitat from Vancouver (RM 97) to the mouth of the river (RM 0) using bathymetric data from a commonly available U.S. hydrography data layer in GIS. The calculated area of Reach 2 is 20,556 acres, and calculated area of Reach 1 is 87,175 acres. Combined, the injured area is 107,731 acres.

We used the National Wetlands Inventory (NWI; USFWS, 2016) to delineate habitats within the river channel. We conducted separate HEA debit calculations for areas designated as wetland (including estuarine and marine wetland, freshwater emergent wetland, and freshwater forested/shrub wetland), and areas designated as other habitat (primarily riverine, with some areas of marine deepwater near the mouth). Reach 1 has 15,757 acres of wetland habitat, and Reach 2 has only 395 acres of wetland habitat. In the Commencement Bay NRDA (Commencement Bay Natural Resource Trustees, 2002), shallow subtidal habitats provided 40% of marsh habitat, and deep subtidal habitat provided 5% of marsh habitat. In the LCR, some of the riverine/estuarine habitat is deep and some is shallow. For the assessment of injury in the river channel, we assume that all habitats classified as wetland provide 100% of marsh services, and non-wetland habitats provide 10% of marsh services.

In Section 4.4, we discussed the toxicity of the oil in the river and the likelihood that substantial numbers of salmon would be injured by oil exposure. Despite the weathering and dispersion of oil as it moves downstream, the models in the DEIS suggest that more PAHs enter the water column in Reach 1, and the oil persists for longer in Reach 1 because of diurnal current reversals. We assumed a higher service loss in Reach 2 because of its proximity to the oil source; however, because Reach 1 is much bigger and has substantially more wetland habitat, most of the HEA debit in this analysis comes from oil exposure in Reach 1.

While most of the acute oil exposure will occur over a matter of days or weeks, it is likely that oil in sediments and stranded oil re-entering the river from the banks will keep some level of service loss occurring well into the future. To calculate damages in this scenario, we assumed that the spill occurs in May 2016 (in the present year, for purposes of discounting). Because debit and credit are calculated on a yearly basis, we estimated that overall habitat services provided in Reach 2 was 10% in 2016 (i.e., services were reduced by 90% as a result of the spill). We then estimated recovery to 90% of pre-spill services by the end of 2017, with a progressive increase to 100% of pre-spill services by 2025. In Reach 1, we estimated services to be 25% in 2016, increasing to 90% by the end of 2017 and 100% by 2025. For the Reach 1 and Reach 2 habitats combined, the total HEA debit is 21,276 DSAYs (Table 4.3).

Credit

The Commencement Bay Natural Resource Trustees (2002) estimated that restored estuarine marsh reaches 100% habitat services 15 years after the project is completed. The habitat services that were provided prior to restoration can range widely; for this analysis, we assumed that the typical estuarine habitat restoration project would increase habitat services by 90%, with services increasing linearly over a 15-year period as vegetation becomes established and complex habitat develops. Restoration projects typically do not start until many years after a spill occurs and the NRDA process has concluded; here, we assumed that restoration would be complete 5 years after the spill (2021). We further assumed that the project would continue to provide benefits for 100 years, through 2120. The HEA credit for this restoration is 20.5 DSAYs per acre (Table 4.4).

Table 4.3. HEA debit calculations for the LCR Reach 1 riverine/subtidal habitat (A) and Reach 2 riverine habitat (B), Reach 1 wetland habitat (C), and Reach 2 wetland habitat (D)

A. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine and subtidal)							
	2016	25%	2017	90%	0.1	71,418	5,952
	2018	90%	2025	100%			
B. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine)							
	2016	10%	2017	90%	0.1	20,161	1,832
	2018	90%	2025	100%			
C. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	25%	2017	90%	1.0	15,757	13,133
	2018	90%	2025	100%			
D. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	10%	2017	90%	1.0	395	359
	2018	90%	2025	100%			
						107,731	21,276

Table 4.4. Restoration credit per acre restored

Start year	%services	End year	% services	Scalar	Area (ac)	Credit (DSAYs)
2021	10%	2035	100%	1.0	1	20.5
2036	100%	2120	100%			

Quantity and Cost of Restoration Required

The unit cost of estuarine march habitat restoration varies widely. Some projects are quite simple; dozens of acres of new inundated habitat can be created by simply breaching a dike. Other projects are much more complicated and expensive, requiring fee purchase of habitat, removal and disposal of contaminated soils, and weeks of work with heavy machinery to create a new habitat.

We reviewed several sources to compile restoration cost information. NOAA (2016) has an online database of restoration projects (the Restoration Atlas) that contains summary project information, including type, cost, and year, for over 2,800 restoration projects. Several documents summarized the ecosystem-level benefits of estuarine restoration projects

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(e.g., Johnson et al., 2012; USACE and BPA, 2013), which further demonstrated the wide range of restoration costs and net habitat benefits. The unit cost of estuarine marsh restoration in these documents range from several hundred dollars to well over $1 million per acre.

For the Commencement Bay settlement (Commencement Bay Natural Resource Trustees, 2002), the unit cost of estuarine marsh restoration (in 2002 dollars) was approximately $1.2 million per acre. A 2012 evaluation of potential mitigation projects in the Port of Tacoma, Washington (Port of Tacoma, 2012, Table 6) included a summary of Port-owned properties where marsh habitat could be restored to mitigate other impacts. One project had a unit cost of $1 million per acre; the other six projects for which unit costs were listed were between $100,000 and $200,000 per acre.

We used the recent Fir Island restoration project in the Skagit River valley of northwestern Washington is as the basis for our estuarine marsh restoration cost estimate. According to the web site (WDFW, 2014):

> Estuary restoration has been identified as a priority in the Skagit Chinook Recovery Plan 2005. Based on the findings of the Fir Island Farm Snow Goose Reserve Restoration Feasibility Study (2011), WDFW's preferred 130 acre restoration site will significantly contribute to the recovery of Skagit Chinook salmon by restoring 126 acres of tidal marsh habitat, restoring 17.44 acres of new tidal channel habitat and producing an estimated 65,000–320,600 new Chinook smolts annually. Snow goose management and public access will be maintained at the project site and measures to maintain drainage, flood protection and protection from saltwater intrusion for adjacent farmland will be incorporated into the final project design. Climate change and sea level rise predictions will also be incorporated into the final project design.

Shannon & Wilson Inc. (2011) produced the feasibility study. The detailed estimate of project costs at the 90% design stage (Shannon & Wilson, 2014) was $14,235,565. Although the total area restored is hard to decipher from the WDFW quote above, we assumed 130 acres of restoration, which is a unit cost of approximately $110,000 per acre.

With a total calculated debit of 21,276 DSAYs and a credit of 20.5 DSAYs per acre, the total quantity of restoration required to offset the injuries to river channel habitats in Reach 1 and Reach 2 of the LCR is 1,040 acres. At an average cost of $110,000 per acre, the total damages would be about $114.4 million (Table 4.5).

Table 4.5. Estimated cost to restore habitat sufficient to offset river habitat injuries in the LCR

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
21,276	20.5	1,040	$110,000	$114.4 million

4.5.5 Restoration-Based Damages: Wildlife Refuges

In addition to the oil causing injury to the river habitat, it will also injure birds and riverbank and floodplain habitat. Some oil will become stranded in these habitats. To account for injuries to birds and riverbank/floodplain habitat, we conducted a separate HEA for wetlands located within

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the 100-year floodplain but outside of the designated channel of the Columbia River in Reaches 1 and 2. This includes designated NWI wetlands in the Sauvie Island Wildlife Area, the Ridgefield National Wildlife Refuge, the Julia Butler Hansen Refuge for the Columbian White-tailed Deer, and the Lewis and Clark National Wildlife Refuge (Figure 4.4). The total area of floodplain wetlands in Reaches 1 and 2 is 29,867 acres. The amount of oiling in these floodplain wetlands would depend on the river stage at the time of the spill; if the river was at flood stage, most of these wetland habitats would be oiled. If the river stage was low, the habitats could be oiled at the margins, but birds living within those habitats would likely be oiled when exposed to oil in the river.

Debit

To calculate debit for floodplain wetland habitat, we assumed that the spill occurred in May 2016. Habitat services in Reaches 1 and 2 were 75% of pre-spill conditions in 2016, recovering to 95% by the end of 2017 and 100% by 2025. For the 29,867 acres of floodplain wetland habitat, the total HEA debit is 10,580 DSAYs (Table 4.6).

Table 4.6. HEA debit calculations for Reach 1 floodplain wetland habitat (A) and Reach 2 floodplain wetland habitat (B)

A. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	75%	2017	95%	1.0	16,108	5,706
	2018	95%	2025	100%			
B. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	75%	2017	95%	1.0	13,759	4,874
	2018	95%	2025	100%			
						29,867	10,580

Credit

Because all injuries are scaled to marsh habitat and credit is based on marsh restoration, the credit for restored habitat is also 20.5 DSAYs per acre (Table 4.4), as described previously for the river channel HEA.

Quantity and Cost of Restoration Required

With a total calculated debit of 10,580 DSAYs and credit of 20.5 DSAYs per acre, the total quantity of restoration required to offset the injuries to floodplain wetland habitat and biota is 517 acres. At an average cost of $110,000 per acre, the total damages would be about $56.9 million (Table 4.7).

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Figure 4.4. Wildlife refuges and managed areas along the LCR.

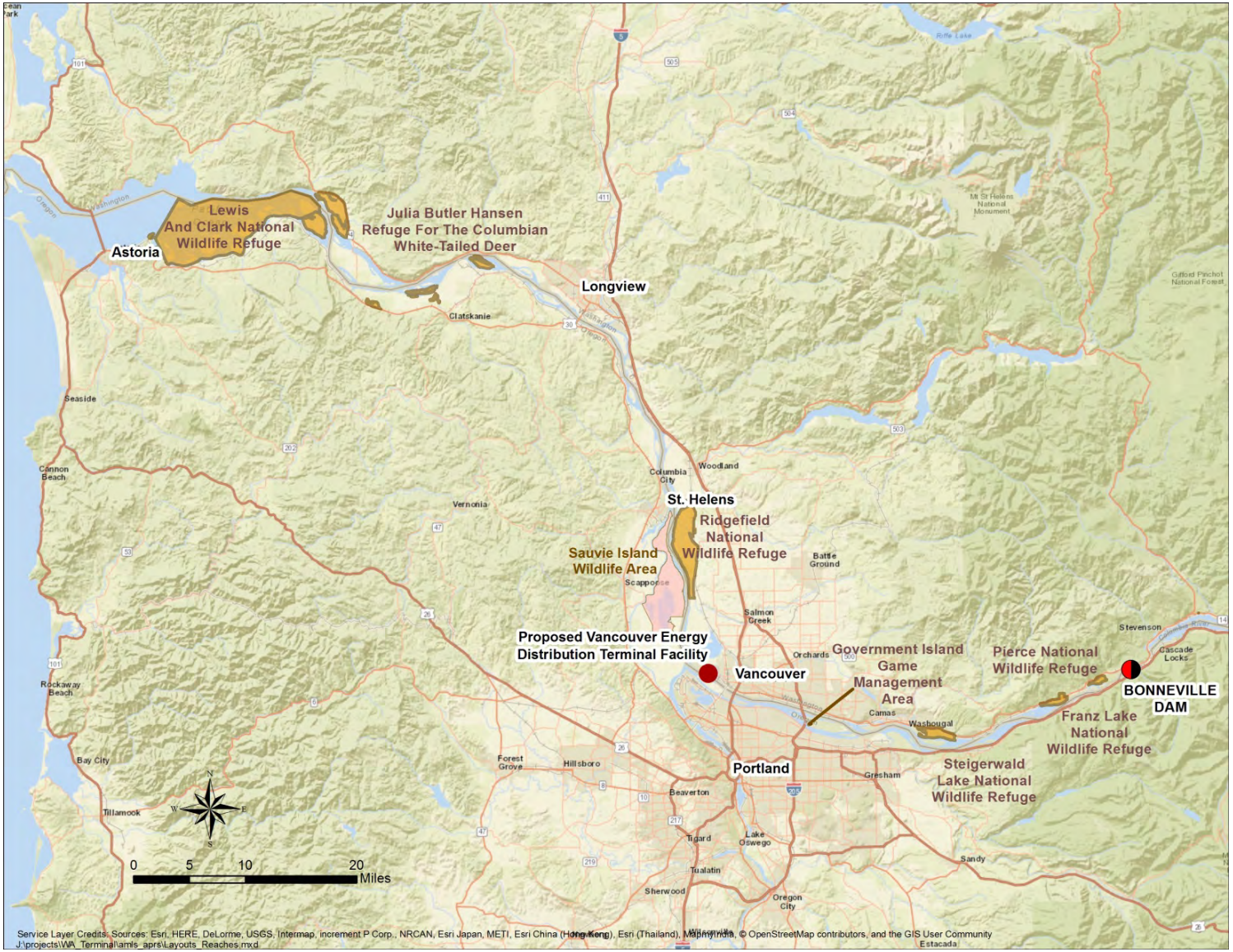

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Table 4.7. Estimated cost to restore habitat sufficient to offset floodplain injuries in the LCR

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
10,580	20.5	517	$110,000	$56.9 million

4.5.6 Summary

Damages estimates presented in this section are summarized in Table 4.8. The estimates from scaling past damages calculations based on unit cost per volume of oil spilled do not account for specific natural resource injuries that may occur; instead, they are based on damages that occurred in similar habitats or on similar scales as the effective WCD spill.

Table 4.8. Summary of damages estimates for the effective WCD spill in the LCR

Method	Damages estimate
Possible range based on past major spills ($/bbl)[a]	$455 million to $1.16 billion
Extrapolation based on past (relatively minor) incidents in the Columbia River ($/gallon)[a]	$232 million
Value of lost recreational fishing (assuming 6-month closure plus additional 6 months recovery)	$17.8 million
Cost to restore injured river habitat + cost to restore injured floodplain wetland habitat (HEA)	$114.4 million + $56.9 million = $171.3 million

a. Settlements from other spills in other locations are generally not scalable, but they can be used to suggest a potential range of damages.

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5. Natural Resource Damages from an Upstream Train Derailment

The methods for calculating natural resource damages for the train derailment scenario are similar to those described in the previous chapter for calculating damages from a tanker grounding. The worst-case impacts from a 20,000-bbl spill are again going to be in the Columbia River. In this scenario, the oil is discharged farther upstream, and the total amount of oil discharged is about 10% of the effective WCD of a tanker grounding. Because this oil is going into the same river, we would expect the same types of adverse impacts in similar habitats.

There are some differences in this scenario, however, which are explained in the following sections. In particular, as described in Chapter 2, we have assumed that the worst-case scenario is for all the spilled oil to go over or through the Bonneville Dam, which will mix the oil into the water column and greatly increase the PAH concentrations in Reach 4 below the dam. Also, there are several more wildlife refuges in Reaches 3 and 4 with valuable habitat and biota that would exposed to the oil from this upstream spill. The adverse effects of the oil in the most downstream reach would be diminished, and the quantity of oil discharged to the ocean would be considerably less, as more oil would be weathered, evaporated, stranded, and deposited in sediments after traveling 140 miles downstream. Because we did not assess injuries and damages to oceanic and coastal habitat, this reduction in oil discharged to the ocean is not reflected in any of our damages calculations.

5.1 Natural Resource Exposure

Natural resources that would be exposed to the oil discharged from the derailed train are similar to the resources that would be exposed in the tanker spill scenario. The impoundment behind the Bonneville Dam (the Bonneville Pool) is primarily in a canyon, with little floodplain habitat. The habitat immediately below the dam is particularly high-value habitat, including salmon spawning habitat (Figure 5.1), protected spawning habitat for sturgeon, two wildlife refuges, and large areas of wetland habitat (Figure 5.2).

5.1.1 Fish

We estimated salmon exposure based on 5-year average adult and smolt passage data at the Bonneville Dam (Columbia Basin Research, 2016a, 2016b; see Figure 4.2). The average number of adult salmon per day counted at the Bonneville Dam in mid-May from 2011 to 2015 was about 4,000 (ranging from 2,000 to 9,000). The estimated travel time for a salmon to reach the dam from the mouth of the river is up to 3 weeks (Rub et al., 2012). Thus, as the oil plume travels downstream, it would intersect many daily cohorts of adult salmon traveling upstream. It is likely that the quantity of oil and the PAH concentrations would decrease with the distance downstream through Reaches 4 and 3. However, the oil transport modeling data in the DEIS (EFSEC, 2015; see Chapter 2) do not include Reaches 4 and 3. Therefore, for this train derailment WCD, we have not attempted to estimate adult salmon exposure to oil beyond the 1-day cohort that would be exposed in Reach 4 near the dam.

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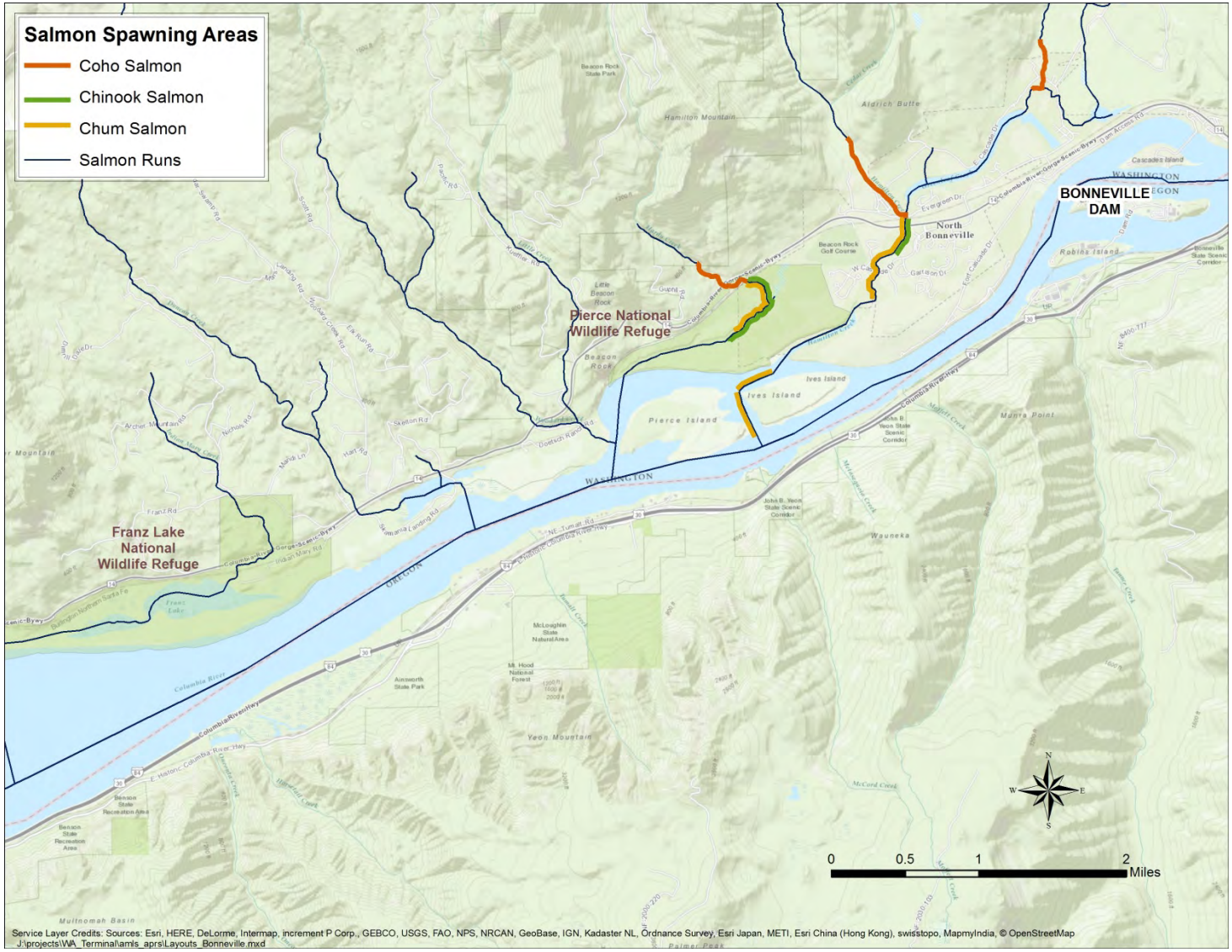
Figure 5.1. Tributaries off Reach 4 of the Columbia River are known salmon habitat, including several spawning areas.



Source: Statewide Washington Integrated Fish Distribution data repository.

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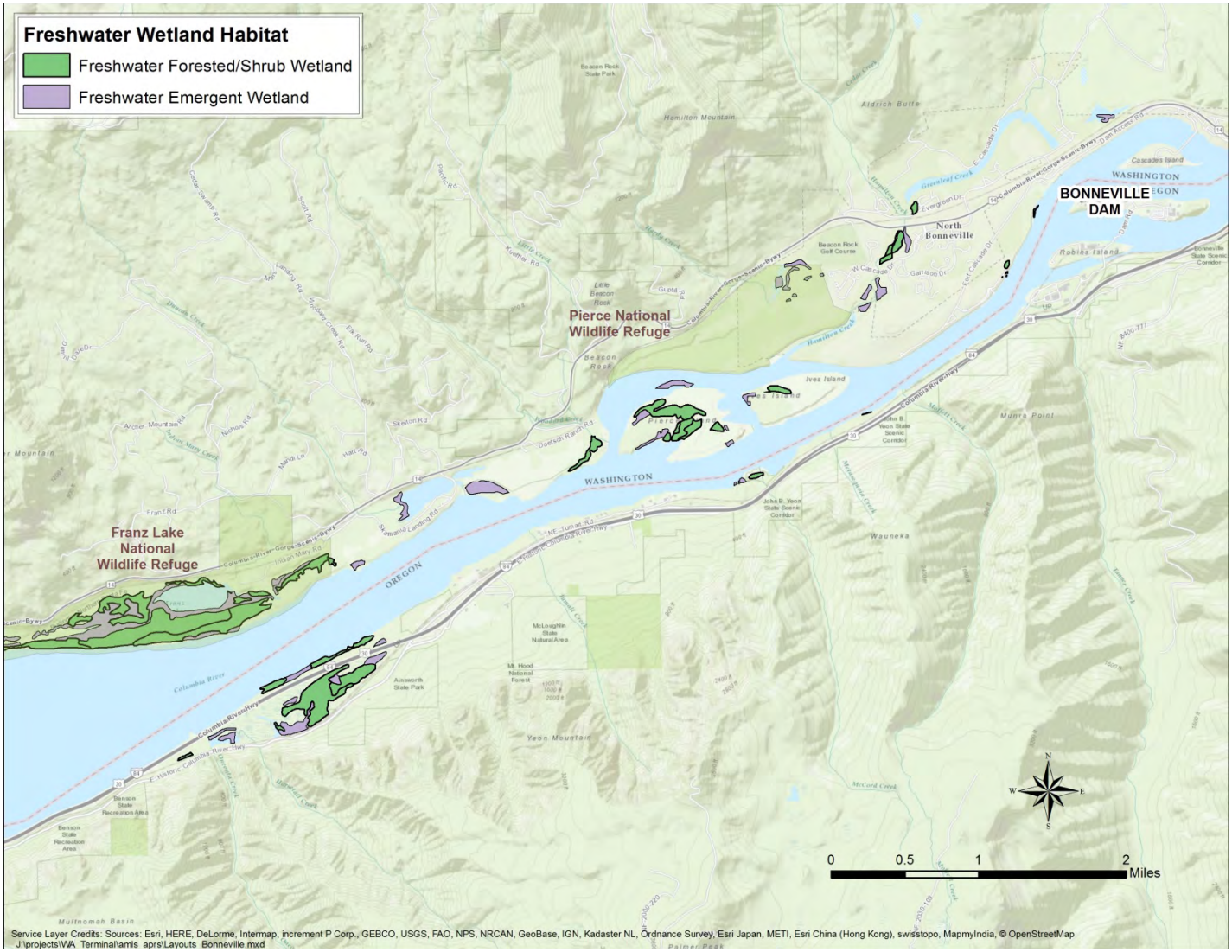
Figure 5.2. Wetland habitat downstream of the Bonneville Dam.



Source: NWI.

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The average number of smolts per day in mid-May is about 112,000 (ranging from 27,000 to 220,000). This daily cohort of smolts would move downstream with the oil for several days until reaching the estuary (McMichael et al., 2013; see Chapter 4). The total number of smolts exposed to the plume of oil would increase by an unknown number coming from tributaries downstream of the Bonneville Dam. We have not attempted to quantify these additional smolts, or any additional daily cohorts of smolts counted at the dam that might intersect oil in the estuary, where smolts remain for several days before swimming to sea (McMichael et al., 2013).

In addition to exposing salmon to oil, this spill scenario would expose white sturgeon to oil in a particularly important sturgeon spawning habitat. The upper 4.5 miles of Reach 4 directly below the Bonneville Dam is a protected spawning sanctuary for white sturgeon, which spawn from late April through early July (McCabe and Tracy, 1994). Sturgeon embryos (which are affixed to the bottom of the river) and larvae would also likely be exposed, as these life stages typically reside in the vicinity of where they were spawned until larvae begin downstream dispersion activities (Kynard and Parker, 2005).

5.1.2 Birds

Reaches 4 and 3 of the LCR downstream of the Bonneville Dam include three wildlife refuge areas and one (small) game management area (see Figure 1.1). As with the refuges in Reaches 2 and 1, these upstream refuges support thousands of bird species present at all times of the year. The bird species most likely to be exposed to oil will be those that most heavily rely on water access to obtain food, including piscivores and dabbling and diving birds.

High-profile obligate piscivores like bald eagles, harlequin ducks (*Histrionicus histrionicus*), great blue herons, osprey, and belted kingfishers will be greatly impacted by reductions in fish numbers and exposure to contaminated water caused by a spring oil spill. These species, and many others, breed during this period, so adults and young will be impacted. Exposure of eggs and nestlings to oil occurs through transfer from contaminated food, nesting materials, and parental feathers. Impacts to adult bird health may in turn lead to nest abandonment and further loss.

The national wildlife refuges maintain lists of birds that are typically present in each refuge. Nearly 100 bird species are listed as abundant or common in the Steigerwald National Wildlife Refuge in the spring (USFWS, 2010; see Figure 4.4). Many of these birds would be at risk of oil exposure if the effective WCD from a train derailment occurred in the spring immediately upstream of the Bonneville Dam.

5.1.3 Pinnipeds

Seals and sea lions tend to congregate near the mouth of the Columbia River but are known to travel up the river all the way to the Bonneville Dam to feed on salmon and sturgeon (NOAA, 2006; Wiles, 2015). Over 100 sea lions have been observed at one time feeding on fish at the bottom of the Bonneville Dam (Norman, 2006). These sea lions would be exposed to oil if the WCD spill occurred immediately upstream of the dam and the oil rapidly discharged downstream.

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5.2 Natural Resource Injuries

Natural resource injuries from this train derailment WCD would be the same as those described for the tanker grounding in Chapter 4. The oil type (Bakken crude) is the same; see Chapter 4 for a discussion of the properties of this oil and the methods for estimating PAH concentration in the water column. Because in this scenario the oil goes over or through the dam in a highly turbulent environment, it will mix into the water column substantially more than oil spilled from a tanker grounding (see Chapter 2), and thus fish and other biota in the water column would be exposed to considerably higher concentrations of PAHs.

To summarize from previous chapters (see also DWH NRDA Trustees, 2016), PAHs are known to be toxic to fish. ELS fish exposed to PAHs experience cardiac disruption or death when exposed to elevated PAH concentrations, particularly in the presence of UV light. High-performance fish (such as migrating salmon) may experience a marked decrease in swim performance after PAH exposure, and juvenile fish (such as smolts) may suffer from compromised immune systems.

Oil has been shown to be toxic to birds through multiple pathways, including high embryo mortality when egg shells are oiled, induced hemolytic anemia when oil is ingested, and hypothermia and reduced flight performance when oil is on feathers (Ziccardi and Drayer, 2015; DWH NRDA Trustees, 2016).

5.3 Injury Quantification

5.3.1 Fish

The concentration range of total PAH predicted in Reach 4 following a train derailment above the Bonneville Dam in May would be 200–500 µg/L of total PAH (see Chapter 2), which is well above ranges of published adverse effects levels (Figure 5.3). Assuming a range of mortality from 75% to 100%, we predict smolt mortality ranging from 20,250 (75% of the lowest daily smolt count of 27,000) to 220,000 (100% of the highest daily smolt count). Similarly, we predict adult mortality ranging from 1,500 (75% of the lowest daily adult count of 2,000) to 9,000 (100% of the highest daily adult count). Downstream of Reach 4, there would be additional adult salmon mortality, as the plume of oil moving downstream intersects other daily cohorts of adult salmon migrating upstream. As mentioned previously, we do not have sufficient data to quantify the injuries to these other adult cohorts.

In this scenario, the oil is mixed into the water column after going over the dam, which would likely expose larval sturgeon to highly elevated PAH concentrations in the protected spawning area downstream of the dam. We have not quantified the exposure or injuries to sturgeon.

5.3.2 Birds

We do not have an analogous model for estimating total numbers of potential dead birds resulting from oil exposure. While the avian toxicity data presented previously clearly demonstrate that most birds exposed to oil are likely to die, and oiled eggs rarely develop into healthy birds, it is particularly challenging to quantify the number of birds that would likely be exposed to oil in the LCR.

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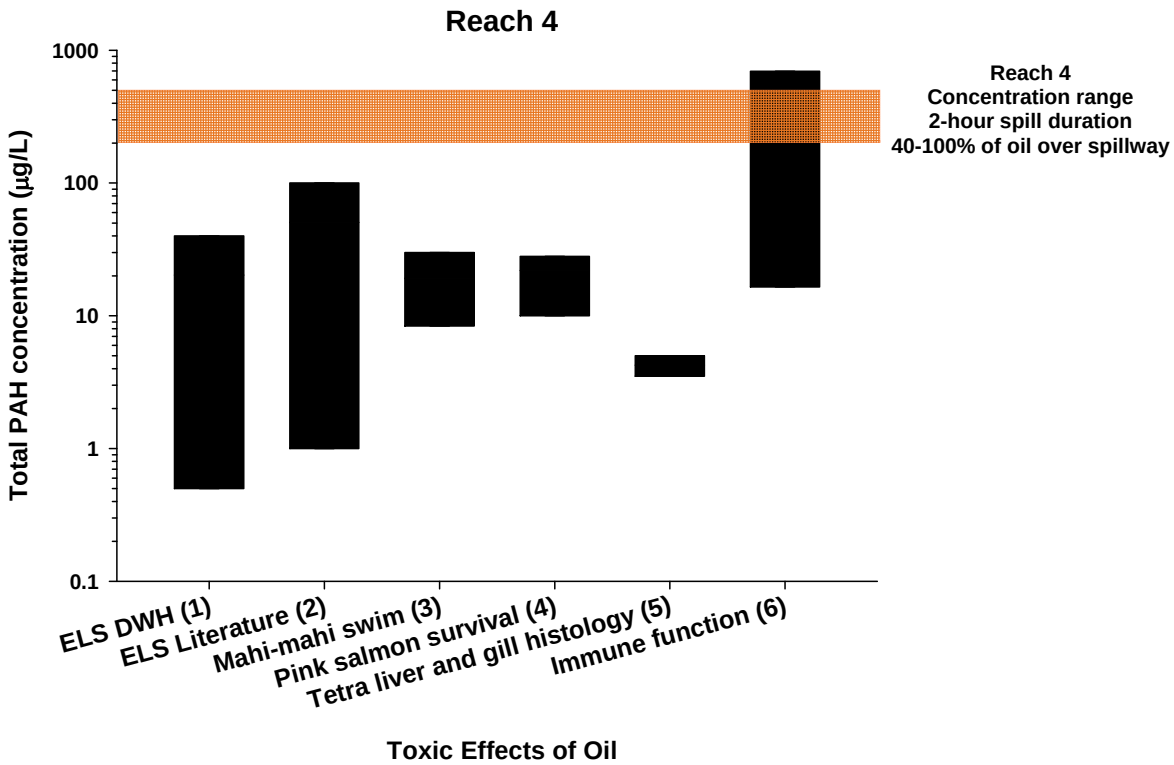
Figure 5.3. Ranges of published adverse effects levels of total PAH to ELS and older life stage fish (black bars) compared to the concentration ranges estimated for Reach 4, given spill scenarios described in Chapter 2.



Sources: Carls et al., 1998; Birtwell et al., 1999; Akaishi et al., 2004; Lee et al., 2015a, 2015b; Ortell et al., 2015; DWH NRDA Trustees, 2016.

The data from the 1984 *MobilOil* spill provided some information to help estimate bird mortality from a major spill near Vancouver. Those data are less relevant for this scenario, as most of those bird mortalities were found along the coast after the oil discharged into the ocean.

Isaacs and Anthony (2011) reported 83 nesting pairs of bald eagles in Oregon and 57 in Washington as of 2007, for a total of 140 eagles (assuming each identified nesting site in fact had a pair of birds). Given the magnitude of the spill, it is highly likely that some bald eagles nesting along the Columbia River would get exposed to some oil and perish. Site-specific data would need to be collected during and after the spill to assess the impacts.

Many thousands of songbirds living and nesting along the river would be exposed to oil and likely would die as well. For this analysis, we have not attempted to quantify songbird mortality, as we have little data on which to base an estimate.

5.3.3 Pinnipeds

Although more than 100 sea lions have been observed at the base of the Bonneville Dam in the past (NOAA, 2006), we do not have data to quantify the potential injuries to pinnipeds. Marine mammals are known to be sensitive to oil exposure; the overall health of common bottlenose dolphins exposed to DWH oil in Louisiana dropped substantially (DWH NRDA Trustees, 2016).

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While it is likely that some pinnipeds would be injured in this WCD spill, we have not tried to quantify those injuries here.

5.4 Damage Determination

As discussed previously, natural resource damages are frequently calculated based on the cost to restore equivalent resources or habitat. As in Chapter 4, we present restoration-based damages for injuries to Columbia River habitat using an HEA model, where restoration is estuarine habitat restoration in the Columbia River estuary. This estuarine habitat is not equivalent to the oiled habitat in Reaches 4 and 3, which are well upstream of the estuary; therefore, we have used additional scaling factors to reflect the greater habitat services that estuarine habitat provides.

As in Chapter 4, prior to presenting a restoration-based damages estimate, we first review other lines of data that can help provide an initial estimate of damages for a spill of this magnitude.

5.4.1 Washington State Oil Spill NRDA [WAC 173-183]

As discussed previously, WAC 173-183 provides formulas for calculating damages from oil spills, when certain criteria are met. Those criteria would not be met for a major spill scenario such as the effective WCD from a train derailment, but we can use the past settlements context when examining compensation required. It is highly unlikely that the spill formula in WAC 173-183 would be used for a spill of this magnitude.

WAC 173-183 generally states that for spills less than 1,000 gallons, the range is $1 to $100 per gallon; and for spills of 1,000 gallons or more, the range is $3 to $300 per gallon spilled. For an effective WCD spill of 20,000 bbl (840,000 gallons), that scales to $2.5 million to $250 million.

As presented in Chapter 4, the Washington Department of Ecology (2016) provides a spreadsheet of RDA oil spill incidents since 1991. None of the incidents is even remotely as large as the scenario here. As summarized in the previous chapter, the average compensation for a spill in the Columbia River and the estuary was $29 per gallon; based on that unit cost, a spill of 840,000 gallons at $29 per gallon is about $24.4 million in required compensation.

5.4.2 Scaling Damages per Volume Spilled in Other Spills

In Chapter 4 (Section 4.5.2), we presented damages per bbl spilled from DWH, *Exxon Valdez*, and *Nestucca*, with the caveat that these damages settlements from different locations at different times are not scalable but can provide useful context. The settlements ranged from $2,400 to $6,100 per bbl (see Table 4.2). If we apply these to the train derailment WCD, the range of natural resource damages would be $48 million ($2,400/bbl) to $122 million ($6,100/bbl).

5.4.3 Value of Lost Adult Salmon Fishery

It is likely that a 20,000-bbl spill at the Bonneville Dam will discharge sufficient oil downstream of the dam to result in fisheries closures and/or reduced recreational fishing visits. However, quantifying lost recreational fishing for this train derailment scenario was not part of the scope of this report.

5.4.4 Restoration-Based Damages: Columbia River Habitat

For this scenario, we used the identical approach that we used for the tanker grounding spill in the previous chapter, where we estimated lost wetland and non-wetland habitat services in the

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river and scaled estuarine habitat restoration to calculate damages. We again assumed that non-wetland habitat provides 10% of estuarine marsh habitat services, with the exception of the riverine habitat in Reach 4, which contains protected sturgeon spawning habitat. Although the habitat type is different, we assumed that riverine habitat in this reach provides the equivalent of 100% of the services that estuarine marsh habitat provides.

As described in the previous chapter, all habitats are scaled to estuarine marsh habitat, and the unit cost for estuarine marsh habitat restoration is $110,000 per acre.

Debit

We calculated the area of Columbia River habitat from Bonneville Dam to the mouth of the river using a commonly available U.S. hydrography data layer in GIS. The calculated area of Reach 4 is 880 acres, Reach 3 is 18,392 acres, Reach 2 is 20,556 acres, and Reach 1 is 87,175 acres. The calculated total habitat area for the LCR is 127,003 acres. The vast majority of wetland habitat is in the estuary (Reach 1), with 15,757 acres of wetland. Reach 2 has 395 acres, Reach 3 has 521 acres, and Reach 4 has 14 acres of wetland habitat.

To calculate damages, we assumed that the spill occurs in May 2016 (in the present year, for purposes of discounting). We assumed the following service losses for each habitat in each reach (Table 5.1):

- In Reach 4, where 20,000 bbls of oil will be mixed throughout the water column after going over the dam, we estimated severe impacts, with habitat services declining to 10% of pre-spill conditions. By the end of 2017, services returned to 90%, increasing incrementally each year until reaching 100% in 2025.
- In Reach 3, we estimated habitat services declining to 50% of pre-spill conditions. By the end of 2017, services returned to 90%, increasing incrementally each year until reaching 100% in 2025.
- In Reaches 2 and 1, we estimated habitat services declining to 85% of pre-spill conditions. By the end of 2017, services returned to 95%, increasing incrementally each year until reaching 100% in 2025.

The total HEA debit is 10,135 DSAYs (Table 5.1). The estuary (Reach 1) is two orders of magnitude larger than Reach 4 and contains most of the wetland habitat in the LCR channel; even though the presumed service loss is small in Reach 1, it contributes most of the total debit.

Credit

As discussed in Chapter 4, we assumed that restoration would be completed in 2021, with habitat services increasing linearly by 90% over a 15 year period, with benefits provided for 100 years. The HEA credit for this restoration is 20.5 DSAYs/ac (Table 5.2).

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Table 5.1. HEA debit calculations for riverine/subtidal habitat in Reach 1 (A), Reach 2 (B), Reach 3 (C), and Reach 4 (D), as well as debit calculations for wetland habitat in Reach 1 (E), Reach 2 (F), Reach 3 (G), and Reach 4 (H)

A. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine and subtidal)							
	2016	85%	2017	95%	0.1	71,418	2,173
	2018	95%	2025	100%			
B. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine)							
	2016	85%	2017	95%	0.1	20,161	613
	2018	95%	2025	100%			
C. LCR Reach 3							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine)							
	2016	50%	2017	90%	0.1	17,871	1,266
	2018	90%	2025	100%			
D. LCR Reach 4							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Non-wetland (primarily riverine)							
	2016	10%	2017	90%	1.0	866	787
	2018	90%	2025	100%			
E. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	85%	2017	95%	1.0	15,757	4,794
	2018	95%	2025	100%			
F. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	85%	2017	95%	1.0	395	120
	2018	95%	2025	100%			
G. LCR Reach 3							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	50%	2017	90%	1.0	521	369
	2018	90%	2025	100%			
H. LCR Reach 4							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Wetland							
	2016	10%	2017	90%	1.0	14	13
	2018	90%	2025	100%			
Total						127,003	10,135

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Table 5.2. Restoration credit per acre restored

Start year	% services	End year	% services	Scalar	Area (ac)	Credit (DSAYs)
2021	10%	2035	100%	1.0	1	20.5
2036	100%	2120	100%			

Quantity and Cost of Restoration Required

With a total calculated debit of 10,135 DSAYs and credit of 20.5 DSAYs/ac, the total quantity of restoration required to offset the injuries to channel habitats in the LCR under this spill scenario is 495 acres. At an average cost of $110,000 per acre, the total damages would be on the order of $54.5 million (Table 5.3).

Table 5.3. Estimated cost to restore habitat sufficient to offset injuries in the LCR

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
10,135	20.5	495	$110,000	$54.5 million

5.4.5 Restoration-Based Damages: Wildlife Refuges

To account for injuries to birds and riverbank/floodplain habitat, we conducted a separate HEA for wetlands in the 100-year floodplain that are not in the designated channel of the Columbia River. Some of these wetlands can be found in the four refuges described previously for Reaches 1 and 2, as well as the three refuges between Vancouver and Bonneville Dam (Pierce, Franz Lake, and Steigerwald NWRs; see Figure 4.4). The combined area of these floodplain wetland habitats in Reaches 1 through 4 is 32,055 acres.

Debit

To calculate damages, we assumed the following service losses for each reach (Table 5.4):

- In Reach 4, we estimated habitat services declining to 25% of pre-spill conditions in 2016. By the end of 2017, services returned to 75%, increasing incrementally each year until reaching 100% in 2025.
- In Reach 3, we estimated habitat services declining to 75% of pre-spill conditions. By the end of 2017, services returned to 90%, increasing incrementally each year until reaching 100% in 2025.
- In Reaches 2 and 1, we estimated habitat services declining to 90% of pre-spill conditions. By the end of 2017, services returned to 98%, increasing incrementally each year until reaching 100% in 2025.
- The total HEA debit for estimated service losses in floodplain wetland habitat for all four reaches is 5,643 DSAYs (Table 5.4).

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Table 5.4. HEA debit calculations for floodplain habitat in Reach 1 (A), Reach 2 (B), Reach 3 (C), and Reach 4 (D). Numbers may not sum due to rounding.

A. LCR Reach 1							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	90%	2017	98%	1.0	16,108	2,282
	2018	98%	2025	100%			
B. LCR Reach 2							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	90%	2017	98%	1.0	13,759	1,949
	2018	98%	2025	100%			
C. LCR Reach 3							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	75%	2017	90%	1.0	2,045	1,193
	2018	90%	2025	100%			
D. LCR Reach 4							
Habitat	Start year	% services	End year	% services	Scalar	Area (ac)	Debit (DSAYs)
Floodplain wetland							
	2016	25%	2017	75%	1.0	144	219
	2018	75%	2025	100%			
Total						32,055	5,643

Credit

We used the same credit calculation here as we did for the river habitat; the calculated HEA credit is 20.5 DSAYs/acre (see Table 5.2).

Quantity and Cost of Restoration Required

With a total calculated debit of 5,643 DSAYs and credit of 20.5 DSAYs/ac, the total quantity of restoration required to offset the injuries to floodplain wetland habitat and biota is 276 acres. At a cost of $110,000 per acre, the total damages would be on the order of $30.4 million (Table 5.5).

Table 5.5. Estimated cost to restore habitat sufficient to offset floodplain habitat injuries in the LCR

Debit (DSAYs)	Credit (DSAYs/acre)	Restoration required (acres)	Unit cost ($/acre)	Total
5,643	20.5	276	$110,000	$30.4 million

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5.4.6 Summary

Damages estimates presented in this section are summarized in Table 5.6. The estimates from scaling past damages calculations based on unit cost per volume of oil spilled do not account for specific natural resource injuries that may occur; instead, they are based on damages that occurred in similar habitats or on similar scales as the effective WCD spill.

Table 5.6. Summary of damages estimates for the effective WCD spill in the LCR

Method	Damages estimate
Range-finding based on past major spills ($/bbl)[a]	$48 million to $122 million
Range-finding based on past incidents in the Columbia River ($/gallon)[a]	$24.4 million
Cost to restore injured river habitat + cost to restore injured floodplain wetland habitat (HEA)	$54.5 million + $30.4 million = $84.9 million

a. Settlements from other spills in other locations are generally not scalable, but they can be used to suggest a potential range of damages.

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BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN THE MATTER OF: APPLICATION NO. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 EXHIBIT NO. _____ (-TRB) PREFILED DIRECT TESTIMONY OF: BABTIST PAUL LUMLEY SPONSORS: CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION AND COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

REGARDING THE FISHING INTERESTS OF THE COLUMBIA RIVER TREATY TRIBES RELATED TO THE TESORO-SAVAGE, LLC, VANCOUVER ENERGY DISTRIBUTION TERMINAL PROJECT

QUALIFICATIONS

My full name is Babtist Paul Lumley III, but my common name is Paul Lumley. I am a citizen of the Yakama Nation. I grew up fishing along the Columbia River with my dad and brothers. I come from a long family lineage of tribal fishers from the Columbia River area. I have fished throughout the area between Bonneville Dam and McNary Dam, known as Zone 6.

I completed my Bachelor of Science degree in Mathematics at Western Washington University in 1986. I began working for the Columbia River Inter-Tribal Fish Commission (CRITFC) in 1987. I have testified on numerous occasions in federal court as a subject matter

expert in the United States v. Oregon court case. I am currently the Executive Director of CRITFC. Among other departments, CRITFC has a Fisheries Enforcement department that enforces tribal fishing regulations and maintains public safety at the tribes' fishing sites along the Columbia River. CRITFC also has a Fishing Sites Maintenance department that implements operations and maintenance responsibilities for 31 In-Lieu and Treaty Fishing Access Sites along the Columbia River. CRITFC's Fishery Science and Fish Management departments provide technical assistance to CRITFC's member tribes. CRITFC currently employs approximately 100 staff, which varies seasonally. Among these are more than 20 scientists with advanced degrees in fisheries or related sciences.

PURPOSE OF MY TESTIMONY

The purpose of my testimony is to highlight the importance of the Columbia River and its fishery resources to the tribes of the Columbia River Basin and in particular to the member tribes of the CRITFC; the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation of Oregon and the Confederated Tribes and Bands of the Yakama Nation. This importance is exemplified by the commitment of the tribes to salmon and other species restoration as well as the work of the Commission. It is important for the governments the tribes work with to understand tribal perspectives with regard to salmon and the Columbia River. I have chosen several examples of the CRITFC's work to help explain this perspective.

THE TRIBES AND THE COLUMBIA RIVER

The Columbia River system is the life-blood of all the tribes and First Nations found along its entire length. Since time immemorial, the water, salmon, game, roots, and berries of our homeland—the sacred first foods—have sustained our health, spirit, and cultures. So fundamental was this connection that when the Yakama, Umatilla, Warm Springs, and Nez Perce tribes entered into treaties with the United States in 1855, they specifically included language to ensure that they could continue to fish, hunt, and gather their first foods. (See the Columbia River Inter-Tribal Fish Commission's Web site, www.critfc.org, for the full text of each member tribe's 1855 treaty.)

In their treaties, these four tribes ceded a collective 66,591 mi2 (172,470 km2) of their lands to the United States, agreeing to live on reservations. The tribes' ceded lands are depicted in Figure 1 as lightly shaded areas. The current tribal reservation lands make up a small percentage of the tribes' ceded areas. The tribes customarily undertake fisheries restoration projects within their ceded lands. The tribes also reserved rights to fish at their usual and accustomed fishing areas, which as confirmed by the federal courts may extend beyond the tribes' ceded area boundaries.

TRIBAL FIRST FOODS

Through a review of the notes of the negotiations that led to their treaties with the United States, it is obvious that the U.S. negotiators recognized the importance of salmon and first foods to the tribes. Article 3 of the U.S. treaty with the Yakama Nation in 1855 states:

> *the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory, and of erecting temporary buildings for curing them: together with the privilege of hunting, gathering roots and berries.*

There is similar language for treaties with Umatilla, Nez Perce, and Warm Springs tribes. Through the treaties, the tribes reserved these rights to their first foods, including salmon.

Even today, the tribal first foods are served in our tribal longhouses in the order described in the treaties; first the salmon, then the game, roots, and berries. This order is so engrained in our tribal cultures that the Natural Resources program of the Umatilla Tribe has organized its functions around these first foods.

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION (CRITFC)

Human impacts on the Columbia basin have dramatically altered the entire ecosystem since the signing of the treaties. Increased human population, dam construction, unregulated harvest, and substantial habitat modifications drastically reduced salmon populations. Annual salmon runs today average fewer than 2 million fish—about one-tenth of what they were, on average, historically (NWPPC 1986).

The four Columbia River treaty tribes united forces to address the significant decline of salmon returns. Together they formed CRITFC in 1977 to coordinate their management activities and restoration efforts. Since then, these tribes have become leaders in accomplishing their stated goal to "put fish back in the rivers and protect the watersheds where fish live." They participate in interstate agreements and international treaties controlling salmon harvest and water management. These tribes are also successfully rebuilding naturally spawning salmon populations, restoring habitat, and protecting the water flowing in the rivers. Initially focusing on salmon and steel- head, CRITFC's efforts have since expanded to include Pacific Lamprey *Entosphenus tridentatus* and White Sturgeon *Acipenser transmontanus*, the two other anadromous fish species found in the Columbia basin.

WY-KAN-USH-MI WA-KISH-WIT

Several salmon populations were listed as endangered or threatened under the Endangered Species Act, beginning in the early 1990s. Due to years of frustration at federal inaction to develop the required recovery plans to address salmon survival at all life stages, the tribes developed their own plan to rebuild fish populations. The plan is called Wy-Kan-Ush-Mi Wa-Kish-Wit (Spirit of the Salmon), which was developed through CRITFC by the four member tribes and published in 1995. The plan was updated in 2014 (CRITFC 2014; http://plan.critfc.org).

To date, this is the only plan that quantitatively addresses the full lifecycle of the anadromous fish species for the entire Columbia River basin. The plan seeks to halt the salmon decline

and sets specific numeric goals for full recovery of Columbia basin salmon, steelhead, Pacific lamprey *Entosphenus tridentatus*, and White Sturgeon *Acipenser transmontanus*. It has a goal of doubling the 1995 salmon runs by the year 2020. The plan provides for the full recovery of anadromous fish to the rivers and streams that support the historical, cultural, and economic practices of the tribes within seven human generations. The seven-generation goal is a common theme for tribes that guides decision-making processes to meet the needs of the next seven generations of their people.

WATER QUALITY AND TRIBAL FISH CONSUMPTION

Historically, tribal members drank water directly from the Columbia River. Today, a host of contaminants in the river makes this unadvisable and even dangerous. The fish, however, do not have a choice when it comes to the water; they must swim in the river. By doing so, the fish are exposed to and absorb these contaminants. The state governments set fish consumption recommendations based on the amount of contaminants found in the fish. In the past, these rates were based on the amount of fish the average citizen consumes and did not account for the higher levels consumed by tribal members. A CRITFC study completed in 1994 concluded that tribal members consume an average of 6–11 times more fish than the general public. The results of a U.S. Environmental Protection Agency fish contaminant survey, completed in cooperation with CRITFC, showed that 92 priority pollutants were detected in resident and anadromous fish tissue collected from 24 different tribal fishing sites on the Columbia River (USEPA 2002). Contaminants measured in these fish included various Polycyclic Aromatic Hydrocarbons (PAHs) as well as dioxins and other chlorinated organic compounds. As a result, the tribes raised a substantial concern that state water quality

standards were not sufficiently protective for the tribal community that still subsisted on large numbers of salmon in their diet.

In 2011, Oregon adopted water quality standards based on the tribal fish consumption rate of 175 grams per day (g/d), the fish consumption levels documented in the CRITFC survey. Currently, water quality standards for Washington and Idaho are 6.5 g/d and tribal fish consumption rates are at the center of debates related to revising these standards. Washington and Idaho are in the process of revising water quality standards that hopefully will better protect tribal consumers. In 2012, the U.S. Environmental Protection Agency disapproved Idaho's request to use an updated fish consumption rate of 17.5 g/d because it was not protective of tribal consumers. If water quality standards for either state do not provide adequate protection for tribal subsistence populations, then the tribes will be compelled request the federal government will need to step in and promulgate water quality standards to protect the tribal members.

When the tribes signed the treaties in 1855, contaminated fish were not part of the deal. Large-scale pollution is a result of both federal and non-federal actions. The damming of the Columbia basin has exacerbated this problem. Despite these concerns, tribal members continue to consume large amounts of fish for subsistence purposes. Salmon are a healthy food source and must be protected for human consumption. In 2013, CRITFC's chairman submitted letters to the region's governors advocating for stricter water quality standards based on the higher tribal fish consumption rates. He stated, "The tribes believe that the long-

term solution to this problem isn't keeping people from eating contaminated fish, it's keeping fish from being contaminated in the first place."

COLUMBIA RIVER TREATY

The Columbia River Treaty between the United States and Canada governs hydropower and flood control on the 1,200-mi (1,900 km) Columbia River. The current treaty, implemented in 1964, does not consider the needs of fish, a healthy river, or the tribes' treaty fishing rights and cultural resources that are now recognized and fully protected under modern laws. The tribes were not consulted during the negotiation of the Columbia River Treaty. As a result, the treaty fails to include tribes or tribal interests. The impacts of the Columbia River Treaty on the tribes' cultural and natural resources multiplied the already disastrous effects that had resulted from the decision by the United States to dam the Columbia River in the 1930s.

The United States and Canada negotiated the Columbia River Treaty to last at least 60 years (2024). After that date, either party may choose to terminate it, but they must provide a 10-year notice of their intent to do so. That 10-year window opened in September 2014. Seeing that date on the horizon, many tribes in the Columbia basin started taking actions in 2007 to secure seats at the table to contribute to analyses and participate in the decision- making process. These efforts have grown into a coalition of 15 Columbia basin tribes that are actively working with several federal agencies and four states to reshape the Columbia River Treaty to protect and benefit tribal culture and resources. The coalition of 15 tribes also

coordinates with 17 First Nations in Canada to provide information on fish passage and ecosystem needs to inform all sovereigns and stakeholders in the basin.

The tribes' participation in the Columbia River Treaty 2014–2024 review is critical for protecting tribal rights and interests, including improving ecosystem functions and ensuring favorable conditions for other tribal resources. The tribes also seek representation on the U.S. negotiating team if changes to the Columbia River Treaty are discussed with Canada. The tribes gained the agreement of the United States to regard ecosystem function as co- equal with flood control and power production during the treaty review and to include measures to restore and preserve tribal re- sources and culture. Tribal interests were included in the U.S. Entity Regional Recommendation on the Future of the Columbia River Treaty After 2024 (U.S. Entity for the Columbia River Treaty, 2013) submitted to the U.S. Department of State in December 2013.

The U.S. Department of State retains the authority to renegotiate international treaties, but did use the regional recommendation as a key resource during its national interests determination regarding the future of the treaty. The regional recommendation is unique in that it includes the broad consensus of 11 federal agencies, four states, 15 tribes, the power sector, water users, environmental groups, and others. The U.S. Department of State indicated early in the review process that the ability to reach a regional consensus would govern its decision about whether or not to renegotiate the Columbia River Treaty. The tribes' look forward to modernizing the Columbia River treaty to serve the ecosystem needs of the Columbia Basin.

FOSSIL FUEL DEVELOPMENT PROPOSALS

Proposals for shipment of fossil fuels through the Columbia River Gorge corridor reached unprecedented levels in the last few years. Attachment 1 to my testimony is a table showing recent fossil fuel transportation proposals that would travel along the Columbia River. The cumulative effects of these proposals are of great concern to the Commission and its member tribes. We have consistently advocated that all jurisdictions with authority to do so recognize the cumulative impacts that these proposals would generate. CRITFC's comments on each of these proposals have stressed this point. In 2014 and 2015, CRITFC adopted resolutions addressing fossil fuel transportation issues. CRITFC resolution 2014-1 is provided as Attachment 2 to this testimony.

CRITFC's member tribes and the Quinault Nation filed an appeal of the "tank car rule" adopted by PHMSA and the U.S. Department of Transportation due to the tribes' concerns about railroad safety issues and the number of derailments, spills and explosions of crude oil. The Secretary of Transportation denied the appeal, but pledged' further rulemaking. The tribes' concerns have not been resolved.

TESORO SAVAGE, LLC, VANCOUVER ENERGY DISTRIBUTION TERMINAL PROJECT

CRITFC also filed extensive comments on the Tesoro-Savage Draft Environmental Impact Statement in January, 2016. These comments highlighted inadequacies in the DEIS including its:

- Consideration of impacts to tribal people and their resources.
- Failure to consider the effects on increased rail traffic on tribal people.
- Assessment of climate change impacts.
- Under-estimating the impacts to natural resources from the development proposal.
- The DEIS' failure to recognize the most recent science concerning the biological

CONCLUSION

The Columbia River treaty tribes have endured an incredible amount of change in the Columbia River basin since the treaties were signed in 1855. However, the protection or our first foods is paramount to our relationship with the Creator and these protections were promised in the 1855 treaties. Despite the many challenges, the tribes have persevered in protecting the treaty fishing right and reversing the decline of the salmon runs. In many places in the Columbia River basin, salmon runs have even begun to rebuild, which is a direct result of tribal action and advocacy. Tribal and non-tribal citizens of the Pacific Northwest enjoy these increased salmon runs. The advance of fossil fuel transportation projects in the Columbia River Gorge presents a great threat to the hard work of the tribes to restore these salmon runs that are protected in the treaties of 1855.

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END OF DIRECT TESTIMONY

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Babtist Paul Lumley

BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN THE MATTER OF: APPLICATION NO. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 EXHIBIT NO. _____ (-TRB) PREFILED DIRECT TESTIMONY OF: BLAINE L. PARKER SPONSORS: CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION AND COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

REGARDING POTENTIAL EFFECTS TO AQUATIC SPECIES SUCH AS WHITE STUREON AND PACIFIC LAMPREY RELATED TO THE TESORO-SAVAGE, LLC, VANCOUVER ENERGY DISTRIBUTION TERMINAL PROJECT

Q. PLEASE DESCRIBE YOUR QUALIFICATIONS.

A. I have been employed with the Columbia River Inter-Tribal Fish Commission (CRITFC) since 1991. In my 25 years of employment with CRITFC, I have accumulated knowledge, experience, and technical expertise in a variety of disciplines related to management of Columbia River aquatic species. I currently serve as a Fish Management Department white sturgeon program leader and researcher, and also coordinator for avian predation and aquatic invasive species.

My duties at CRITFC began with the management of northern pikeminnows at the eight federal mainstem dams. Years of access to the Corps' dams gave me a unique perspective on the complexity of the facilities and how the water flows around and through them. In

addition, I worked for a number of years in the study of Pacific lamprey. These efforts included movement studies through the mainstem hydroelectric projects for both adults and juveniles, life history work of juveniles in their rearing habitat, and educating the non-tribal co-managers about the importance of this native fish to tribal people with presentations at fisheries society meetings, co-management meetings, and coordination with tribal, state, and federal researchers.

Invasive species monitoring, meetings, and rapid response sessions for the entire Columbia River basin have also been among my consistent duties since 1997; geographic areas include the Snake River Basin, Upper Columbia PUD reservoirs, the Columbia River Estuary, federal hydro projects, key tributaries to the Columbia and Snake Rivers, and regions outside the Basin. I currently serve as the aquatic invasive species coordinator for CRITFC and have served on the Oregon Invasive Species Council and the Columbia River Basin working group of the 100th Meridian Invasive Species Council.

I have eight years' experience addressing avian predation on juvenile salmonids. These efforts have resulted in many field trips to the Columbia River estuary and the mainstem Columbia River upstream to Public Utility District projects on the Columbia River in Washington.

White sturgeon are the largest and one of the most ancient aquatic species in the Columbia River basin. Over the decades at CRITFC I have worked with white sturgeon in a variety of capacities, including but not limited to artificial supplementation, disease investigations,

stock assessment, young of year indexing, translocation, diet investigations, spawning and rearing using wild broodstock, and harvest management. I have actively worked with white sturgeon since 1994. I serve as regional expert in white sturgeon management and research.

Q. PLEASE DESCRIBE STURGEON POPULATIONS IN THE COLUMBIA BASIN.

A. White sturgeon are present throughout much of the mainstem Columbia and Snake rivers. White sturgeon are most numerous in the Columbia River estuary where hundreds of thousands of sturgeon are estimated to be present. Populations in the reservoirs upstream range from roughly 192,000 in Bonneville reservoir to fewer than 1,000 in Wells Dam reservoir. There are approximately 40,000 sturgeon in John Day reservoir and in McNary reservoir there are less than 10,000. Populations in the Columbia river upstream of Priest Rapids Dam range from a 6-10 thousand in each of Priest Rapids and Wanapum reservoirs to hundreds of fish in the mainstem reservoirs above Wanapum reservoir. Populations from Priest Rapids Dam up to the Canadian border are all currently undergoing long-term supplementation and population recovery efforts. There is a genetically distinct population found in the Kootenai River, which is listed as endangered under Endangered Species Act (ESA).

My experience with sturgeon also extends to other sturgeon and paddlefish species in North America. The overall study area detailed in the Draft Environmental Impact Statement for the Tesoro Savage Vancouver Energy Distribution Terminal Facility (DEIS), specifically the rail corridor study area (page 3.6-1), Rail-Columbia River study area, and the vessel corridor study area parallels the riverine habitat for the shovelnose sturgeon, paddlefish, pallid

sturgeon (ESA listed as "Endangered"), Kootenai River white sturgeon (ESA listed as "Endangered"), white sturgeon and the green sturgeon (ESA listed as "Threatened").

Q. PLEASE DESCRIBE YOUR CONCERNS WITH THE DEIS REGARDING THESE AQUATIC RESOURCES.

A. The DEIS Aquatic Species section (3.6) contains numerous oversights and omissions. For example, the protected fish section 3.6.2.2 does not list Endangered Pallid Sturgeon and Kootenai River white sturgeon, both of which inhabit drainages that are crossed by the trains carrying oil to the proposed site. Burbot, an endemic fish in the Kootenai River is not mentioned in the DEIS, and are considered endangered by the state of Idaho. The railroad tracks that carry oil to Vancouver cross and follow critical habitat for these species often for miles. In some cases, a spill of oil along certain sections of this route has the potential to cause localized fish extinction.

Q. PLEASE DESCRIBE YOUR CONCERNS RELATED TO THE LIFE CYCLES OF STURGEON AND LAMPREY.

A. White sturgeon are long lived fishes (>100 years) and generally spawn for the first time at 15 and 25 years of age for male and female fish, respectively. Males generally spawn every 1-2 years, whereas female sturgeon may only spawning every 2-5 years, depending upon available food resources. Spawning occurs in the late spring and early summer in water temperatures ranging from 53 to 64 degrees Fahrenheit or 12 to 18 degree Centigrade. White sturgeon are broadcast spawners, using a polyandrous mating strategy, one female's eggs are fertilized by many male sturgeon. Fertilized eggs sink to the river bottom, adhering to rocks,

logs, and other obstructions. Incubation is brief, less than 2 weeks, and newly hatched larval sturgeons are carried downstream to quiet eddies and backwaters were they rear and metamorphose within the substrate and debris on the river bottom. Once they complete metamorphisis, juvenile sturgeon continue to forage and live on or near the river bottom as they grow and mature into adult fish. The river bottom consistently remains the primary habitat component the rest of their lives. This dependence on the river bottom (i.e. benthic life history strategy) makes them exceptionally vulnerable to events or occurrences that contaminate, damage, or permanently alter the river bottom habitat, particularly the spawning, food and rearing habitat components.

Pacific Lamprey. These native fish have a life cycle very similar to anadromous salmon and steelhead. Pacific lamprey are also anadromous and die soon after spawning. Pacific lampreys enter freshwater nearly a year prior to spawning; overwintering in large clean substrate in or near their natal stream. Spawning occurs the following spring; adult lamprey creating a redd similar to salmon; using their mouth to grasp and remove substrate from the river bottom to create the redd. Eggs are laid into the redd and then fertilized by the males, again similar to anadromous salmonids. Newly hatched eyeless larval lamprey drift down river and rear for 2-7 years in fine sediments and gravels, gradually moving to larger substrate and faster water velocities prior to metamorphosing in eyed juveniles that move to the ocean, again similar to juvenile salmonids.

Like white sturgeon, Pacific lamprey spend a significant amount of their life cycle in or on the river bottom. Their dependence on the benthic environment makes them extremely

vulnerable to events or occurrences that contaminate, damage, or permanently alter the benthic habitat and its food and rearing components.

Unlike white sturgeon, this vulnerability is magnified many times, since juvenile lamprey spend up to 7 years living directly in the sediments. A single damaging event can impact up to 7 years' worth of year classes at once. This can effectively eliminate lamprey from a river for multiple generations; as the returning adult lamprey cue in on the scent of rearing juveniles as the final signal to return to their specific spawning habitat.

Q. HOW DOES THE DEIS GENERALLY ADDRESS FRESHWATER AQUATIC SPECIES VERSUS MARINE SPECIES?

A. The DEIS spends significantly more time on the marine life sections (page 3.6-19 to 3.6-36) yet the bulk of the route for active transport of oil to the proposed site follows freshwater fish habitat. DEIS sections on non-listed animals, such as flatfishes, surfperch, forage fish, and marine mammals greatly exceed those for listed salmonids, eulachon, and sturgeon. The section on invertebrates is a total of one paragraph, yet fails to mention the iconic invertebrates off the Oregon and Washington coastlines, the Dungeness crab and razor clam. The diverse invertebrate populations thorough the basin from the upper reaches to the ocean are the basis for the food webs that drive both resident and anadromous fish populations in the Columbia River basin.

Q. WHAT OTHER CONCERNS HAVE YOU IDENTIFIED?

A. A variety of other concerns were found in the review of the DEIS including propeller scour from the large tankers which break down the habitat of the shallow estuary habitats and shorelines. The noise, lighting, and infrastructure around the terminal has impacts on migration smolts, and may also support avian and aquatic predators which find shelter around the terminal. The noise associated with the construction can impact both resident and migrating anadromous fishes. The current work season listed in the DEIS will impact migrating fall chinook salmon and later in the winter, eulachon spawning runs. CRITFC's comments on the DEIS addressed these issues.

Increased shipping traffic will add the increase use of ballast water for the large ships. Some estimates are that the ballast water releases will be approximately 50% of the entire flow of the Columbia or 6 million cubic metrics of water. This water can bring in a variety of non-native invertebrates, fishes, and even human disease pathogens. Little details are provided on how the project will prevent the release of these invasive materials as well the impacts of the millions of cubic meters of salty waters into the freshwaters of the Columbia.

END OF DIRECT TESTIMONY

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Blaine L. Parker

BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN THE MATTER OF: APPLICATION NO. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 EXHIBIT NO. _____ (-TRB) PREFILED DIRECT TESTIMONY OF: STANLEY RICE, PhD SPONSORS: CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION AND COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

REGARDING EFFECTS OF OIL SPILLS ON AQUATIC ORGANISMS

Q. PLEASE SUMMARIZE YOUR QUALIFICATIONS.

A. I was hired by NOAA Fisheries in 1971 to initiate an oil effects study program in Alaska, relative to Alaska Fisheries, and to comment for the Agency on the marine portion of the draft Environmental Impact statement for the TransAlaska Pipeline and terminal at Valdez. The decisions for these facilities became final about six months after I was hired.

For NOAA, I have worked on damage assessment following several spills*: Ixtoc, Exxon Valdez, Kuroshima, Selendang Ayu, and Deepwater Horizon*.

As a scientist at Auke Bay Lab for NOAA, I supervised and managed a team of chemists and biologists, initially on the toxicity of oil prior to Exxon Valdez, and then from 1989 to my retirement in 2014. I spent 25 years on post spill damage assessment of the Exxon Valdez.

In this regard, I led or participated in studies of oil persistence, embryo sensitivity, and long term effects. I have worked on many species- from invertebrates to fish to whales.

I have published more than 130 peer reviewed scientific papers, the most recent in 2015, and continue to participate in publications from continuing work, with some still in draft form. About 90% of those are on oil toxicity and effects. A copy of my resume is attached to this testimony.

In 2014-15, I consulted with the U.S. Department of Justice in its prosecution of British Petroleum for environmental damages resulting from their 2010 *Deepwater Horizon* blowout in in the Gulf of Mexico. I testified before Judge Barbier in the *Deepwater Horizon* case regarding natural resources damage assessment on behalf of the United States. During that proceeding I evaluated the risk of the spill to aquatic resources and provided a critique of the methods used by witnesses for British Petroleum in conducting its risk assessment.

Q. PLEASE DESCRIBE YOUR CONCERNS WITH THE DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS).

A. My concerns fall into two broad categories.

- First, the extent of possible oil exposure is not well portrayed in the DEIS, primarily because of the reliance on weathering models to predict the spread of spilled oil rather than using available literature, such as the report on the 1984 *Mobiloil* spill at river mile 88 of the Columbia River, which has real observations that contrast sharply with the modeled characterizations in the DEIS.

- Second the sensitivity of aquatic species to oil contamination is not well portrayed because of the reliance on acute toxicity information. The DEIS does not suitably address available literature coming from recent oil spill studies.

An oil spill risk analysis needs to evaluate two halves of the risk equation that addresses exposure risk, and environmental sensitivity risk. Oil spills are classic "low-probability/high-consequence" events, requiring careful assessment of the risk of exposure, as well as the resulting consequences to species and habitats. The overall risk is confounded when either half of the equation is under-represented. In this case, neither half was portrayed well, primarily because DEIS did not utilize key pieces of literature in discussions of the exposure and sensitivity risks.

Risk evaluation also must address temporal considerations. The evaluations of both exposure and sensitivity risk in the DEIS did not portray the sense of long-term effect time scales adequately. Spilled oil can persist for years in some contaminated habitats, and affected species can suffer long lasting impacts. Available literature was not used to address the possible length of exposure or of persistent impacts from an oil spill.

Q. HOW WOULD YOU CHARACTERIZE THE EXPOSURE RISK ASSESSMENT FOR AQUATIC RESOURCES IN THE DEIS?

A. I believe the exposure risk assessment portrayed in the DEIS has several critical weaknesses.

- It under-represents the extent of toxic oil spreading, particularly down river, in the water column and at the river bottom.

- The DEIS does not use available, pertinent literature
- The time-scale of impacts is under-emphasized.

The spreading of the oil in the DEIS, based on a weathering model and suggests that only a few river miles may be affected. This portrayal starkly conflicts with the real life spill that occurred in 1984, when the *Mobiloil* vessel ran aground at river mile 88 on the Columbia River. Table 4-13 of the DEIS suggests that a small/medium vessel spill of 2200 barrels will only affect two river miles; or a large facility spill of 5000 barrels will only affect seven river miles. In contrast, the 1984 *Mobiloil* spill, of 3000 barrels of oil, had oil swept down stream, as fast as 50 miles in 24 hours. Oil reached the mouth of the Columbia River in 3 days, and was transported up the Washington coastal shoreline to Grays Harbor and Willapa Bay over the next few days.

River current is a key dominant factor, because it causes spilled oil to be carried down stream rapidly. Additionally, oil will mix into the water because of the turbulence from the current; measurements from the *Mobiloil* spill found oil on the river surface, in the water column, on river bottom sediments, and in the mouths of white sturgeon (Kennedy and Baca, 1985; Krahn et al. 1986). The current will also impact response efforts, because of the rapid spread oil downstream due to current, and because the effectiveness of booms to contain oil is curtailed at currents above one knot (Fang and Wong, 2006). Currents in the Columbia River will exceed one knot at many times even above Bonneville Dam. Rice Exhibit 1.

Clearly, more than two river miles of contamination can be expected to result from a spill of one rail car (750 barrels) to the Columbia River. In addition to the 1984 *Mobiloil* spill on the Columbia River, the expectation for rapid oil spreading and down stream contamination is

corroborated by a Bakken crude oil spill in the lower Mississippi where *Barge E2MS 303* released 750 barrels from a gash. In this case, oil was swept downstream as far as 65 miles over the next two days (Doeling et al. 2014 - Rice Exhibit 2). Less than 1 % of the spilled oil was recovered. The lack of use of the real life *Mobiloil* spill in the Columbia River and the *Barge E2MS 303* casts doubt on the validity of exposure risk in the DEIS and related model estimates.

Q. HOW WOULD YOU COMPARE THE INFORMATION FROM THE *MOBILOIL* SPILL, THE DRAFT ENVIRONMENTAL IMPACT STATEMENT AND IT'S APPENDICES?

A. The *Mobiloil* spill report used actual field data and observations, and included chemical measurements of the oil below the surface and on the river bottom sediments.

- Appendices E and J are based on output of a weathering model [ADIOS2], used to predict possibilities for the extent of oiling. The output can vary with the input variables. It is not clear what specific variables were inputed into the model for Appendices E and J, but the output of the model contrasts extremely with the real life *Mobiloil* spill, suggesting that river current may have been under estimated or devalued.
- The draft environmental impact statement selectively emphasizes the extent of oil spill distribution to a few limited river miles, primarily reporting only oil present at a thickness of ½ mm. *Mobiloil* spill report documented oil traveling down stream on the surface, rapidly; contamination was documented on river banks and Washington

ocean shorelines, and oil was documented in the water column, on river bottom sediments, as well as in mouths and tissues of white sturgeon.

The net result of the choices in the DEIS is that it under-reports the down stream spread of oil via the current.

Q. WHY IS UNDER-REPORTING OF EXPOSURE A CRITICAL ISSUE?

A.

- Under predicting the spread of the oil under predicts the habitats and species that can be expected to be exposed in a spill event, and would then under-predict the response needed to cope with a spill event.
- Under-predicting the spread of oil, along with reliance on acute toxicity thresholds for effects will under predict the adverse effects of oil exposure to species and habitats, particularly early life stages that can be impacted in the low parts per billion polycyclic aromatic hydrocarbons (PAH). (this will be discussed in more detail later under sensitivity issues).
- Limiting the discussion of effects to oil distributions ½ mm thick is inappropriate as oil of this thickness primarily relates only to birds, marine mammals, and shoreline habitats. Further, it only addresses acute toxicity, a flawed concept when evaluating biological risks to sensitive species (discussed subsequently in greater detail).

Q. HOW DOES APPENDIX J TREAT EXPOSURE RISK TO AQUATIC RESOURCES?

A. Poorly. As mentioned previously, there are two parts of the risk assessment: the chances of exposure, and the chances of effect from that exposure. Appendix J attempts to quantify the chances of exposure, based on vessel and transfer operations, and concludes the risk of an

individual event is very low, but nevertheless concludes that vessel related spills will almost certainly occur during the life of the project.

The low risk of exposure is then inappropriately minimized by the modeling of the oil spreading, and river miles that might be impacted. The percent of oil remaining after 120 hours (35% for Bakken crude, Table 21 and 75% for Dilbit, Table 22; 0.1 mm thickness of oil from Appendix J) is based on a model of evaporation and spreading, to arrive at an estimate of 0.31 RM or 0.66 RM impacted by 1000 barrel spill of Bakken crude or Dilbit, respectfully. Real life experience with the 3000 barrel *Mobiloil* spill contrast sharply. This spill contaminated many miles of river shoreline between river mile 88 and the mouth of the Columbia River in three days, because of the river current. River current is the dominant factor in determining the river miles impacted. The under-estimate of 0.31 and 0.66 river miles impacted is misleading.

The estimate of 35% oil remaining after 120 hours is also misleading. First, some of the oil will mix into the water column because of the current, and not be available to evaporation, but nevertheless will be available to organisms in the water column. Disappearance from the surface does not translate to disappearance from the river ecosystem (e.g. oil in the mouths of white sturgeon from the *Mobiloil* spill report). Second, the 120 hours used in the table is sufficient time for the oil to be transported as far down stream as the river mouth from the terminal facility, and is sufficient time to exert effects to embryos and other tiny organisms, such as zooplankton and invertebratesin the water column. Once habitat is contaminated, however, the persistence in shorelines, particularly wetlands, will be quite significant. Oil in contaminated wetlands from the *Florida* spill at West Falmouth has persisted more than

three decades (Reddy et al 2002), and oil from the Exxon Valdez spill continues to persist in contaminated beaches after 25 years.

The risk is communicated in terms of exposure risk (chances for a spill event; river miles that could be exposed), but the risks to sensitive life stages of aquatic organisms for example are not covered in Appendix J. The risk for a specific spill event is low, but this is a multi-decade project, and the risk of spill over the life of the project is significant. In 10 years, 1.8 million rail tank cars may be expected to travel to the port facility for transfer to vessels.

Q. IF RIVER CURRENT IS A DOMINANT FACTOR IN A POTENTIAL SPILL IN THE COLUMBIA RIVER, IS IT A GOOD THING OR BAD THING?

A. Both. The current is a good thing in that it will transport new clean water from upstream, on a steady basis, bringing continual dilution, and uncontaminated prey items. Exposures are likely to be transient for many species, thus minimizing the potential exposure to acute toxic doses of oil, particularly for the larger organisms.

It is bad in the sense that current will rapidly carry surface oil down-stream, and most importantly, aid in the mixing of oil down into the water column. The "mixing issue" is critical, because mixing oil into the water column means that the subsurface species are now vulnerable to exposure. The risk expands from primarily birds and marine mammals on the surface to fish, invertebrates, and vulnerable life stages in the water column. For the largest organisms, the transient nature of spills may be tolerated, but for the smallest and most fragile embryonic life stages, "transient" exposures can be more than adequate to absorb toxic PAH, and harm critical developmental processes (e.g. heart development, as shown later).

From a response viewpoint, the current is a very bad thing. The spill will expand downstream rapidly, and hinder responders from containing or limiting the geography of the spill. More wetlands, tidal areas, and even bottom sediments (because of the mixing) will be more vulnerable to contamination. Contamination of any of these habitats translates to greater difficulty in cleanup, and expands the time scale for chronic oil exposure to many organisms. Once oil is in the water column, cleanup operations will do little or nothing to protect exposed aquatic organisms.

Q. HOW WOULD YOU CHARACTERIZE THE SECOND HALF OF THE RISK EQUATION, SENSITIVITY OF SPECIES AND HABITATS TO OIL EXPOSURE?

A. There are several shortcomings in the DEIS relative to discussion of risk to species and habitats.

- Assessing risk to species and habitats is more complex than measuring the statistics of spill events
- Reliance on acute toxicity measures to gauge or predict sensitivity issues is a flawed concept
- Avoidance of recent spill study literature focusing on high sensitive embryonic life stages is inappropriate.
- Time scales relative to sensitivity are not treated meaningfully, because of reliance on acute toxicity as a measure of risk.

Measuring the risk to species is a complex task compared to measuring the risk of a spill event (such as derailment of a tank car) where there are hard statistical data to work with.

Biological sensitivities are a much more complex, and while we certainly have spill events in the past to examine, none have a complete understanding of the impacts from such a spill. The two most studied spills in world history, Exxon Valdez and Deepwater Horizon, have produced hundreds of scientific papers, yet were not studied satisfactorily: Pre-spill chemical and biological baselines are largely absent; there are no spill replicates; and only the *Exxon Valdez* spill has been tracked for a long time period, but only on limited species and habitats. The spill most relevant to the Columbia river DEIS, the 1984 *Mobiloil* spill is a good example of inadequate studies of biological consequences: the report (Kennedy and Baca, 1985) documents response effort, oil tracking, but biological effects were under studied in general (e.g. oiled bird carcasses were collected and disposed of, but the numbers and the species were not recorded). Some larger spills, such as *Exxon Valdez, Cosco Busan*, and *Deepwater Horizon* (Gulf of Mexico blowout) have been tracked with more scrutiny, and have revealed a wealth of information in the form of many scientific publications: oil persists in many habitats, embryos are extremely sensitive, some species have impacts that last for decades (see reviews by Peterson et al 2003; Rice 2009; Bodkin et al. 2014). The DEIS did not take advantage of this important literature. Instead it relies heavily on acute toxicity information, a flawed concept when predicting potential impacts from spilled oil.

Q. PLEASE EXPLAIN YOUR CONCERNS ABOUT EMPHASIZING ACUTE TOXICITY MEASURES WITHOUT COMPARABLE TREATMENT OF SUBLETHAL EFFECTS.

A.

- Acute toxicity, typically measured as an LD50, is a flawed concept for predicting biological effects from an oil spill. Standard 1-4 day acute toxicity tests will describe

a lethal toxic dose ("the ceiling"), but they do not describe what a safe exposure is. Standard acute toxicity tests are a scientific tool designed to determine the relative acute toxicity of different toxicants. The concept was originally applied to pesticides to see which formulation was most toxic and rapid. The method was not developed to assess the sensitivities of different organisms, or different life stages, or predict survival potential if exposures were not acutely toxic.

- Acute toxicity is often a relatively rapid death because the mechanism of toxic action is usually at respiratory (gills, lungs) and/or neural functions. When these critical functions are impaired, death follows rapidly, and is easily observed.

- There are many different mechanisms of toxic action, from impacts to DNA in a nucleus, to subcellular structures and function in a cell, or to tissues and organs. Some of these mechanisms are captured by the term sublethal effect, a term that is very inclusive, meaning that some damages may be slight and repairable with no measureable loss in survival potential, while other sublethal effects may not show as visible damages, but the survival potential can be severely impacted. In the latter case, death may be assured, either physiological, or more likely, as result of predation because the organism is impaired in ways not easily measured.

- The term sublethal is easily misinterpreted, because there is an implication that this level of dosage is not deadly. However, survival in nature is more complicated. Any sublethal effect from exposure to an organism that makes it more difficult to acquire energy (be a predator) or avoid predation (e.g. grows slower, swims slower) will diminish the survival potential. A population effect can occur if the net result of

sublethal effects is increased predation, decreases in recruitment, or impairment to reproduction. Acute toxicity tests determine the "ceiling" of negative effects, but never determine the "floor" of negative effects. For example, a crustacean larvae that is still alive after a 4 day exposure tests, but fails to molt weeks later is ecologically dead. The same holds true for an exposed fish larvae that can not swim as fast as their unexposed cohorts; they are eaten.

Q. HAVE YOU STUDIED SUBLETHAL EFFECTS? PLEASE PRESENT RELEVANT INFORMATION FROM YOUR STUDIES.

A. Yes, I have studied sublethal effects in many studies, most dating back to the *Exxon Valdez* spill, when I led a group of biologists and chemists studying the persistence of oil and the impacts for over 25 years in my career with the NOAA. Our studies along with several others found long-term persistence of oil, and long term impacts from the spill, on the order of decades. Oil is still present in many beaches of Prince William Sound; Elevated mortalities in pink salmon embryos were detected in the four year classes following the oil spill; sea otter population recovery was were impacted for nearly two decades in the hardest hit areas of the spill, and two pods of killer whales (one resident pod- fish predators, and one transient- marine mammal predators) have not recovered from the 40% losses they incurred in the first year of the spill.

These major findings were reviewed in a paper published in *Science* (Peterson et al. 2003), of which I am a co-author. We concluded, based on the suite of studies, that long term impacts were very significant, and that oil spills can no longer be viewed as short term

events. Most importantly, these findings were not predictable from the acute toxicity studies that dominated the literature prior to the Exxon Valdez spill.

The DEIS did not use this available literature that discusses the significance of sublethal effects or embryo sensitivity. Yet, the DEIS did cite Neff (page 4-77), stating that acute toxicity levels were not reached in the days following the *Exxon Valdez* spill. While that is a true statement, it is misleading. By omitting the literature on long-term effects, the DEIS presents a one-sided slant that would suggest that spills do not present a toxicity risk to fauna. That is not the case.

An illustrative example would be the DEIS's omission of substantial literature on Pink Salmon embryos sensitivity to polycyclic aromatic hydrocarbons (PAH) found in crude oil: Pink Salmon embryos were impacted by parts per billion of PAH, much lower concentrations than parts per million (3 orders of magnitude). The impacts at these low doses were for the most part subtle and difficult to see, in contrast to a dead animal in an exposure container; but the impacts were very important. An exposure of 18 ppb PAH during the embryonic stage decreased the adult returns by 40%, and an exposure of 5 ppb PAH reduced the returning adults by 20%. These studies were unique; they combined laboratory exposures and with releases of juveniles to the environment for 18 months; the tests were large and intense experiments, requiring about 70 thousand tagged fry from embryonic exposures per dose group. They were repeated in multiple years. These oil exposures were "sublethal", only normal looking fry were released (including controls), yet the impacts were significant; population level of effect was measured in the returning adults. (Heintz et al. 1999) These embryo studies, along with oil persistence, delayed sea otter recovery for two decades, and

lack of recovery in two pods of killer whales, changed our thinking of how to study spills, and influenced the studies years later of the *Cosco Busan* and *Deepwater Horizon* spills.

Comments on the DEIS by Vancouver Energy (page 4-64) acknowledge that sublethal impacts to fish have been reported in developing embryos and juveniles (Incardona et al. 2015), but do not give these results much significance. Vancouver Energy fails to mention the low exposure levels in the test or the probability that affected embryos will die. The significance of the sublethal effects in embryos is further under-represented by the discussion and reference to the work of Lee and Anderson (2005) suggesting that sublethal effect measurements like the presence of Cytochrome P450, while indicating exposure to PAH, do not necessarily indicate injury. The DEIS and Vancouver Energy's discussion of Cytochrome P450 is misleading. For embryos, where tissues and organs are in a complex continuum process of cell differentiation and development, indices of exposure may well predict damage, as indicated in the embryo exposure tests by Carls et al. (2005); Pink Salmon embryos with elevated P450 response later had decreased growth and poor survival compared to controls with baseline levels of P450 activity.

Q. EACH SPILL IS DIFFERENT, EACH OIL IS DIFFERENT- HOW RELEVANT IS THE LITERATURE FROM OTHER SPILLS TO THE COLUMBIA RIVER OIL TRANSPORT PROJECT?

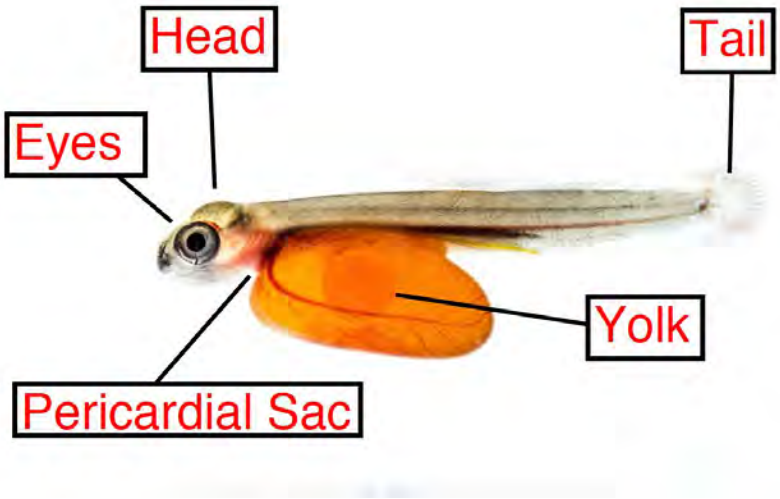
A. Each spill event is different in many ways, from volumes and types of oil spilled to differences in species and habitats that are impacted. *Exxon Valdez* spill in Alaska and the *Deepwater Horizon* spill in the Gulf of Mexico are examples of the diversity and differences between spills, yet these spills and others give us insight on how to deal with other spills,

how to cope with them, and what to expect. Although no two spills are exactly alike, hence they are not replicates, we have learned that when habitats are contaminated, oil can persist for decades; surface species such as birds and marine mammals are vulnerable to acute toxicity (inhalation and direct contact with oil; and heat loss issues from having feathers compromised), subsurface species are threatened by "sublethal" exposures, and embryos are 2-3 orders of magnitude more sensitive than older life stages. While the sensitivity of Tuna embryos from the Gulf of Mexico do not have direct applicability to the Columbia River risks, they are informative of the general sensitivities of the embryos from species specific to the Columbia River.

Q. PLEASE EXPLAIN THE EXTREME SENSITIVITY IN EMBRYOS, AND THE SIGNIFICANCE OF "SUBLETHAL" EXPOSURES TO DEVELOPING EMBRYOS.

A. The impacts of oil on developing embryos, at very low exposure concentrations, is perhaps the best example of the significance of sublethal effects. Let me explain this using the research of John Incardona and his collaborators that has been developed in the last few years since the *Deepwater Horizon* spill

The picture in Figure 1 shows a single coho embryo; note the head, tail, eyes, yolk, pericardial sac.



The images in Figure 2 show embryos of other species; each different to some degree, but they have the same features. Many fish embryos go through similar developmental stages. The sensitivities that we are able to measure may differ between the species, but they are likely to be more similar at the embryonic stage across species compared to their own sensitivities at juvenile and adult life stages within the same species.

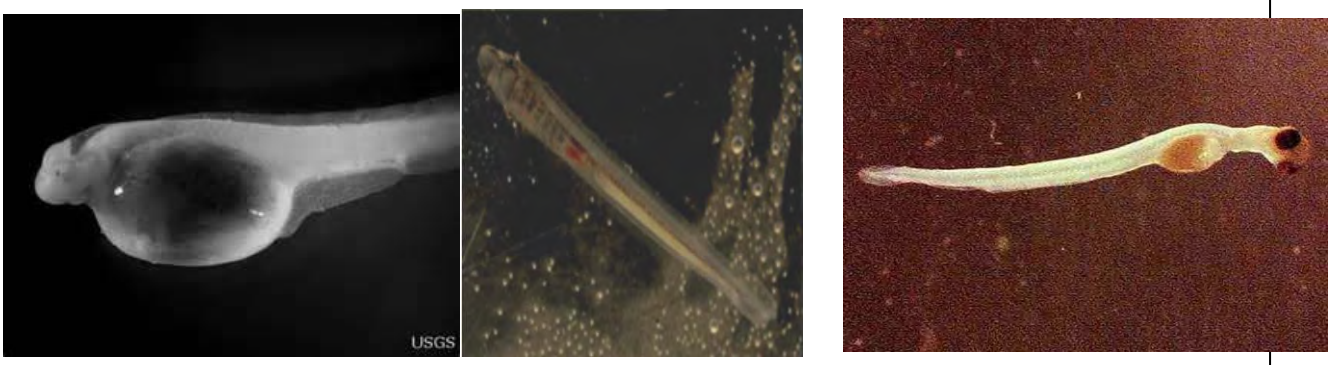


Figure 2. Left to right: Image of larval white sturgeon. Courtesy USGS. Image of a larval lamprey, courtesy of Ralph Lampman, Yakama Nation Fisheries. Image of larval Eulachon courtesy of Canadian Department of Fisheries and Oceans.

In Figure 3, two embryos (yellow fin tuna, from Incardona et al. 2014) are shown, with the one on the right being an exposed and damaged embryo. The damage does not appear catastrophic, note the edema around the pericardial sac of the heart. However, in the video accompanying Figure 3 http://www.critfc.org/blog/advocacy/effects-of-petroleum-spills-on-fish/ note the heart beat rate in the control, which has a good steady rhythm. Now, consider the heart beat of the exposed embryo. The heart rate of the exposed embryo is much slower. Because the heart is affected, there are many down-stream effects. The net result: this animal, if it survives to be a juvenile, is less fit. "Less fit" was demonstrated in the embryonic exposure study of Mahi-Mahi by Mager et al (2014): exposures of 48 hrs to embryos at parts per billion PAH resulted in juveniles that did not swim as well as their control cohorts a month after the exposures. Their chances of surviving the critical juvenile stage were diminished.

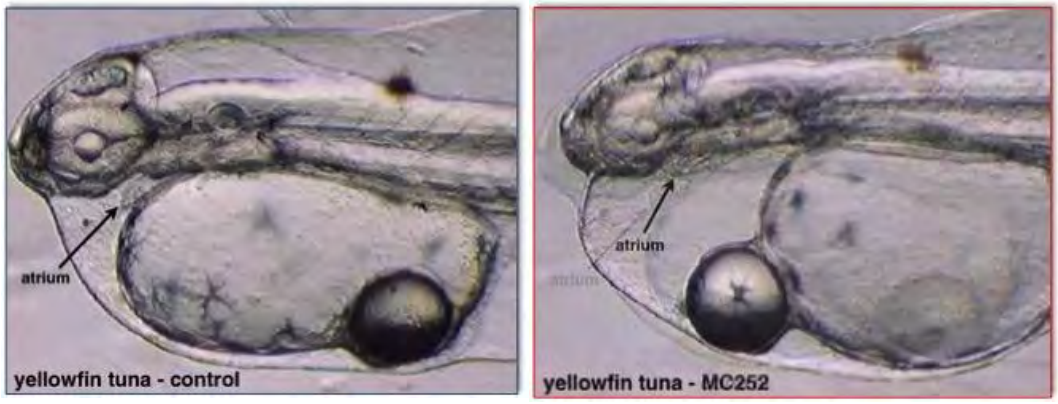


Figure 3. From Incardona et al. 2014. The embryo on the right was exposed to 3.4 PPB polycyclic aromatic hydrocarbons. Video available at http://www.critfc.org/blog/advocacy/effects-of-petroleum-spills-on-fish/

There are similar results for many other species, including pink salmon and herring. Heart damage, function, and decreased swimming performance were found in juveniles up to nine months post exposure of embryos to low parts per billion of PAH (Incardona et al. 2015).

These and other studies demonstrate the significance of a sublethal exposure during the embryo stage. Brief exposures can have long lasting results that require detailed studies and time to detect. Although the exposure doses will seldom reach acute toxicity levels and kill an embryo out right, the sublethal effects will eventually lead to increased predation (less fit), and poorer percentages of survival. Slow swimming performance will make it difficult to be a successful predator, and more difficult to avoid predation. This is an example of how sublethal effects are actually lethal to a population.

Q. PLEASE PROVIDE A SUMMARY OF YOUR CONCLUSIONS.

A. The DEIS paints an optimistic picture. It relies heavily on low odds of an event, but given the length of the project, and the numbers of trains, tank cars, and vessel trips, it is more likely than not there will be an incident. The *Exxon Valdez, Kuroshima, Selendange Ayu, Cosco Busan, Ixtoc, Deepwater Horizon* accidents all had low odds of an event, yet they did happen with severe impacts to the environment. Second, the time scale is important. Time scale of the project is decades long, giving time for a low probability event to happen. The time scale of oil persistence and effects can also be a long term event, as shown in some well-studied spills. Disappearance of oil from the surface signals the end of the response effort, but oil may persist for decades below the surface, particularly wetlands, and effects can last for decades also, particularly for long lived species like white sturgeon and green sturgeon. Oil spills are not a one week or one month event.

The DEIS under-represents effects because of its reliance on acute toxicity concepts and data, and ignores the growing literature on the extreme sensitivity of embryos and the significance of sublethal effects to subsurface organisms. Given the volumes of oil transported over the number of years of the project, there is cause for concern for sensitive life stages.

The DEIS with its reliance on low spill event risk, poor projections of down stream oil movement, reliance on acute toxicity mechanisms as the measure of effects, and the avoidance of important modern literature, paints an overly optimistic picture. Profit is for the oil and transport industry; risk is on the river, organisms living in that habitat, and those who use it.

END OF DIRECT TESTIMONY

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Stanley D Rice

Stanley Rice, PhD

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BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN THE MATTER OF: APPLICATION NO. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 EXHIBIT NO. _____ (-TRB) PREFILED JOINT DIRECT TESTIMONY: MITCHELL HICKS & MICHAEL BRONCHEAU SPONSORS: CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION AND COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

REGARDING TREATY FISHING ACCESS AND IN LIEU FISHING SITE CONCERNS RELATED TO THE TESORO-SAVAGE VANCOUVER ENERGY PROJECT

Q. CHIEF MITCHELL G. HICKS, PLEASE DESCRIBE YOUR JOB DUTIES, BACKGROUND AND QUALIFICATIONS.

A. As the chief enforcement officer for the Columbia River Inter-Tribal Fish Commission's (CRITFC) Enforcement Department, I am responsible for the department's administration of police and dispatch services on behalf of the four member tribes of the Columbia River Inter-Tribal Fish Commission. I am a citizen of the Shoshone-Bannock Tribes of Idaho, I have 23 years of law enforcement experience, possess an Executive Certification from the Oregon Department of Public Safety Standards and Training. The geographical mission area of CRITFC's Enforcement Department encompasses approximately 700 square miles of land and water of the Columbia River corridor, of Oregon and Washington, between the Bonneville Dam and the McNary Dam. This area includes 31 In-Lieu Sites (IL) and Treaty Fishing Access Sites (TFAS), plus the community of Celilo Village where the Enforcement

Department has emergency services responsibilities. Title to these properties is held by the United States for the benefit of CRITFC's member tribes. I supervise a staff of nineteen officers and dispatchers in the Enforcement Department.

Q. MR. MICHAEL BRONCHEAU PLEASE DESCRIBE YOUR JOB DUTIES, BACKGROUND AND QUALIFICATIONS.

A. I manage CRITFC's Fishing Site Maintenance Department (FSMD), which provides operations and maintenance (O&M) services to the IL/TFAS along the Columbia River. My duties include preparing and monitoring budgets and contracts; supervising O&M crews; approving budgeted expenditures; ensuring that capital improvements and emergency repairs to the IL/TFAS are done in a timely and fiscally responsible manner; coordinating IL/TFAS maintenance and related site closures as needed; and acting as a liaison with tribal fishers, contractors, USArmy Corps of Engineers, Bureau of Indian Affairs, state parks agencies, port authorities and municipalities. I have worked for CRITFC since August 17, 2003 as the Project Coordinator for the IL/TFAS sites; this position was reclassified as a mangerial post in 2012. I supervise a staff of six to seven members in the FSMD.

I am a Nez Perce tribal member, born in Grangeville, ID and graduated high school in Ukiah, Oregon in 1971 . I started at Eastern Oregon College in September 1971 and was drafted into the U.S. Army on January 10, 1973. I served over thirty years active duty in the U.S. Army and the Oregon Army National Guard, retiring in May 2003. I am a graduate of the Calvary Officer Basic and Advance Course, Command and Staff Service School, Inspector General Course and the Anti-Terrorist Train the Trainer course and several non-commission

officer schools in Europe and the U.S. I have an Associate of Science degree from Blue Mountain Community College in Civil Engineering Technology.

Q. PLEASE DESCRIBE THE IN-LIEU SITES.

A. The In-Lieu sites (IL) are those sites identified in 25 CFR Part 248. Appendix A to this testimony contains maps of the sites. Among other things, the maps show the proximity of the sites to the Burlington Northern Santa Fe (BNSF) railroad tracks near the Washington shore of the Columbia River and Union Pacific (UPRR) railroad tracks near the Oregon shore of the Columbia River. At the Cooks and Cascade Locks IL sites, the railroad tracks are immediately adjacent to the sites. Tribal member dwellings are located within thirty yards of the railroad tracks at both sites.

The Cascade Locks IL is located at the west end of the Port of Cascade Locks riverfront park within the city limits of Cascade Locks, Oregon. There are approximately ten people who reside at the Cascade Locks IL year round. The only means of egress are via a road that parallels UPRR tracks for approximately 300 yards to an underpass of the UPRR tracks to get to the main street out of Cascade Locks, or, alternatively, via the public boat ramp to the Columbia River in the Port of Cascade Locks river front park.

The Cooks IL is on a rocky peninsula along the Columbia River near Underwood, Washington at a location commonly known as Cooks Landing. The only means of egress from the Cooks IL are via a road that crosses the BNSF railroad tracks at grade or via a boat ramp to Columbia River by watercraft. Approximately twenty-five people reside at the

Cooks IL year round. Dwellings are crowded, there is some utility infrastructure, there are many vehicles, boats and trailers, valuable commercial fishing equipment, and ancillary structures.

The Underwood IL is within 100 yards of the BNSF railroad tracks. State route (SR) 14 separates Underwood IL from the BNSF railroad tracks.

None of the IL have fire hydrants or other firefighting water supply capabilities. None of the IL have firefighting apparatus on site.

Q. PLEASE DESCRIBE THE TREATY FISHING ACCESS SITES.

A. The Treaty Fishing Access Sites (TFAS) are those sites identified in the Bureau of Indian Affair's regulations at 25 CFR Part 247. Appendix B to this testimony contains maps of the TFAS showing the proximity of the sites to BNSF and UPRR railroad tracks on the Washington and Oregon shores of the Columbia River, respectively.

There are six sites on the Oregon side that are immediately adjacent to UPRR tracks. There are fifteen sites on the Washington side that are immediately adjacent to BNSF tracks. All of these sites require passage over or under rail or via watercraft transit to ingress or egress. Campsites are located at each of the sites and can be quite crowded. There is some utility infrastructure, many vehicles, boats and trailers, valuable commercial fishing equipment, and ancillary structures.

Except for Wyeth, none of the TFAS have fire hydrants or other firefighting water supply capabilities. None of the TFAS have firefighting apparatus on site. The proximity of apparatus ranges from a one to two miles (such as at North Bonneville and Faler Road) and as far as twnety miles (such as at Pasture Point and Three Mile Canyon).

Q. HOW MANY PEOPLE RESIDE AT THE SITES DURING FISHING SEASONS BETWEEN MARCH AND OCTOBER?

A. Between 115 and 901 tribal fishers resided at the IL/TFAS each month between March and October 2015. There is year-around residential use at Cooks (25), Underwood (4), Cascade Locks (6), Lyle (18) and Lone Pine (26). See attached table for additional information concerning the numbers of people residing at the IL/TFAS.

Q. WHAT IS THE EGRESS SITUATION AT THE TREATY FISHING ACCESS SITES?

A. There are six sites on the Oregon side that are immediately adjacent to UPRR tracks. There are fifteen sites on the Washington side that are immediately adjacent to BNSF tracks. All of these sites require passage over or under rail or via watercraft transit to ingress or egress. For example:

- North Bonneville TFAS: In case of a derailment on the track adjacent to the TFAS, the only egress would by on SR-14 to the west. The BNSF tracks are within 5-10 yards of 25% of the most eastern part the TFAS. That 25% area includes the drain-field, dry shed, fish cleaning station, septic holding tanks and the restroom/shower facilities. There are no boat ramps or docks at North Bonneville TFAS.

- Wyeth TFAS: In case of a derailment adjacent of the TFAS the only vehicle accessible land based egress is over the bridge that cross the UPRR tracks or by boat from the boat ramp and dock to the north. Almost the entire site is within 150 yards of the UPRR tracks. The facilities within 150 yards include the front gate, pump house & well, fish cleaning station, double vault toilet and five camp sites.

- White Salmon TFAS: The site is directly adjacent to the BNSF tracks. There is one paved access road onto or off of the site. 80% of the fishing site is between 50 and 150 yards of the tracks. Facilities include the front gate, fish cleaning stations, restroom/shower facility, drain field & septic tanks and all seven camp sites. The only other egress is by boat at the boat ramp and dock. Egress by land along the banks of the river may be possible but there are wooded area with a lot of under-growth that could be engulfed in flames during a derailment.

Separate from the IL/TFAS, it is important to note that there are many undeveloped locations that tribal members, and others, use via vehicle and pedestrian crossings to access the Columbia River for fishing and recreational purposes along the 150 mile reach between Bonneville and McNary of the BNSF and UPRR railway

Q. WHAT FIREFIGHTING CAPABILITIES EXIST AT THE TREATY FISHING ACCESS SITES?

A. With the exception of Wyeth, none of the IL/TFAS have fire hydrants or other firefighting water supply capabilities. The proximity of apparatus ranges from a mile or two for North

Bonneville and Faler Road and as far as twenty miles for Pasture Point and Three Mile Canyon.

Q. WHAT EMERGENCY SERVICES DOES THE COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION PROVIDE TO THE TREATY FISHING AND IN-LIEU SITES?

A. Mitch Hicks. The Enforcement Department provides twenty-four hours a day, seven days a week law enforcement services at the IL/TFAS. These services include fish and wildlife law enforcement, response to criminal calls, investigations, search and rescue, community policing, and interagency mutual aid. However, given the geographic area that we must cover, our capabilities are very limited.

The Enforcement Department provides water-borne rescue services along the Columba River between Bonneville and McNary. CRITFC's patrol staff are generally capable of reaching any point on this stretch of the River within 90 minutes, 12 months per year.

Q. DOES THE COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION PROVIDE FIREFIGHTING OR RELATED EMERGENCY RESPONSE SERVICES FOR THE IN-LIEU OR TREATY FISHING ACCESS SITES?

A. No. We have reviewed the comments of the City of Vancouver regarding its emergency preparedness concerns related to the proposed Vancouver Energy development. Many of the concerns expressed by the City of Vancouver would apply with equal or greater degree to the IL/TFAS. For instance, to the best of our knowledge there are:

- No tribally authorized plans for evacuating residents at any of the IL/TFAS in case of a derailment or or spill;
- No plans for sheltering tribal members that might be evacuated in the event of a spill;
- No emergency notification procedures to protect tribal members using the IL/TFAS in the event of a derailment and oil spill;
- No assessment of the burden that a derailment and spill would place on the dispatch services of the CRITFC Enforcement Department; CRITFC maintains one of the only radios systems on the Columbia River with continuous single channel service from the Tri-Cities, WA to below Bonneville Dam;
- No water supplies at any of the IL/TFAS sufficient for emergency fire-fighting capability, the only water supplies are for drinking water;
- No identified fire-fighting or emergency response teams that would be specifically responsible for protecting the IL/TFAS and residents in the event of a derailment and oil spill;
- No provision for the establishment and resourcing tribal emergency responders with capability of protecting the IL/TFAS and tribal residents; and
- No independent analysis of the risks and impacts the project represents to tribal members fishing and living along the Columbia River.

Q. PLEASE SUMMARIZE YOUR CONCERNS.

A. Broadly speaking, CRITFC is the only tribal first-responder located along the Columbia River and it lacks:

- Pre-emergency plans

- Tactics and strategies
- Training
- Equipment
- And other related resources

To effectively deploy such capabilities, they must be developed in close coordination with the tribes' governing bodies, the tribes' on-reservation emergency response capabilities, the Bureau of Indian Affairs, the U.S. Environmental Protection Agency, and other federal agencies and local governments.

Q. HAVE YOU ATTENDED ANY TRAINING SESSIONS CONCERNING SAFETY ISSUES AND FOSSIL FUEL SHIPMENTS ALONG THE COLUMBIA RIVER?

A. Yes. This training has been especially informative as to the very limited capabilities dedicated to protecting the tribes' interests along the Columbia River. Federal, state and county agencies have expressed concerns about their limited emergency response capabilities to address a train derailment and oil spill. Through these trainings we have learned that tribal emergency response resources along the Columbia River, compared to the inadequate state and federal resources, are essentially non-existent.

Q. DO YOU HAVE CONCERNS ABOUT THE GEOGRAPHIC RESPONSE PLANS FOR THE COLUMBIA RIVER FROM BONNEVILLE TO MCNARY DAMS.

A. The three Geographic Response Plans (GRPs) for the section of the Columbia River between Bonneville and McNary dams anticipate using a number of these IL/TFAS for oil collection

actions. Neither CRITFC nor its member tribes officially participated in the development of these GRPs.

Q. WHAT TECHNICAL CAPABILITIES WERE OFFERED AT THESE TRAINING SESSIONS?

A. Information and training only. No funding, equipment or personnel.

END OF DIRECT TESTIMONY

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Mitchell G. Hicks

Mitchell Hicks

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Michael A. Broncheau

Michael Broncheau

2015 In-lieu TFAS Population Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Site Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Average**
2	North Bonneville			11	60	75	28	60	65	65	55	22	14	455	45.5
3	Cascade Locks	7	6	7	12	30	15	19	25	20	7	5	5	158	13.2
4	Wyeth			4	1	15	12	14	60	35	13	8	3	165	16.5
5	Wind River				8	14	8		25	20	3	3		81	11.6
6	Cooks	25	28	25	20	50	21	40	30	50	31	33	28	381	31.8
7	Underwood	4	4	4	12	8	15	15	15	15	5	4	5	106	8.8
8	White Salmon			5	3	25	50	50	35	63	36	6	4	277	27.7
9	Stanley Rock			5	13	50	25	34	35	50	7	2		221	24.6
10	Lyle	18	18	24	26	50	75	75	76	100	65	34	36	597	49.8
11	Dallesport				3	30	25	25	40	60	15	11	11	220	24.4
12	Lone Pine	24	26	26	25	50	50	31	45	65	47	36	34	459	38.3
13	Avery													0	0.0
14	Celilo				1	30	30	30	20	40	8			159	22.7
15	Maryhill			4	2	65	45	51	26	70	10	11	4	288	28.8
16	Rufus					2	10	10	14	25	0			61	12.2
17	Preacher's Eddy				6	15	22	22	20	50	5			140	20.0
18	North Shore													0	0.0
19	LePage					18	16	50		30	3			117	23.4
20	Goodnoe													0	0.0
21	Pasture Point					18	28	30		60	5			141	28.2
22	Rock Creek													0	0.0
23	Sundale													0	0.0
24	Roosevelt				4	40	41	42	20	55	30	13	12	257	28.6
25	Moonay													0	0.0
26	Pine Creek									10	0			0	0.0
27	Threemile Canyon													0	0.0
28	Alderdale					4	4	4		10	0			22	5.5
29	Alderdale Creek													0	0.0
30	Crow Butte					4	3	3		8	0			18	4.5
31	Faler Road													0	0.0
32	Total	78	82	115	196	593	523	605	551	901	345	188	156	4333	361.1
33	Average	15.6	16.4	11.5	17.8	32.9	18.5	37.8	36.7	42.9	20.3	14.5	14.2	23.3	
34															
35															
36															
37															

Google Maps Bonneville In-Lieu Site

Imagery ©2016 Google, Map data ©2016 Google 200 ft

Google Maps

Google Maps Cascade Locks In-Lieu Site

Imagery ©2016 Google, Map data ©2016 Google 50 ft

Google Maps

Google Maps Wyeth Treaty Fishing Access Site

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Google Maps Wind River In-Lieu Site

Imagery ©2016 Google, Map data ©2016 Google 100 ft

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Google Maps Cooks In-Lieu Site

Imagery ©2016 Google, Map data ©2016 Google 100 ft

Google Maps

Google Maps Underwood In-Lieu Site

Imagery ©2016 Google, Map data ©2016 Google 50 ft

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Google Maps White Salmon Treaty Fishing Access Site

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Google Maps Stanley Rock Treaty Fishing Access Site

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Google Maps Lyle Treaty Fishing Access Site

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Google Maps Dallesport Treaty Fishing Access Site

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Google Maps Lone Pine Treaty Fishing Access Site

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Google Maps Preacher's Eddy Treaty Fishing Access Site

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Google Maps North Shore Treaty Fishing Access Site

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Google Maps Pasture Point Treaty Fishing Access Site

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Google Maps Pine Creek Treaty Fishing Access Site

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Google Maps Alderdale Treaty Fishing Access Site

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Google Maps

Google Maps Aldercreek Treaty Fishing Access Site

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Google Maps Crow Butte Treaty Fishing Access Site

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Google Maps Faler Road Treaty Fishing Access Site

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BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

IN THE MATTER OF: APPLICATION NO. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 EXHIBIT NO. _____ (-TRB) PREFILED DIRECT TESTIMONY OF: ZACHARY PENNEY, PhD SPONSORS: CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION AND COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION

REGARDING POTENTIAL EFFECTS OF INCREASED CRUDE OIL TRANSPORT ON COLUMBIA RIVER ANADROMOUS SALMONIDS

Q. PLEASE BRIEFLY DESCRIBE YOUR EDUCATION AND EMPLOYMENT.

A. I completed my B.S. at Sheldon Jackson College in Sitka, Alaska, where I worked at the campus salmon hatchery during the school year raising pink, chum, coho, and chinook salmon. I completed my M.Sc. at the University of Victoria, studying otolith microchemistry in sockeye salmon stocks important to the subsistence users in Sitka, Alaska. My doctoral research investigated the physiological and energetic constraints of repeat-spawning in steelhead trout in the Columbia basin and I received my doctorate (Ph.D.) in 2013 from the University of Idaho.

During the course of my studies and work, I have become familiar with fish ecology, physiology, and energetics. I have prepared papers relating to the biochemistry of the salmon

lifecycle, including papers addressing fatty acid consumption in muscle and liver tissue of migrating steelhead, blood plasma chemistry of migrating steelhead, and trace elements found in the otoliths of sockeye salmon. A copy of my Curriculum Vitae is attached.

In my present capacity, I serve as the Fishery Science Department Manager for the Columbia River Inter-Tribal Fish Commission (CRITFC) in Portland, Oregon. As Department Manager, I supervise over 30 scientists and technicians. Of these, eighteen have either master's degrees (9) or doctorate degrees (9). My job duties at CRITFC include synthesizing scientific information related to the salmon life-cycle, as well as other fish species, and communicating that information to other departments at CRITFC, to CRITFC's governing body, and to its member tribes. I am Nimi'ipuu, a member of the Nez Perce Tribe.

Q. WHY ARE YOU PROVIDING A DECLARATION?

A. The proposed Tesoro-Savage facility could receive an average of 360,000 barrels of crude oil per day via train, store it on site, and load it onto marine vessels. These projects will result in high volumes of crude transport on the rail line from Spokane through the Columbia River Gorge along the Columbia River, as well as multiple transfers between land and water-based shipping and storage containers. The possibility of an oil spill could have acute and delayed effects on anadromous salmonids at various life stages. There are threatened and endangered populations of anadromous salmonids on the Columbia River Basin.

Q. WHAT IS THE SCOPE OF YOUR DECLARATION?

A. The scope of my declaration is to briefly identify and discuss the anadromous salmonid species present in the Columbia River Basin that could be potentially affected by increased oil transport/contamination from the proposed Tesoro-Savage terminal in Vancouver, Washington. I have outlined the basic life cycle of anadromous salmon and steelhead to highlight what life stages could be affected by oil contamination. This declaration provides no analyses of the acute and delayed effects of oil on salmon and steelhead survival or fitness. Accompanying testimony from Dr. Stanley Rice addresses the potential acute and delayed effects of oil contamination on fish, as well as other species.

Q. DISCUSS COLUMBIA RIVER BASIN ANADROMOUS SALMONIDS.

A. The Columbia River presently hosts five species of Pacific salmon, which include chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*). Columbia Pink salmon populations are considered extinct, but strays do occasionally occur above Bonneville Dam. The Columbia River also hosts two anadromous trout species, steelhead trout (*O. mykiss*) and coastal cutthroat trout (*O. clarki*). Historically, anadromous salmon returned and spawned in tributaries in Washington, Oregon, Idaho, Nevada, and British Columbia. (Fig 1.)

By definition, anadromy refers to diadromous fish that spend most of their life maturing/growing in the sea, but return to freshwater when fully grown (Bond 1996). In the case of anadromous Pacific salmon and steelhead, life begins and ends in freshwater.

Pacific salmon and steelhead follow 6 general phases of development during their life cycle (Fig. 1), which includes: 1) egg, 2) alevin, 3) fry, 4) smolt, 5) adult and 6) spawner phases. The egg, alevin, fry, and spawner phases occur solely within freshwater. The smolt and adult phases include the migratory transitions between freshwater and the ocean (smolt) and between the ocean and freshwater (adult) (Fig.2). A basic description of the anadromous life cycle was provided by Groot and Margolis (1991)"

> *"Pacific salmon spawn in gravel beds in rivers, streams, and along lake shores. They generally migrate to sea after an early freshwater life and are widely distributed over the North Pacific Ocean and Bering Sea during the marine years of their lives. Most perform extensive migrations while at sea. Some populations or subpopulations of certain species stay in coastal waters or remain in freshwater….Upon maturation, after one to seven years (depending on species and stock), Pacific salmon usually return to their home rivers and natal breeding grounds."*

For some Columbia River salmon populations (e.g. Redfish Lake, ID sockeye salmon), freshwater migrations to and from the ocean can extend well beyond 600 km, whereas Columbia River chum salmon migrate less than 100 km from the ocean.

Comparatively, sea-run coastal cutthroat trout do not exhibit the expansive migrations of Pacific salmon and steelhead in the ocean. Unlike Pacific salmon and steelhead, sea-run coastal cutthroat trout do not always return to freshwater in a sexually mature[ing] state and may make multiple sea-water migrations to feed and attain growth (Johnston 1982).

Post-spawn survival is different between anadromous Pacific salmon and sea-run trout (Quinn and Meyers 2004). Pacific Salmon are semelparous and die after their first and only spawning cycle. Steelhead and coastal cutthroat trout are iteroparous and can spawn more than once, although repeat spawning rates can be variable (Quinn and Myers 2004).

Life history variation and reproductive strategies are variable between and within anadromous salmonids in the Columbia River Basin. These differences include, but are not limited to the timing/return to freshwater to spawn (i.e. seasonal races), actual spawn timing, spawning location/migration distance, gonadal maturation, period of egg incubation and rearing periods of fry. For example, Columbia River Chinook salmon fry exhibit high variation in freshwater residence and age of smoltification. Depending on the seasonal race, (e.g. spring-, summer-, and fall-chinook), chinook fingerlings may reside in freshwater between a few weeks to a few years (Brannon et al. 2004). As such, a multitude of different sized chinook salmon smolts could potentially be exposed to oil contamination in the event of a spill in the Columbia River gorge or tributary.

Due to the large number of life cycle differences and reproductive strategies that occur between anadromous salmonid populations in the Columbia River, a full review of each species, subspecies (inland vs. coastal steelhead), seasonal-race (e.g. fall vs. spring run chinook salmon), run-type (A vs. B-run steelhead), or genetic group is beyond the scope of this declaration. Rather it is simply important to note, that these anadromous salmonids exist in the Columbia River at numerous phases of their life cycle. Anadromous salmon and trout

in the Columbia River also use different portions of the river during various phases of their life cycle. For example, smolt migrations of most chinook, coho, sockeye, and steelhead at Bonneville Dam occurs between April and July (Table 1). An oil spill during smolt migration could have severe consequences to all populations of salmon and steelhead in the States of Idaho, Oregon, and Washington; including threatened and endangered populations. Similarly, most Columbia River adult salmon and steelhead return to spawn in the between April and October, although winter-run steelhead can return between November and April (Fig. 3). Furthermore summer-run stream-maturing steelhead, like those in the Snake River subbasin, overwinter in various areas of the Columbia River before spawning in the spring of the following year (Behnke 1992). A helpful discussion of anadromous salmonid use of the Columbia River estuary can be found in the National Marine Fisheries Service "Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead." (NMFS, 2011). The Recovery Plan module also makes recommendations for actions to benefit anadromous salmonids, including reducing sources of pollutants.

In summary, the Columbia River basin contains anadromous salmonids at various life stages year-round. The threat of acute or delayed effects of an oil spill could affect numerous species at various life stages.

END OF DIRECT TESTIMONY

I declare under penalty of perjury that the above testimony is true and correct to the best of my knowledge. Executed this 13th day of May, 2016.

Zachary Penney, PhD

BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 **PREFILED TESTIMONY OF MICHAEL S. HILDEBRAND, FILED BY THE CITY OF VANCOUVER**

Q: Please state your name, place of employment and title, and address.

A: Michael S. Hildebrand, CSP, CHMM, CFPS
Hildebrand and Noll Associates, Inc.

Q: What does Hildebrand and Noll Associates, Inc. do?

A: Hildebrand and Noll Associates, Inc. is a Florida based, 100 percent Veteran owned S-corporation. The company was founded in 1989 by Michael S. Hildebrand and Gregory G. Noll. Our consulting firm specializes in hazardous materials emergency planning and response.

Q: What types of businesses have you worked with?

A: My business partner Gregory Noll and I have designed, planned, and managed over 700 hazardous materials emergency planning and response, safety, and security projects in the United States, Canada, South America, Europe, Central Asia, the Middle East, Australia, and the Caribbean. I specialize in hazardous materials emergency response and planning

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in three primary markets: industry; U.S. military; and public safety. Some examples of our experience in industry include:

- We have served as consultants at 30 refineries, 27 chemical plants, and 13 gas plants where we have conducted operational readiness reviews of emergency response programs, developed facility Emergency Response Plans, and trained Incident Management Teams.
- We have conducted 55 comprehensive emergency preparedness program audits and assessments of petroleum refineries, petrochemical plants, pipelines, bulk storage tank farms, and hazardous waste facilities.

As senior partner with Hildebrand and Noll Associates, Inc. I have served as a Subject Matter Expert or witness on many legal cases involving industrial emergency response and fatal accidents. A few examples include:

- Torrance, California. *Gower, et al v. Mobil Oil Corporation*. Provided technical support concerning complaint against the Mobil Torrance Refinery concerning risks to the community from operating a Hydrofluoric Acid Alkylation Unit. (Latham and Watkins) 1990.
- San Francisco, California. *United States v. Chevron*. Conducted investigation and provided deposition concerning the use of specialized protective clothing in refineries. (Chevron Office of General Counsel) 1990.
- Baltimore, Maryland. *Atlantic Mill and Lumber v. Autoline Lubricants, Inc*. Provided technical support concerning complaint against Autoline Lubricants regarding ultra hazardous operations. (Stein, Mitchell and Mezines) 1991.
- Kansas City, Missouri. *Heim/Herken, et al v. Simco Petroleum Co., et al*. Conducted investigation and provided deposition concerning oil field production tank standards. (Payne and Jones) 1991.
- Orange County, California. *Mullenax v. Mobil Oil Corporation*. Provided technical assistance concerning a bulk storage tank explosion resulting in injury. (Cummins and White) 1991.

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- Los Angeles, California. *Lekberg and Mostoufi v. Mobil Oil Corporation*. Conducted investigation and provided deposition concerning a storage tank explosion. (Cummins and White) 1991.

- Columbus, Ohio. *United States v. Gem Industrial, et al.* Provided technical assistance concerning the use of protective clothing in refineries. (Bricker and Ecker) 1992.

- Denver, Colorado. *Diamond Shamrock Refining & Marketing v. AMR Combs-Denver, Inc.* Conducted investigation of safe operating practices used at Denver Stapleton International Airport's bulk storage tank facility prior to the 11/25/90 tank farm fire. This fire burned for 55 hours and damaged seven storage tanks consuming more than 1.6 million gallons of jet fuel for a loss of $32 million. (White and Steele) 1993.

- Wichita, Kansas. *Township of Buena Vista, Michigan v. C. Reiss Coal Co. and Saginaw Asphalt & Paving Co.* Conducted investigation and provided technical advice concerning how a coal fire was managed by the fire department at the Reiss Coal Company. (Koch Industries Office of General Counsel) 1994.

- Boston, Massachusetts. Provided technical advice in support of *Stanley J. Johnson, et al. v. Exxon Corporation* regarding an underground tank explosion. (Nutter, McClennen & Fish) 1996.

- Bakersfield, California. Conducted investigation of oil tank explosion at the World Oil refinery and served as consulting expert in *Greater Bakersfield Separation of Grade District v. World Oil, et. al.* (Latham & Watkins) 1997.

- Lansing, Michigan. Served as consulting expert and provided testimony for the State of Michigan MIOSHA Appeals Division concerning underground tank explosion and fatality involving Midland Environmental Services 1997.

- Tulsa, Oklahoma. Provided technical consulting in defense of the National Propane Gas Association in *Nehring, et al. v. Thermogas, et al.* involving a propane tank explosion at Albert City, Iowa (Conner & Winters) 1999.

- Chatham, New Jersey. Provided technical advice in support of *Gonzalez/Lopez/Rivera v. Genie Co., et al f.* Case involved a fire resulting in employee burns from using acetone inside an ocean yacht under construction (McCusker, Anselmi, Carvelli & Walsh) 2000.

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- Mobile, Alabama. Served as a consulting expert concerning *Plaintiffs v. Celanese Chemicals, et. al.* Case involved a fatality of an industrial emergency responder. (Frazer, Greene, Upchurch & Baker, LLC) 2003.

- Milwaukee, Wisconsin. Provided technical support concerning a warehouse fire involving a fire at a large warehouse and propane storage facility in Dania, Florida. *Travelers Property Casualty Company of America a/s/o Uniweld Products v Chilton Manufacturing Corporation* – Case No. 04-60013 - United States District Court. (Folley & Lardner, LLP) 2004.

- Calgary, Alberta, Canada. Served as consulting expert on *Shell Canada, Ltd v. Superior Propane Plus, Inc.* concerning March 18, 2002 propane truck fire at Albian Sands. 2006.

- San Jose, California. Served as technical consultant in support of *McCormack v. PG&E, et. al.* This case involved an accidental electrocution of a Santa Clara County Fire Captain at a multiple alarm residential occupancy fire. (Shea & Shea) 2007.

Q: Can you review your professional experience prior to forming Hildebrand and Noll Associates, Inc. as it relates to hazardous materials emergency planning and response?

A: I served as the Director of Safety and Fire Protection for the American Petroleum Institute (API) from March 1980 – May 1989 (9 years 3 months) in Washington, D.C. I managed the safety and fire protection program for the American Petroleum Institute's member companies. Areas of responsibility included legislative and regulatory affairs, fire protection engineering standards, and recommended practices for safety and fire protection of refineries and bulk storage terminals.

I was employed as a Fire Safety Research Analyst for the International Association of Fire Chiefs from May 1979 – March 1980 (11 months) in Washington, D.C. At the IAFC I managed a Federal Emergency Management Agency contract in fire service disaster planning and wrote the *Disaster Planning Guidelines for Fire Chiefs*.

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I served as a Hazardous Materials Safety Technician with the U.S. National Transportation Safety Board from January 1978 – May 1979 (1 year 5 months) in Washington, D.C. At NTSB I supported senior investigators with analysis of accident data, conducted telephone interviews with accident victims, and prepared technical reports for NTSB's Hazardous Materials and Railroad Divisions.

I served as an active duty firefighter with the United States Air Force from September 1972 –1976 (4 years) with service at Mountain Home Air Force Base and at Sembach Air Base in Germany. While with the Air Force I served as a firefighter, rescue technician and medic, rescue crew chief, and fire department communications supervisor. I was a member of the USAF Prime Beef Disaster Mobility Team. I received the Good Conduct Medal and an Honorable Discharge.

Q: Can you review your education as it relates to emergency preparedness and management?

A: I attended the following colleges and attained the following degrees:

- University of Maryland at College Park (1976 – 1979) and obtained a Bachelor's Degree in Science. My major was Fire Safety Analysis and Investigation.
- Montgomery College, Rockville, Maryland (1976 – 1977) where I obtained an Associate in Arts Degree in Fire Science.

Q: Have you earned any professional certifications?

A: Yes, I am certified by the following organizations:

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- Certified Safety Professional - Board of Certified Safety Professionals, License 13750. Starting in 1995.
- Certified Fire Protection Specialist (CFPS), Fire Protection Specialist Certification Board, License 772. Starting January 1995.
- Certified Hazardous Materials Manager (Masters Level), Institute of Hazardous Materials Management, License 6915. Starting January 1996.
- Certified Hazardous Materials Incident Commander, National Board on Fire Service Professional Qualifications, Certificate 29185. Starting January 1995.
- Merchant Marine Officer - Master of Inland Steam or Motor Vessels (50 Gross Tons), with Commercial Assistance Towing. U.S. Coast Guard, License 906817 (License in Continuity) Active license 1995 – 2010.

Q: Have you written or instructed on the topic of hazardous materials emergency planning and response?

A: Yes, I have authored or co-authored the following publications:

- Gasoline Tank Truck Emergencies: Responding to MC-306/DOT-406 Cargo Tank Trucks Transporting Gasoline/Ethanol Blends and Fuel Oils, 4th edition (2016) Jones and Bartlett Learning.
- Guide for Communicating Emergency Response Information for Natural Gas and Hazardous Liquid Pipelines, HMCP Report 14, by Jennings, Charles, Groner, Norman, Hildebrand, Michael, Noll, Gregory, and Zimmerman, Rae, Transportation Research Board, The National Academy of Sciences, Washington, D.C. The HMCRP Report 14: Guide for Communicating Emergency Response Information for Natural

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Gas and Hazardous Liquids Pipelines is designed for use as a pre-incident planning tool for both pipeline operators and public safety agencies, such as fire departments, law enforcement, and emergency management agencies. It is intended to provide information to assist all parties in identifying information needs and the means for communicating this information.

- Hazardous Materials: Managing the Incident, 4th edition (2014) Jones and Bartlett Learning. This textbook is now in its 28th year of continuous publication. The textbook is designed to train emergency responders how to safely respond and manage emergencies involving hazardous materials. It meets the requirements of the National Fire Protection Association Standard NFPA 472, "Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents" for Incident Commanders and Hazardous Materials Technicians. (622 pages).
- Pipeline Emergencies, 2nd edition (2011), National Association of State Fire Marshals. This textbook provides emergency responders with information on how liquid and gas pipelines systems operate and how to safely respond to pipeline emergencies. It includes many scenarios that can be used for training. (204 pages).
- NFPA Fire Protection Handbook, 20th Edition Chapter 13-6, "Public Fire Protection and Hazardous Materials Management," National Fire Protection Association (2007). This chapter describes the various hazardous materials regulations and standards that relate to emergency planning and response to hazardous materials emergencies. It contains useful information for fire marshals and inspectors as well as responders.

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- Propane Emergencies, 3rd edition (2007) Propane Education and Research Council (PERC) This textbook provides information on how to safely respond to propane emergencies. It explains the chemistry of propane, the various types of storage tanks and transportation vehicles, and a variety of tactical scenarios. (302 pages).

Q: What organizations are you a member of related to hazardous materials emergency planning and response?

A: I belong to and have volunteered for the following organizations:

- National Fire Protection Association (NFPA), NFPA 472 – Committee on Professional Competencies of Emergency Responders to Hazardous Materials and Weapons of Mass Destruction Incidents. (Alternate Member since 1997).
- Yvorra Leadership Development Foundation (YLD). YLD is 501C (3) non-profit organization. I am the President and member of the Board of Directors. (Founded 1988). YLD promotes leadership development within the U.S. emergency services. For more information go to www.yld.org.
- 10 Year member of the Prince Georges County (Maryland) Hazardous Materials Response Team. Served as HazMat Team Shift Commander for 5 years. Served from December 1980 – December 1990.
- Firefighter, Montgomery County (Maryland) Fire Department. Served as volunteer firefighter with the Silver Spring, Maryland Station-19 (1976-1977).

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- Volunteer Firefighter, Hagerstown Fire Department, Engine Company-2. Served from March 1970 to September 1972.

Q: Can you please give an overview of the oil terminal proposal as it relates to the opinions you have in this proceeding?

A: I understand that Tesoro Savage Petroleum Terminal LLC proposes to construct and operate a new crude oil terminal in the Port of Vancouver, Washington. The terminal will receive an average of 360,000 barrels of Bakken crude oil and diluted bitumen per day by way of the BNSF railroad. The crude oil will be moved by High Hazard Flammable Trains (HHFTs).[1] The crude oil will be unloaded from the HHFTs, stored on-site, and loaded onto marine vessels at the terminal. Marine vessels would deliver crude oil to refineries primarily located on the U.S. West Coast. Vancouver is Washington's fourth largest city with a population of approximately 170,000 people. The BNSF's mainline railroad tracks which will transport HHFT trains will travel through an urban environment consisting of residential and commercial areas as well as the city's downtown.

The DEIS for the project indicated that the Applicant would "require all tank cars used to transport crude oil to the proposed Facility to meet or exceed DOT-117 (or newer) specifications." [2] However, the applicant commented that this is not the case. According to the applicant it will "follow the requirements of the new US DOT / PHMSA Tank Car

[1] The U.S. Department of Transportation – Pipeline and Hazardous Materials Safety Administration (DOT / PHMSA) defines High Hazard Flammable Trains (HHFT) as trains that have a continuous block of twenty (20) or more tank cars loaded with a flammable liquid (i.e., unit train), or thirty-five (35) or more cars loaded with a flammable liquid dispersed through a train (i.e., manifest train with other cargo-type cars interspersed).
[2] DEIS at 4-116.

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rule Final Rule on Enhanced Tank Car Standards" due to concerns that using only the DOT 117 cars would put it at a "commercial disadvantage."[3] The Enhanced Tank Car Standards" allow for the use of DOT-111 and DOT CPC-1232 cars in crude oil service according to the following schedule: non-jacketed DOT-111 cars until May 1, 2017; jacketed DOT-111 cars until March 1, 2018; non-jacketed CPC-1232 cars until April 1, 2020; and jacketed CPC 1232 cars until May 1, 2025.

Q: What can you tell us about the performance of tank cars used to transport crude oil by rail?

A: At the present time, crude oil and ethanol are transported in DOT-111 or CPC-1232 tank cars.[4] On May 8, 2015, PHMSA issued a final rule, Hazardous Materials Enhanced Tank Car Standards and Operation Controls for HHFTs, which established standards for the construction of new tank cars built to transport crude oil and ethanol in HHFTs.

The following facts can be noted with respect to the behavior of the railroad tank cars in a HHFT derailment scenario:

- Legacy DOT-111 and non-jacketed CPC-1232 (i.e., Interim DOT-111) tank cars have not performed well in high-energy derailment scenarios.[5] Jacketed CPC-1232 tank cars have performed slightly better than non-jacketed tank cars. See Exhibit-A for examples of rail car breaches and damage.

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[3] See Comments submitted by Vancouver Energy at page 2-20.

[4] CPC stands for Casualty Prevention Circular, which was issued by the Association of American Railroads. The CPC-1232 is a DOT-111 tank car that has enhanced features, including head shields constructed of ½ inch thick steel to protect the bottom half of tank heads during derailments and some are equipped with insulation and jackets.

[5] In the 24 HHFT derailments occurring between 2015 and 2006 there were a total of 442 tank cars derailed. Of these, 314 tank cars breached (71%).

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- Observations from actual derailment performance show that the number of tank cars that breach or fail is dependent on the type of tank car involved (e.g., DOT-111, CPC-1232 jacketed vs. non-jacketed tank car) and the configuration of the derailment (i.e., in-line vs. accordion style). Tank cars that pile up generally sustain greater numbers of car-to-car impacts that result in breaches, or will be susceptible to cascading thermal failures from exposure to pool fires. Tank cars that roll over in-line are less susceptible to a container breach, but may leak from damaged valves and fittings.
- During a dynamic derailment, tank cars are stressed mechanically and may breach due to punctures from couplers or other objects such as broken rails or as a result of damaged fittings. Tank cars damaged by mechanical stress often ignite and burn. Other causes of tank car failure may include: (a) thermal stress from an external fire impinging on the tank car shell; (b) the heat-induced weakening and thinning of the tank car shell metal; and (c) internal tank car pressure. The hazards posed by the release of flammable liquids include flash fires, pool fires, and dynamic energy release from container failure; i.e., fireballs with associated shock wave and possible separation of the tank shell.

A review of research literature by the Sandia National Laboratory for U.S. DOT/PHMSA showed that a 100 ton release of a flammable liquid (approximately equivalent to a 30,000 gallon tank car) with a density similar to kerosene or gas oil would produce a fireball diameter of approximately 200 meters (656 feet) and a duration of about 10 – 20 seconds. Note: "Gas Oil" is fuel distilled from petroleum.

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Observations that can be made with respect to the behavior of the railroad tank cars in a HHFT scenario include:

- Derailments resulting in a liquid pool fire scenario can lead to the failure of valve gaskets, which leads to additional tank car leaks and associated issues during derailment clean-up and recovery operations.
- Heat induced tears have been observed on tank cars containing both crude oil and ethanol. While the majority of heat induced tears have occurred during the initial 4-6 hours of an incident, tank car failures can occur at any time. Heat induced tearing has occurred within 20 minutes of the derailment and as long as 8+ hours following the initial derailment. This is significant from an emergency response context because tank car breaches due to heat induced tears can rapidly release flammable liquid and immediately increase the magnitude of the fire, which can further impinge on un-breached cars. If firefighters are engaged in rescue, evacuation, or firefighting when a heat induced tearing occurs their lives would be at risk.

Experience has demonstrated that HHFT incidents are large, complex and lengthy response scenarios that will generate numerous response issues beyond those normally seen by most local-level response agencies. In addition to the hazardous materials issues associated with the response problem, there will be a number of other secondary response issues that will require attention by the Incident Commander. These will include evacuation, foam and water supply logistics, situational awareness, information

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management, public affairs, and infrastructure protection. Managing an HHFT derailment and fire in an urban environment may also require an Incident Management Team supporting a Unified Command structure; e.g., National Incident Management System Type-III Team.

Q: How are HHFT fires different than the type of fires an agency such as the Vancouver Fire Department would typically respond to?

A: Based on our experience as hazardous materials emergency planning and response specialists, and from studying the experience from actual HHFT train derailments and fires, there are a number of observations that can be made that would directly relate to what the City of Vancouver would face in dealing with an HHFT derailment with fire.

Most fire service emergencies are "high intensity, short duration events" that are terminated in a matter of hours. In contrast, HHFT train derailment spills and fires are long duration, major environmental incidents that will extend over several days. With few exceptions HHFT incidents cannot be safely managed by a single agency or organization. These are "All Hands" incidents that require a coordinated fire department, law enforcement, and Emergency Management Agency response that is supported by mutual aid organizations, State and Federal technical support, Oil Spill Removal Organizations (OSRO's), and emergency response specialists from the railroad that are organized in a Unified Command format to bring the incident to closure.

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An HHFT train derailment scenario may likely be the largest flammable liquid incident encountered by most emergency response agencies in their history. Challenges will include the location and access to the incident, the overall size and scope of the problem, the rapid growth of the fire, spill control, and the level of resources available in the first one hour of the incident. The large quantities of foam concentrate required for fire control present most fire departments with significant challenges that include: (a) Having the right type of foam concentrate and in sufficient quantities; (b) A foam logistics plan to move foam caches to the scene of the incident; (c) Ability to access the burning tank cars; and (d) Adequate and sustainable water supply and the proper foam eductors and application devices. Initiating large flow foam operations at HHFT scenarios will be a significant operational challenge for most public fire departments.

In comments to the DEIS submitted by the Applicant, it is stated, "As generally discussed in the DEIS, if a potentially fiery crude by rail incident is not within the capabilities of certain responders to actively combat, then those first responders are unlikely to be prepared to actively combat a similar rail incident involving any flammable liquid or gas."[6] I believe this statement tries to simplify what is, in reality, a range of factors that are inputs into the incident commander's risk-based decision making response process. I would agree that there is a high probability of failure to successfully combat a HHFT fire. Responding to a HHFT derailment and fire will be different than responding to derailments and fires of tank cars containing Hazard Class 2.1 Flammable Gases

[6] Vancouver Energy comment letter, dated January 22, 2016 at Attachment 4-6, page 9.

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regardless of the relative volatility of the Class 3 liquid.[7] Class 3 flammable liquids account for the highest number of hazardous materials incidents in both transportation and fixed facilities. However, the challenge in the HHFT scenario is the overall size and scope of the response problem as compared to the level of available resources. A 100 car general freight train consists of a variety of rail cars like flat and box cars carrying a mixture of commodities as well flammable gas and liquid cars. In contrast, an HHFT train made up of a block of 20 to 100 flammable liquid cars in a row will present a different, and potentially more hazardous, dynamic than a general freight train.

Q: Can you describe the behavior and phases of an HHFT fire?

A: The behavior of HHFT derailments resulting in tank car breaches and fire goes through three distinct phases as illustrated in the graphic shown on page-17. These include:

The **first phase** is the initial derailment and fire. This is usually the first hour of the incident. If the derailed tank cars are initially breached through mechanical stress or valve failure and an ignition occurs, the breached cars burn and the fire will impinge adjacent exposures. These exposures may include adjoining tank cars that are initially intact, but are now stressed by fire. This behavior can result in additional tank car failures and an increase in the size of the fire. In this phase of the incident there may be a window of opportunity for the fire department to intervene and use an offensive strategy to attempt to attack and extinguish the fire. An adequate supply of water and foam concentrate must be available to execute an offensive strategy. Based upon our analysis of 24 HHFT incidents, there is a very limited window of opportunity in the early stages of an incident

[7] 49 CFR 173.115 – Class 2, Division 2 (Flammable Gas).

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for implementing offensive fire control strategies. There is a higher probability that response options will be limited to defensive strategies (e.g., exposure protection and spill control) to minimize the spread of the problem or non-intervention strategies. e.g., take no action and allow the fire to burn until equilibrium is achieved. It is important to note that to date, no HHFT fires have been controlled or extinguished using an offensive strategy in this phase of the incident.

The **second phase** is the incident growth (2 to 8 hours into the incident). In this phase of the incident, the fire grows larger and becomes very hot and intense. Incident growth will generally follow a process of: (a) thermal stress from the initial fire upon exposed tank cars; (b) activation of tank car pressure relief devices; (c) continued thermal stress on adjoining tank cars from a combination of both pool fires and pressure-fed fires from activated Pressure Relief Devices; (d) increasing probability of container failures through heat induced tears; and (e) subsequent fire and radiant heat exposures on surrounding exposures when rapid release events occur. During this phase of the incident, the size of the fire and the potential for container failures and associated fireballs make approach to the derailment difficult and unsafe for any offensive operations. Running or unconfined spill fires and releases may occur. Spills may flow into storm drains and other aboveground and underground structures creating secondary spills and fires. In addition, the use of large water streams for cooling may also spread the fire to non-involved areas. The window of opportunity for extinguishment closes and the fire department has to switch to either a defensive or non-intervention strategy. The curve on the graphic shown

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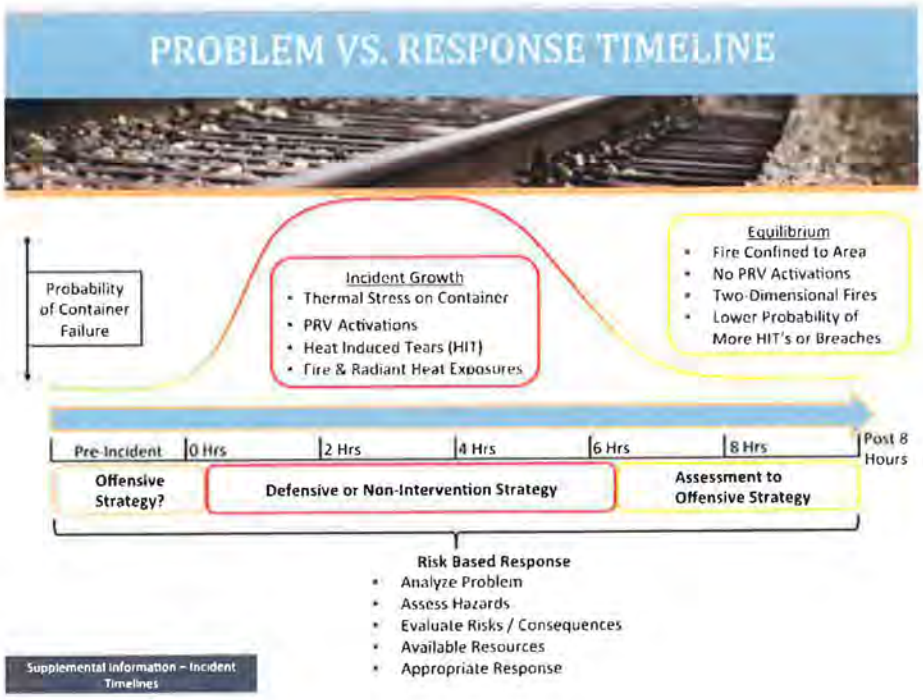
on page-17 represents the probability of additional container failures, which leads to a cascading and growth response scenario.

The **third phase** is what a number of emergency responders would call "Equilibrium." Fires will continue to burn off the available flammable liquid fuel until such time that the fire is no longer growing in size. An analysis of historical incidents shows that equilibrium at a major HHFT incident may not occur for approximately 8-12 hours into the incident timeline. The fire reaches a state when there is a lower probability of additional heat induced tears or tank car breaches. Equilibrium benchmarks would include the fire being confined to a specific area and no longer increasing in size or scope, no Pressure Relief Device activations, and the fire dynamic primarily being two-dimensional.

The graph below illustrates these phases of the incident:



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Q: Could you describe what you would consider to be a couple of plausible worst-case scenarios of HHFT derailments and fires in Vancouver?

A: Yes. First, let me review my work leading up to the preparation of these scenarios.

I and experts from Hall and Associates, LLC examined twenty-four train accidents between 2006 and 2015 that resulted in the derailment of tank cars transporting crude oil or ethanol in the DOT-111 and CPC-1232 tank cars. The focus of the analysis was on types of cars involved, number of cars derailed, train speed, number of cars breached, and the amount of product released. The primary sources for data used in this review were from reports and documents on file at the following organizations: the National Transportation Safety Board (NTSB), the Federal Railroad Administration (FRA), the Pipeline and Hazardous Materials Safety Administration (PHMSA) and the Transportation Safety Board of Canada (TSB of C).

On October 6 and 7, 2015 I along with Robert Chipkevich, who is a railroad safety Subject Matter Expert from Hall and Associates, LLC, conducted site inspections of property along the BNSF rail line, overpasses, grade crossings, adjacent exposures and storm drainage within the city limits of Vancouver. I participated in interviews with city planners and engineers to determine future urban development along the BNSF rail line through the city center. I also conducted interviews with police, fire, and emergency management senior leadership to determine current emergency response capabilities, including, communications, command and control, fire suppression, and evacuation.

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The first scenario would evolve as follows:

At 3:35 pm on a weekday, seven rail cars from a 100-car tank train carrying Bakken Crude Oil derail at a track speed of 10 mph. The derailment occurs at the new overpass near Esther and Phil Arnold approximately 400 feet from City Hall. Three of the seven derailed cars fall off the overpass onto Phil Arnold Avenue.[8] Each of the three tank cars carrying 30,000 gallons of crude oil is breached due to mechanical damage.

- One tank car is punctured and loses 30,000 gallons of cargo onto the roadway which flows into storm drainage under the overpass.
- A second tank car is breached and loses half of its cargo - 15,000 gallons.
- Valves on a third tank car are damaged and 3,000 gallons of cargo are released.

The low flash point crude oil accumulating in depth under the overpass ignites from an unknown ignition source. The intense burning liquid causes severe spalling to the concrete bridge supports. Burning crude oil enters the storm drainage system which flows into the Columbia River creating an oil spill. Depending on the available oxygen in the storm water system, the fire may pop up at some or all of the storm drains along the drainage route to the river causing secondary fires involving debris and automobiles parked along the curb. If the oil entering the river is still on fire, a second fire front could develop igniting brush and setting structures on fire along the shoreline.

The remaining four of the seven derailed tank cars come to rest on the overpass and adjacent hillsides. Due to the final resting position of these tank cars, orientation, and

[8] The area just south of this location between the BNSF rail line and the Columbia River is planned for waterfront development. This 186-acre site will include commercial retail, office space, and 1,125 residential dwellings. There will be a significant addition to the population density.

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proximity to a large pool fire involving up to 48,000 gallons of crude oil, the tank cars are exposed to intense fire and heat from the pool fire under the overpass.

Within two hours of the initial ignition of the pool fire, additional tank cars are breached due to thermal induced damage to the tank sidewalls and an additional 60,000 gallons of crude oil is involved in the fire.

In this scenario 108,000 gallons of crude oil are released and involved in fire, the equivalent of 12 large highway cargo tank trucks. The fire would grow rapidly in the first hour and emergency response would shift from an offensive strategy to a defensive or non-intervention strategy. The fire would may reach equilibrium for six to eight hours and might not be approachable by firefighters for approximately 8 to 12 hours.

The second scenario would evolve as follows:

At 2:45 pm on a sunny summer weekend, 27 cars of a 100-car Bakken Crude Oil tank train traveling 33 mph derails east of Interstate-5 along the SR-14 EB near Marine Park and the Marine Park Wastewater treatment plant along 45th Street. The wind is blowing 10 knots from the southeast. Seven tank cars are immediately breached due to mechanical punctures or damage to valves releasing 102,000 gallons of crude oil and resulting in large pool fires which flow downhill into Marine Park, threatening the waste water treatment plant.

The length of the train blocks the only exit from Marine Park trapping people in the park between the railroad track along SR-14 EB and the Columbia River. The SE wind

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spreads the fire to brush, which extends to the wooden residential buildings uphill from the railroad track near Shorewood. Residents in homes near Kaiser, Victory, and Assembly Roads are unable to evacuate.

Within 4-hours, an additional 13 tank cars are breached due to thermal damage from the fire and release an additional 275,000 gallons of crude oil.

In this scenario, 377,000 gallons of crude oil is released with much of it involved in fire, the equivalent of 42 highway cargo tank trucks. The fire would grow rapidly in the first hour and emergency response would shift from an offensive strategy to a defensive or non-intervention strategy. The fire would not reach equilibrium for six to eight hours and might not be approachable for firefighters.

Q: What concerns do you have, if any regarding Vancouver Fire Department's (VFD) ability to respond to the two HHFT derailment scenarios you have described?

A: The biggest challenge for the VFD in dealing with a HHFT derailment incident with breached tank cars and fire involved would be the ability to rapidly deploy fire suppression resources and intervene with an offensive strategy, and confine, contain, and extinguish the fire within the first hour. As noted earlier, no HHFT derailment with fire has been successfully extinguished in Phase-1 of the incident.

In addition to the challenge of sufficient personnel required to deploy large diameter hose lines and master streams, large quantities of foam concentrate would be required early in the incident. In order for a flammable liquids fire to be extinguished, you need the right amount of foam concentrate, at the right application rate, for the right length of time or

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the fire will not go out. There is a total of 18,365 gallons of foam concentrate available in the Vancouver metro area.[9] While this is an impressive inventory, the quantity of foam concentrate available does not necessarily translate to an immediate successful deployment and operability at the fire scene. The foam concentrate needs to be transported to the scene and turned into foam solution using fire pumps, hose lines, foam eductors, and application devices. There are significant logistical factors involved in a large scale foam operation. For example, in the Vancouver Metro Area there are 18,365 gallons of foam concentrate available in the foam cache. Of that total, only 1,600 gallons or 8.7% of the foam cache is immediately mobile and could likely arrive quickly at the fire scene; i.e., 20-30 minutes. This time factor would also apply to a response to the proposed terminal. Further, of the 6,365 gallons (34.6%) of the foam cache readily available and owned by fire departments, 4,765 gallons are stored on pallets or POD's. Transporting a POD requires a flatbed type chain truck to trans-load the POD to the vehicle so it can be driven to the scene. 12,000 gallons of the 18,354 gallons of the foam concentrate available is stored in fixed storage tanks on site at Boeing and would require transfer to totes or tanker trucks to be useful.

Q: What concerns do you have, if any regarding Vancouver Fire Department's (VFD) ability to respond to a fire at the proposed terminal?

A: In my opinion, the Vancouver Fire Department would be able to manage most High Probability/Low consequence incidents at the terminal like a large office building or warehouse fire with available manpower. On the other hand, responding to Low

[9] DEIS Page-5.4, Appendix-A to the Appendix-B *Fire Protection Assessment Report* – Chapter-5 – *VFD Foam Resources*. Table 5.3 shows the location and amount of foam concentrate available in the Portland/Vancouver Metro area.

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Probability/High Risk incidents like a crude oil bulk storage tank or process and loading area fires would present some strategic challenges.

A typical fire service response to a major hydrocarbon industrial facility like a refinery, tank farm, or marine terminal in a city the size of Vancouver would typically include: 4-Engine Companies, 2-Ladder Companies, 1-Hazardous Materials Unit, and 1-Command Officer. The table below shows the most likely 1st due through 5th due fire stations to the proposed Tesoro terminal, the type of fire apparatus, staffing level, and estimated response times.

Fire Station	Fire Apparatus	Staffing	Response Time
Station-1	Engine-1, Truck-1, Batt-1	8	8-Minutes
Station-2	Engine-2	3	9-Minutes
Station-3	Engine-3	3	14-Minutes
Station-4	Engine-4	3	18-Minutes
Station-5	Truck-5	4	15-Minutes
Station-10	HazMat Unit and Foam Unit	3	23-Minutes

This response would require 24 firefighters or 60% of the on duty complement of 40 VFD firefighters. The VFD runs about 70 emergency calls per day. This would leave 16 firefighters to cover the rest of the city and staff the other uncommitted stations. Mutual aid and a backfill would be required to support a sustained incident at the terminal.

Q: What are your concerns as they relate to evacuation?

A: The DOT Emergency Response Guide provides emergency responders with general evacuation guidance.[10] Evacuation Guide #128 provides guidance for petroleum crude oils and recommends an initial evacuation of at least 300 meters (1,000 feet) for large

[10] U.S. Department of Transportation PHMSA, Transport Canada, and Secretariat of Transport and Communications, 2016 Emergency Response Guidebook: A Guidebook for FirstResponders During the Initial Phase of a Dangerous Goods/Hazardous Materials Transportation Incident.

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spills with no fire. For fires, involving rail cars the Guide recommends an initial isolation and potential evacuation of 800 meters or ½-mile in all directions.[11] Using the DOT guidance, most Incident Commanders would initially defer to the Guide 128 recommendations and implement an evacuation of ½-mile radius around the incident until additional risk-based information becomes available. Therefore, using the Emergency Response Guidebook guidance the initial evacuation zone would be one-mile from one side to the other.

According to information provided to me by the Clark Regional Emergency Services (CRESA) during our October 2016 interview, the BNSF mainline as it transects Vancouver is located along the north shore of the Columbia River. State Highway 14 also parallels the north shore of the river to the north of the railroad tracks. This area is 4.78 square miles in size and has a population of 3,261 people. It is steeply sloped and there are only five streets (Columbia Shores, Shorewood, Lieser, Ellsworth and 164th Avenue) that allow vehicles or people to evacuate the area between the river and Highway 14. A map of this area is attached as Exhibit B. These streets are not designed or built to serve as evacuation routes. In the event of a derailment, an evacuation of this area would be extremely difficult. Additionally, a derailed train that is 1.5 miles long would block several at-grade crossings and the only means of egress for residents living south of the railroad tracks.[12]

[11] This is only guidance. The incident commander may request a larger or smaller evacuation zone based on size up and incident potential.

[12] CRESA has identified 25 Critical Care facilities for senior citizens within 2.75 miles of BNSF rail line, with about 18 of these facilities within 1-1/2 miles of the track.

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The difficulties of evacuation are exacerbated by the inability of the notification system to give differing evacuation instructions to different recipients using the existing Emergency Communications Notification System (ECNS).[13] Clark County does not currently have an enhanced ECNS which would allow focused notification of thousands of people with customized messages based on their location e.g., shelter-in-place, evacuation instructions, or areas to avoid. The current ECNS relies on the Incident Commander to determine how large of an evacuation area is required. This initial assessment will be based upon a combination of the initial size-up reflecting actual incident conditions and the recommendations of the Emergency Response Guidebook. Once the fire department Incident Commander makes a decision, the ECNS is activated and begins to alert telephone numbers inside the identified evacuation area. One restriction of the current ECNS is that it dials only home telephone numbers and not cell phones unless they are registered.

As noted above, many areas along the rail line have limited access for evacuation; a derailed train would isolate people between the Columbia River and the rail tracks. A 1.5-mile train in downtown Vancouver would block 2/3rds of the road exits.[14]

Q: What are your concerns as they relate to sheltering of evacuees?

A: Under the current City of Vancouver Comprehensive Emergency Management Plan, the Vancouver Police Department (VPD) would be responsible for coordinating the evacuation of the population from a hazard area and for safe return when the hazard has

[13] The ECNS is paid for using Homeland Security money through Clark County's budget.

[14] Page 2-2 of Tesoro's comments to the DEIS states that unit trains would be composed of 100 to 118 sole-purpose oil tank cars with two buffer cars and three locomotives. The DEIS Page 3.14-14 states that oil trains are assumed to be 7,800 feet long (1.477 miles).

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passed. This plan addresses evacuation emergency activities for the authorization, direction, routing, and relocation of people from their homes, schools, and places of business. In reviewing a one half-mile evacuation radius, depending on the location in the City, the estimated number of citizens requiring evacuation and relocation to a shelter is 7,000 to 13,000. According to the Washington State Patrol, based on a slow moderate event, approximately 45-60 officers per 10,000 residents are needed for traffic control. Based upon the University of California Crowd Control matrix, VPD would need approximately 7 sergeants and 38 officers for an estimated 13,000 citizens needing evacuation and approximately 4 sergeants and 26 officers for an estimated 7,000 citizens needing evacuation. VPD does not have the resources to meet demands of an evacuation of this nature.

Assuming that a timely and effective evacuation notification could be made to citizens at risk, and the required law enforcement personnel could be marshaled to direct the evacuation, the remaining problem would be locating shelters for evacuees.[15] Once a citizen is evacuated to a shelter their minimum stay time is 48 hours due to the transportation and processing time and availability of vehicles.

Q: Did you review the DEIS regarding fire suppression equipment at the oil terminal?

A: Yes. I did review the DEIS Fire Protection Assessment Report and the Fire Protection System Report. [16] One observation that I noted regarding fire protection systems for the proposed terminal design plan is that there are no provisions in the plan for a back-up power supply for the facility and no provisions for back-up fire pumps.

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[15] According to CRESA officials, there are approximately 1,100 hotel rooms in Clark County.

[16] DEIS *Appendix-B Fire Protection Assessment Report – Appendix-A Fire Protection System Report*.

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As noted in the DEIS report, there will only be one dedicated diesel fire pump in each area. Having one auxiliary fire pump without any type of back-up capability in each area is risky. Diesel fire pumps can be problematic if they are not inspected, maintained, and started on a regular basis. Oil and gas processing facilities typically have redundant fire pumps within the facility that are supplied by alternative energy sources. For example, an area in the facility would include two fire pumps; one diesel and one electric. This approach decreases the potential for a major fire loss due to a single pump failure. It also provides better capability to manage a large fire where both fire extinguishment and exposure protection water is required.

Q: What is a gap analysis as it relates to emergency response?

A: A gap analysis involves comparison of actual capabilities of the emergency response program with potential or desired performance to address the hazards and risks present.

Q: Did you review the Draft Environmental Impact Statement for this project?

A: Yes.

Q: Did the DEIS include a gap analysis of VFD's ability to respond to HHFT fires or fires at the oil terminal.

A: No.

Q: Do you have an opinion on what additional resources VFD would need if the proposed oil terminal project is to be constructed?

A: Based on my interviews with Fire Chief Joe Molina, Deputy Fire Chief Doug Kollermer, Division Chief Steve Eldred, and Battalion Fire Chief Ken Griffee, as well as reviewing

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the potential hazards and risks, I believe that the Vancouver Fire Department would need the following improvements to close gaps in order to maintain the operational readiness to respond to a fire at the proposed oil terminal: (a) More personnel on shift to increase staffing; (b) Training in industrial and storage tank firefighting; (c) Backfill (overtime) funding to cover the cost of attending training; (d) development of a Foam Logistics Plan; (e) Improved mobility, transportation, and deployment for the existing foam concentrate stockpile (e.g., foam tank trucks); and (f) Sustained funding for training, backfill, and equipment maintenance.

I declare under penalty of perjury of the laws of the State of Washington that the foregoing is true and correct to the best of my knowledge.

DATED this 7th day of May, 2016 at Port Republic, Maryland.

Michael Hildebrand, CSP, CHMM, CFPS
Hildebrand and Noll Associates, Inc.

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BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 **PREFILED TESTIMONY OF ROBERT CHIPKEVICH FILED BY THE CITY OF VANCOUVER**

Q: Please state your name, place of employment and title, and address.

A: Robert Joseph Chipkevich
Chipkevich Safety Consulting Group, LLC
Principal
9608 Romano Way
Brentwood, Tennessee 37027

Q: Can you briefly describe your work at Chipkevich Safety Consulting Group, LLC and your experience with transportation safety issues?

A: I established Chipkevich Safety Consulting Group, LLC in 2010 to provide transportation safety consulting services, and have partnered with Hall and Associates in Washington, D.C. on numerous transportation safety projects. I have 42 years of experience in transportation safety including 25 years at the National Transportation Safety Board (NTSB).

I headed the NTSB's Hazardous Materials Accident Investigation Program for 20 years, the Pipeline Accident Investigation Program for 15 years, and the Railroad

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Accident Investigation Program for more than 9 years. As the director for accident investigations, I have assessed hundreds of accidents in the United States each year and launched accident investigation teams to the most serious incidents. I have testified before Congress more than a dozen times on transportation safety issues. I have extensive experience investigating tank car failures in railroad accidents, material failures during transit, and cargo transfer incidents.

Q: Have you investigated accidents?

A: Yes. I have led multiple on-scene investigations and was responsible for directing the investigation of many significant accidents including Superior WI, Graniteville SC, Minot ND, New Brighton PA, and Cherry Valley IL. I have worked to improve the crashworthiness and integrity of tank cars including design, material performance and damage tolerance testing. I have significant experience in freight and passenger railroad accident investigations as well as those involving rail transit systems. As director over all railroad accident investigations for a 9-year period, I addressed safety issues in train operations, crew qualifications, track inspection and maintenance, and equipment performance. I have worked to address human factor issues including fatigue management and train crew distractions, and the use of positive train control technology to prevent collisions and over-speed derailments. My work on pipeline safety has included hazardous liquid, natural gas transmission and distribution pipeline systems. I have experience in pipeline safety integrity management; inspection and test programs; material performance; leak detection; pipeline control systems; remote and automatic shut-off valves; and excavation damage prevention.

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Q: What committees have you served on?

A: I have served on numerous transportation safety committees including the Transportation Research Board's Hazardous Materials Committee within the National Academy of Sciences, the Railroad Safety Advisory Committee, the National Association of State Fire Marshals Pipeline Safety Committee, the Dangerous Goods Panel of Experts – VOLPE, and the Association of American Railroads Tank Car Committee. I have worked with leaders in Canada, Europe and Asia on transportation safety issues.

Q: What is your educational background?

A: I am a graduate of the University of Tennessee. I hold a Bachelor of Science degree from the College of Business, with a major in Transportation. I have taken multiple hazardous materials transportation and accident reconstruction courses at the Transportation Safety Institute in Oklahoma City, Oklahoma.

Q: Have you written on the topic of rail accidents?

A: I have provided written testimony and testified before Committees and Subcommittees of the U.S. Congress on rail safety, pipeline safety and hazardous materials safety issues numerous times. I have also provided written testimony before the California State Assembly, the Maryland House of Delegates and the New Mexico House of Representatives.

- Testimony before the Subcommittee on Highway and Transit, Committee on Transportation Infrastructure, U.S. House of Representatives, Hearing on Public Transit Safety: Examining the Federal Role, December 8, 2009.

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- Testimony before the Subcommittee on Highways and Transit, Committee on Transportation Infrastructure, U.S. House of Representatives, Hearing on Public Transit Safety: Examining the Federal Role, December 8, 2009.
- Testimony before the Subcommittee on Railroads, Pipelines and Hazardous Materials, Committee on Transportation and Infrastructure, U.S. House of Representatives, Reauthorization of the Department of Transportation's Hazardous Materials Safety Program, November 16, 2009.
- Testimony before the Subcommittee on Railroads, Pipelines and Hazardous Materials, Committee on Transportation and Infrastructure, U.S. House of Representatives, Human Factors in Rail Accidents, March 16, 2007.
- Testimony before the Subcommittee on Railroads, Committee on Transportation and Infrastructure, U.S. House of Representatives, Human Factors in Rail Safety, July 25, 2006.
- Testimony before the Subcommittee on Railroads, Committee on Transportation and Infrastructure, U.S. House of Representatives, Current Issues on Transportation of Hazardous Materials by Rail, June 13, 2006.
- Testimony before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives, Pipeline Safety: A Progress Report Since the Enactment of The Pipeline Safety Improvement Act of 2002, April 27, 2006.

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- Testimony before the Subcommittee on Highways, Transit and Pipelines, Committee on Transportation and Infrastructure, U.S. House of Representatives, Regarding Pipeline Safety, March 16, 2006.
- Testimony before the Special Committee on Rail Safety, California State Assembly, Rail Safety, July 20, 2005.
- Testimony before the Subcommittee on Railroads, Committee on Transportation and Infrastructure, U.S. House of Representatives, Positive Train Control, April 28, 2005.
- Testimony before the Subcommittee on Highways and Transit, Committee on Transportation and Infrastructure, U.S. House of Representatives, Hearing on Pipeline Safety, June 16, 2004.
- Testimony before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, U.S. House of Representatives, Pipeline Safety, March 19, 2002.
- Testimony before the Subcommittee on Highways and Transit, Committee on Transportation and Infrastructure, U.S. House of Representatives, Pipeline Safety, February 12, 2002.
- Testimony before the Committee on Environmental Matters, Maryland House of Delegates, NTSB Investigation of April 7, 2000 Oil Pipeline Spill near Chalk Point, Maryland, January 11, 2001.

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- Testimony before the Interim Committee on Radioactive and Hazardous Materials, New Mexico House of Representatives, NTSB Investigation of The Pipeline Accident near Carlsbad, New Mexico, September 25, 2000.
- Testimony before Committee on Commerce, Science and Transportation, United States Senate, NTSB Update on the Investigation of the Bellingham, Washington Pipeline Accident, March 13, 2000.

Q: What is your basic understanding of the nature of the proposal, in very summary form?

A: Well, it is my understanding that the proposal involves the transport and handling of 15 million gallons of Bakken crude oil per day or four HHFTs per day. "HHFT" stands for "High-Hazard Flammable Train" and is the term used by the federal government (USDOT-PHMSA) to describe freight trains carrying 20 or more tank cars of crude oil in a block.[1] This is a highly volatile compound which has been involved in a number of catastrophic accidents. The Port of Vancouver has entered into a lease agreement with the applicant to construct handling facilities on its property, located within the City of Vancouver.

Q: What about the proposal context? Have you visited the City?

A: Yes. On October 6 and 7, 2015, Michael Hildebrand, who is a hazardous material emergency planning and response expert, and I conducted site inspections of property along the BNSF rail line within the City of Vancouver. We reviewed overpasses, grade crossings, adjacent exposures and storm drainage. I participated with Mr. Hildebrand in

[1] 49 CFR § 171.8.

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interviews with city planners, engineers, police, fire and emergency management senior leadership.

Q: To assess risks from the proposal, what would you consider as being relevant?

A: Well for one, the "real world" accident experience with transporting large volumes of crude oil and ethanol in tank cars and the consequences from train derailments involving those movements have to be considered.

Q: So, if you are assessing crude oil transport risks with HHFTs, what is the appropriate time frame for assessing risks associated with crude oil transport?

A: The time period in which trains have been used to transport large volumes of crude oil. The use of HHFTs to transport crude oil is a new phenomenon that has only recently reached historic levels. The number of crude oil-containing rail tank cars has increased over 108 times in the last seven years. And, the volume of crude oil carried by rail increased 423% between 2011 and 2012.[2]

Q: Would you include data from the many years of non-HHFT freight train experience?

A: It is critical to focus on accident history and data that has accumulated for trains transporting large volumes of crude oil and ethanol oil in tank cars since 2006 to appropriately understand the risk presented by HHFTs. Looking at "real world" consequences has long been understood as an important factor to understand risk. For example, the NTSB in 1971 issued a Special Study on Risk Concepts in Dangerous Goods Transportation. NTSB noted that it was not until accident experience began to accumulate that the change in risk became evident. The study found:

[2] 80 FR 26644 (May 8, 2015).

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> [D]ealing with regulators on a case by case basis, shippers and carriers promoted new, larger containers which were incorporated into regulations by the ICC, largely on the basis of their technical feasibility as assessed by expert opinion. Again, there was no documented effort to determine the changes in risk levels, with the result that, though they occurred, they went unnoted. It was not until the accident experience began to accumulate, as in the accidents at Laurel, Mississippi, Crete, Nebraska, and Crescent City, Illinois, that these changes in the levels became evident.[3]

The study found:

> Regulatory changes made in response to the desire for economies of scale then allowed the liquefied petroleum gas tank car size to be increased three-fold, and permitted the external insulation to be eliminated. Allegedly, safety valve capacities were increased to compensate for removal of insulation. No operational requirements were adopted to limit the bunching of the jumbo cars into large shipments. Following the regulatory changes, jumbo cars were put into service in great numbers. These cars often moved in multiple-car shipments. The involvement of jumbo cars in accidents has produced accidents of much larger scope as fire, fed by the contents of one of the cars, rapidly heats the contents of the adjacent cars, resulting in pressure increases which the safety valve cannot relieve, and subsequent explosive ruptures and fires of far larger proportions. Losses in such events have greatly increased compared to losses involving the smaller cars, reflecting the increase in risk levels these decisions unknowingly allowed.[4]

A very similar situation has occurred here, with the rapid shift in the risk profile. Since 2006, there have been several train derailments that demonstrate a high failure rate of crude oil and ethanol tank cars in accidents. Below are examples:

- New Brighton, Pennsylvania, 20 of 23 tank cars failed (86.9%);
- Cherry Valley, Illinois, 15 of 19 tank cars failed (78.9%);
- Arcadia, Ohio, 31 of 31 tank cars failed (100%);
- Plevna, Montana, 12 of 17 tank cars failed (70.5%);

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[3] Special Study, Risk Concepts in Dangerous Goods Transportation Regulations, NTSB (1971), p. 7.
[4] *Id.*, pp. 7-8.

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- Aliceville, Alabama, 25 of 26 tank cars failed (96.1%);
- In two separate accidents in Gogama, Ontario, 19 of 29 tank cars failed (65.5%) and 36 of 39 tank cars failed (92.3%);
- Mount Carbon, West Virginia, 20 of 27 tank cars failed (74%); and,
- Casselton, North Dakota, 18 of 20 tank cars failed (90%).

These are all accidents which the NTSB or FRA investigated. For example, the NTSB accident report includes the below photograph of the Casselton accident:

The accumulation of accident data since 2006 for trains transporting crude oil and ethanol is available in both the United States and Canada and this data provides factual information which is necessary to understand the performance of tank cars in multi-tank car train derailments and the consequences thereof. To focus on a longer time frame when these types of cars were not in use dilutes the risk profile and makes it virtually useless for understanding real world impacts.

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Q: Have any agencies responsible for considering these risks utilized such "real-world" data for risk analysis purposes?

A: Yes. The necessity of using current data is a general truism of course for all technical and scientific analysis, but is particularly important for this specific situation. In this situation, I agreed with the approach taken by The Pipeline and Hazardous Material Safety Administration or PHMSA. PHMSA is an agency within the USDOT that is responsible for establishing and enforcing requirements for the safe transport of hazardous materials by all modes of transportation. This includes the design of railroad tank cars carrying crude oil. In conducting its analysis of the risk of spills from HHFTs, PHMSA chose to focus on derailments from 2006 through 2013. Its rationale was that it is this period which "encompasses the beginning of the shipment of flammable liquids in HHFTs."[5] For the final regulatory impact analysis, PHMSA narrowed the focus to 2009 to 2013 to correspond to a time when a high volume of crude and ethanol was being shipped by rail.[6] To accurately identify the risks associated with HHFTs, this more recent time period beginning in 2006 needs to be utilized, not decades of old data with train make up different than the HHFTs in service today. To use 39 years of train experience, dating back to 1975 when large blocks of tank cars filled with crude oil were not grouped in trains in numbers and tank car size like they are today, and using all variety of freight trains to characterize the HHFT experience, creates a fundamentally flawed risk picture.

[5] USDOT-PHMSA Draft Regulatory Impact Analysis PHMSA-2012-0082, p. 25.
[6] USDOT-PHMSA Final Regulatory Impact Analysis PHMSA-2012-0082, p. 78.

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Q: I understand that PHMSA is using current data, but how is going back to 1975 or comparing all sorts of train loads problematic? In other words, why can't any other shipments of flammable liquids be a proxy for an oil train?

A: Well, the below is PHMSA and FRA's reasoning:

> In general, PHMSA and FRA found that several factors associated with oil trains have given rise to both higher expected damages and probability of a catastrophic event. First, the volumes of crude oil and ethanol carried by rail are relatively large when compared to rail shipments of other flammable liquids. In particular, the volume of crude oil shipped by rail has been increasing rapidly during the past several years. Second, the crude oil originating in the Bakken oil fields is volatile which increases the risks while it is in transportation. Finally, crude oil and ethanol are shipped in HHFTs, compounding the risk when an accident does occur.
>
> Due to these changes, PHMSA and FRA have concluded that the historical train accident record alone cannot determine the probability of a catastrophic event.[7]

Q: Do you agree with that rationale?

A: Yes. PHMSA further explained the reasons why all varieties of freight trains cannot be used as a "proxy" for HHFTs in calculating the risk of derailment and catastrophic events. PHMSA determined:

> There is reason to believe that derailments of HHFTs will continue to involve more cars than derailments of other types of trains. There are many unique features to the operation of unit trains to differentiate their risk. The trains are longer, heavier in total, more challenging to control, and can produce considerably higher buff and draft forces which affect train stability. In addition, these trains can be more challenging to slow down or stop, can be more prone to derailments when put in emergency braking, and the loaded tank cars are stiffer and do not react well to track warp which when combined with high buff/draft forces can increase the risk of derailments.[8]

[7] USDOT-PHMSA Draft Regulatory Impact Analysis PHMSA-2012-0082, p. 20.
[8] USDOT-PHMSA Draft Regulatory Impact Analysis PHMSA-2012-0082, p. 24.

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Q: Do you agree with this assessment?

A: Yes.

Q: So, is the data there? Is there an accident history for crude oil train derailments?

A: Yes. I examined several train accidents that occurred over nine years between October 2006 and September 2015 in which multiple tank cars of crude oil or ethanol derailed and cargo was released. In 20 of the 24 derailments at least three tank cars released product, and in three of the 24 derailments at least 28 tank cars released cargo.

Q: Can you detail each incident?

A: Yes. The below table provides "real world" data on these accidents.

Table 1 - Crude Oil and Ethanol Train Derailments

	Location	Date	Railroad	tc derailed	tc release	Fire	Product	Speed	Released gallons
1	Bon Homme County, SD	9/19/2015	BNSF	7	3	Y	Ethanol	10	49,748
2	Heimdal, ND	5/6/2015	BNSF	6	5	Y	Crude oil	24	98,090
3	Gogama, Ontario	3/7/2015	CN	39	36	Y	Crude oil	43	500,000
4	Galena, IL	3/5/2015	BNSF	21	10	Y	Crude oil	23	110,543
5	Mount Carbon, WV	2/16/2015	CSX	27	20	Y	Crude oil	33	378,034
6	Gogama, Ontario	2/14/2015	CN	29	19	Y	Crude oil	38	264,172
7	LaSalle, CO	5/9/2014	UP	6	1	N	Crude oil	9	7,932
8	Lynchburg, VA	4/30/2014	CSX	17	1	Y	Crude oil	23	29,416
9	Vandergrift, PA	2/13/2014	NS	21	4	N	Crude oil	31	4,310
10	New Augusta, MS	1/31/2014	IC/CN	15	7	N	Crude oil	47	50,450
11	Plaster Rock, NB	1/7/2014	CN	6	2	Y	Crude/ethanol	47	60,759
12	Casselton, ND	12/30/2013	BNSF	20	18	Y	Crude oil	42	436,437
13	Aliceville, AL	11/8/2013	AGC	26	25	Y	Crude oil	39	630,000
14	Lac Megantic, Quebec	7/6/2013	MMA	63	59	Y	Crude oil	65	1,580,000
15	White River, Ontario	4/3/2013	CP	7	2	Y	Crude oil	35	26,600
16	Parkers Prairie, MN	3/27/2013	CP	14	3	N	Crude oil	40	30,000
17	Plevna, MT	8/5/2012	BNSF	17	12	Y	Ethanol	23	245,336
18	Columbus, OH	7/11/2012	NS	3	3	Y	Ethanol	25	54,748
19	Tiskilwa, IL	10/7/2011	IIRR	10	9	Y	Ethanol	37	162,000
20	Arcadia, OH	2/6/2011	NS	31	31	Y	Ethanol	46	834,840
21	Cherry Valley, IL	6/19/2011	CN	19	15	Y	Ethanol	36	323,963
22	Luther, OK	8/22/2008	BNSF	8	5	Y	Crude oil	19	80,746
23	Painesville, OH	10/10/2007	CSX	7	4	Y	Ethanol	48	55,200
24	New Brighton, PA	10/20/2006	NS	23	20	Y	Ethanol	37	485,278
	Totals			442	314				6,498,602

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Q: Where is this data pulled from?

A: I reviewed accident reports and records from the National Transportation Safety Board, the Transportation Safety Board of Canada, and the Federal Railroad Administration. I also reviewed hazardous materials incident reports from the Pipeline and Hazardous Materials Safety Administration.

Q: Can you tell me about the average number of tank cars which derail in these accidents?

A: Yes. Based on the 24 derailments that I reviewed, 442 tank cars derailed and 314 tank cars released cargo (71%). The average number of cars derailed in the 24 accidents is 18.4 and the average number of cars that breached is 13.

Q: What are the spill sizes, when averaged?

A: A total of 6,498,602 gallons of product were released in the 24 accidents. The average release per accident is 270,775 gallons, the equivalent of about 30 gasoline cargo tank trucks; 10 of the 24 accidents had releases of 245,336 gallons or greater, the equivalent of 27 gasoline cargo tank trucks.

Q: When trains derail, how many spill their cargo?

A: I have not attempted to do a statistical analysis on the probability of a train derailment or the frequency of a cargo release when a train does derail. I instead have looked at what has actually happened. I reviewed the consequences of several derailments that have in fact occurred, and those accidents demonstrate that the consequences of a derailment can and have been significant. A high percentage of tank cars that derailed have breached.

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Of the 442 tank cars that derailed in the accidents that I reviewed, 314 released cargo. In one accident 31 tank cars derailed and all 31 tank cars were breached.

Q: Can you describe some of the more significant spills?

A: Well, since 2011, the following significant spills have occurred:

- Lac-Megantic-59 tank cars breached and 1,580,000 gallons of crude oil were released;
- Arcadia-31 tank cars breached and 834,840 gallons of ethanol were released;
- Aliceville-25 tank cars breached and 630,000 gallons of crude oil were released;
- Gogama-36 tank cars breached and more than 500,000 gallons of crude oil were released; and,
- New Brighton-20 tank cars breached and 485,278 gallons of ethanol were released.

Q: How has PHMSA defined a "higher consequence event?"

A: PHMSA used a spill volume of 37,619 bbl/1,579,998 gals. as its "higher consequence event."[9] This is the equivalent of a Lac-Megantic style disaster.

Q: To put this in concrete terms, how many gasoline tank trucks is 1.6 million gallons equivalent to?

A: A full size gasoline cargo tank is approximately 9,000 gallons, so this would be the equivalent of about 178 gasoline cargo tank trucks.

Q: So, when we are talking about a "higher consequence" event, size-wise that is equivalent to 178 gasoline tank trucks breaching?

[9] USDOT-PHMSA Draft Regulatory Impact Analysis, PHMSA-20012-0082, p. 51.

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A: Yes, under PHMSA's explanation of the use of a spill volume for a "higher consequence event."

Q: What about total derailments and releases?

A: The PHMSA, for the time period between 2006 and 2013, identified 40 mainline derailments that resulted in the release of 3,344,081 gallons of crude oil and ethanol for an average of approximately 1,990 bbl/83,602 gals. released per mainline track derailment.

Q: Again, for 83,602 gallons, how many gasoline tank trucks would that be equivalent to?

A: That would be the equivalent of 9 gasoline cargo tank trucks released on average per mainline derailment.

Q: Is it possible that PHMSA's average release figures are low?

A: Yes. The PHMSA acknowledged that its own data may underreport spills.

> The PHMSA hazardous material incident report database often contains inaccuracies. The database presents information on releases of hazardous material in transportation and relies on the person in possession of the hazardous material at the time of the incident to report on the incident. Often the amount of product released from a particular tank car is unclear or reported differently in the description of events than in the appropriate incident report fields.
>
> Additionally, the PHMSA incident reports often do not reflect the full extent of damages including property damage, cleanup and remediation costs because it may be months before full damage figures can be reported. By regulation the filer has a maximum of thirty days from the time of the incident to file a report... When we compared the incident report information from the PHMSA hazardous material incident report database with data obtained through more thorough investigations, we discovered that the quantity of product lost and number of cars releasing product were misreported in a number of cases.[10]

[10] USDOT-PHMSA Draft Regulatory Impact Analysis PHMSA-2012-0082, p. 26.

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Q: Do you agree with this assessment?

A: Yes. These issues are ongoing for the industry.

Q: What about train speeds? Are they a factor in accidents?

A: The speed at which a train is operating is a significant factor in the consequences of a derailment. PHMSA, in its rulemaking to improve the crashworthiness of tank cars transporting crude oil, considered the relationship of train speed to tank car damage and mandated train speed restrictions and improved train braking requirements. PHMSA noted that the laws of physics predict that a faster moving train at the time of a collision or derailment would result in greater damage to tank cars, and mandated speed restrictions for crude oil trains transporting DOT-111 tank cars. However, many of the catastrophic crude oil and ethanol train accidents between 2006 and 2015 were operating at speeds below maximum speeds established by PHMSA in the recent rulemaking; in fact, 17 of 24 serious accidents that I reviewed happened at speeds of 40 mph or less and 8 of those accidents occurred at speeds of 25 mph or less.

Yet, PHMSA's final rule will allow crude oil trains to travel at 50 mph, with speed reduced to 40 mph in high-threat urban areas and the Federal Railroad Administration Emergency Order 30 restricts these trains to only 40 mph in certain highly populated areas.

The following accidents illustrate that train derailments at speeds below those limits established in the PHMSA final rule have resulted in significant tank car damage and significant cargo releases:

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- 46 mph derailment: Arcadia, OH – February 6, 2011 – 31 tank cars derailed and 31 tank cars failed - 834,840 gallons of ethanol were released (the equivalent of 93 gasoline cargo tank trucks);
- 43 mph derailment: Gogama, Ontario – March 7, 2015 - 39 tank cars derailed and 36 tank cars failed - more than 500,000 gallons of crude oil were released (the equivalent of 56 gasoline cargo tank trunks);
- 42 mph derailment: Casselton, ND – December 30, 2013 – 20 tank cars derailed and 18 tank cars failed - 436,437 gallons of crude oil were released (the equivalent of 48 gasoline cargo tank trucks);
- 39 mph derailment: Aliceville, AL – November 8, 2013 – 26 tank cars derailed and 25 tank cars failed - 630,000 gallons of crude oil were released (the equivalent of 70 gasoline cargo tank trucks);
- 37 mph derailment: New Brighton, PA – October 20, 2006 – 23 tank cars derailed and 20 tank cars failed - 485,278 gallons of ethanol were released (the equivalent of 54 gasoline cargo tank trucks);
- 36 mph derailment: Cherry Valley, IL – June 19, 2011 – 19 tank cars derailed and 15 tank cars failed - 323,963 gallons of ethanol were released (the equivalent of 36 gasoline cargo tank trucks);
- 33 mph derailment: Mount Carbon, WV – February 16, 2015 – 27 tank cars derailed and 20 tank cars failed - 378,034 gallons of crude oil were released (the equivalent of 42 gasoline cargo tank trucks);

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- 23 mph derailment: Plevna, MT – August 5, 2012 – 17 tank cars derailed and 12 tank cars failed - 245,336 gallons of ethanol released (the equivalent of 27 gasoline cargo tank trucks);
- 19 mph derailment: Luther, OK – August 22, 2008 – 8 tank cars derailed and 5 tank cars failed - 80,746 gallons of crude oil released (the equivalent of 9 gasoline cargo tank trucks); and
- 10 mph derailment: Bon Homme County, SD – September 19, 2015 - 7 tank cars derailed and 3 tank cars failed - 49,748 gallons of ethanol released (the equivalent of 6 gasoline cargo tank trucks).

Q: Tell me about the fires which have occurred in these "real world" accidents.

A: A fire occurred in 20 of the 24 train derailments that I reviewed for the period between October 2006 and September 2015, which is a rate of 83.3%. This is a particular concern given the nature of the product being handled with this proposal.

> The properties of Bakken shale oil are highly variable, even within the same oil field. In general, however, Bakken crude oil is much more volatile than other types of crude. Its higher volatility may have important safety implications.[11]

The highly flammable nature of the product emphasizes the need to honestly assess the likelihood of fire and explosion should an accident occur.

[11] U.S. Rail Transportation of Crude Oil: Background and Issues for Congress (December 4, 2014), p. 14.

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Q: What about track conditions? Are they also a factor in accidents?

A: Yes. Broken rails, irregular alignment (including buckled rails/sun kinks), wide gage (including missing or defective ties and fasteners, and missing or defective spikes), vertical split heads, broken joint bars, roadbed settled or soft, and worn or broken switch points are all track, roadbed and structure conditions that can cause a train derailment.

Q: What can you tell me about track conditions?

A: FRA data for Class 1 railroads (excluding AMTRAK) identifies 2,522 train derailments on main track for the period 2008 through 2015. This FRA data identifies 780 of those derailments as occurring on the BNSF. The FRA train derailment data identifies broken rails attributed to detail fractures (from shelling or head check), irregular track alignment (buckled/sun kink) and wide gage (including defective or missing cross ties, spikes or other fasteners) as some of the leading causes of derailments assigned to track, roadbed and structure related causes.

The failure to find defects in rail because of shelling or checks has been identified by the NTSB in several accidents. Poor rail surface condition can cause ultrasonic testing to miss internal detail fractures that can grow under train loads and fail once they reach critical size. As real world tank car accident experience provides factual information to help understand the safety performance of tank cars in accidents, the investigation of train derailments provides factual information to help understand the effectiveness of track inspection, testing and maintenance programs.

After a train derailment in Superior, Wisconsin in 1992 that resulted in the evacuation of 40,000 people as a result of a hazardous materials release from a damaged

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tank car, NTSB determined that the probable cause of the derailment was the failure of the rail from an undetected preexisting detail fracture that had initiated from shelling and had reached critical size. NTSB concluded that current ultrasonic and induction inspection methods used to detect internal defects are inadequate when rail has severe shelling or other surface conditions.

NTSB investigated the train accident in New Brighton, Pennsylvania in 2006 that resulted in the derailment of 23 tank cars, the failure of 20 tank cars and the release of 485,278 gallons of ethanol. NTSB had concluded that a detail fracture (fatigue crack) that originated from shelling on the rail head, reached critical size, and caused a piece of rail to break out under the train. NTSB concluded that rail surface conditions prevented the effective transmission of the ultrasonic signals, and the defect (fatigue crack) that led to the derailment may not have been large enough at the time to be reliably detected by the inspection vehicle.

NTSB investigated a train accident in Ellicott City, Maryland in 2012 that had derailed multiple coal cars killing two young women. Investigators reviewed the ultrasonic internal rail test data conducted on the rails for the three most recent tests. The last test before the derailment on August 20 was conducted on August 3. No defective rails were marked near the derailment area. The NTSB report states that the rail carrier was aware of the history of rail defects on the line and an increase in tonnage due to heavy coal traffic and that the railroad operator's consultants recommended that they test the track every 30 days; the railroad operator adopted the policy. NTSB found at the point of derailment, the rail fractured due to a detail fracture that initiated from head checks in

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the gage corner of the rail head and determined that the probable cause of the accident was a broken rail with evidence of rolling contact fatigue.

NTSB investigated the train accident in Lynchburg, Virginia on April 30, 2014 that had derailed 17 tank cars of crude oil. One car was breached and released 29,868 gallons of crude oil, which caught fire. The NTSB report illustrates the fire by photograph:

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The train was traveling 24 mph at the time of derailment. The NTSB report states that the derailment occurred at a sudden break of a rail originating from a reverse detail fracture on the gage corner of the rail head of the high rail in the curve. The report states that a railroad contractor performed ultrasonic testing in the area of the derailment the day before the accident. Investigators reviewed the ultrasonic test data for the failure location and the report states that the data confirm that the test equipment functioned properly and responded to known rail features that would normally be detected by ultrasonic test probes within the failed rail.

> The suspected rail defect that failed at the point of derailment was a 5 percent reverse detail fracture. Historically, regulations have not considered 5 percent reverse detail fractures to be a defect subject to complete failure prior to progressing to a larger size. These types of defects cause a stress concentration on the surface of the rail and may cause a complete rail failure at a much smaller size than typical detail fractures.[12]

NTSB determined that the probable cause of the accident was a broken rail caused by a reverse detail fracture with evidence of rolling contact fatigue.

Q: So, in lay terms, track conditions are a factor in accidents and even when inspections are occurring, defects are missed?

A: Correct.

Q: What are track conditions like within the City of Vancouver?

A: On October 6 and 7, 2015, Michael Hildebrand and I reviewed approximately 25 public and private overpasses and highway at-grade crossings, adjacent exposures and drainage along the BNSF Fallbridge Subdivision's main line track within the City of Vancouver.

[12] NTSB Railroad Accident Brief, Lynchburg, Virginia derailment, p. 9.

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Most of the grade crossings were identified as private crossings and had no active crossing protection devices. While the threat of a train and highway vehicle collision at a grade crossing increases the risk of a train derailment, the lack of active warning devices at the crossing enhances that risk. While conducting a review at one grade crossing location (X-ing 090074M), we observed from the crossing that some crossties in the track had splits and showed signs of deterioration that allowed spikes to lift upward from the ties, suggesting further review of the route is warranted.[13] Photographs we took that day documenting this deterioration are at Attachment 1.

Q: What do we know about the type of tank cars which will be used for the proposal?

A: First, some background. Given the recent history of tank car accidents, tank standards have been under ongoing revision. The DOT-111 is a specification non-pressurized rail tank car, which carries a wide range of hazardous and non-hazardous materials. The DOT-111 tank car has been manufactured for many decades and is continuing to be manufactured today. The CPC-1232 is a DOT-111 tank car that has enhanced features, including head shields constructed of ½ inch thick steel to protect the bottom half of tank heads during derailments and some are equipped with insulation and jackets. This tank car enhancement was initiated by industry in 2011 to help address crude oil and ethanol accident issues. (CPC stands for Casualty Prevention Circular, which was issued by the Association of American Railroads.)

On May 8, 2015, PHMSA issued a final rule, Hazardous Materials Enhanced Tank Car Standards and Operation Controls for HHFTs, which established standards for

[13] Federal Track Safety Standards for track structure, including crossties, are located in Title 49 Code of Federal Regulations Part 213.

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the construction of new tank cars built to transport crude oil and ethanol in HHFTs. The DOT-117 includes enhanced features such as thicker tank walls and heads (9/16 inches), full head shield protection minimum ½ inch thick steel, a thermal protection system including reclosing pressure relief valves, steel jackets, and improved protection for top fittings and bottom outlets. The final rule adopts a risk-based timeline for the retrofit of existing DOT-111 and CPC-1232 tank cars that will continue in HHFTs. Retrofitted tank cars will be designated DOT-117R, and those cars are not required to meet all of the new requirements for DOT-117 tank cars. The rule allows the DOT-117R tank car heads and walls to be 7/16 inch thick instead of 9/16 inch thick as required for new DOT-117 tank cars.

However, Public Law 114-94, Fixing America's Surface Transportation Act, or FAST, was enacted on December 4, 2015 with some modifications to the new requirements in PHMSA's May 8, 2015 final rule. Subtitle C of the Act – Safe Transportation of Flammable Liquids by Rail – requires that "Certain tank cars not meeting DOT-117, DOT-117P, or DOT-117R specifications on the date of enactment of this Act may be used, regardless of train composition, until the following end dates: (1) For transport of unrefined petroleum products in Class 3 flammable service, including crude oil – (A) January 1, 2018, for non-jacketed DOT-111 tank cars; (B) March 1, 2018, for jacketed DOT-111 tank cars; (C) April 1, 2020, for non-jacketed CPC-1232 tank cars; and (D) May 1, 2025 for jacketed CPC-1232 tank cars." The timeline for transport of ethanol is extended until 2023 and other flammable liquids to 2029. The Act allows the Secretary of Transportation to extend deadlines for ethanol and other flammable liquids if

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the Secretary determines that insufficient retrofitting shop capacity will prevent the phase-out of tank cars not meeting the DOT-117, DOT-117P, or DOT-117R specifications by the deadlines. The DOT-117P tank car will have to be constructed to meet performance based standards and approved, but has not been built to date.

Q: Are the newer tank cars available for those who wish to buy them?

A: The final USDOT rule identifying the DOT-117 as the standard for HHFTs was only recently adopted on May 8, 2015. There are some DOT-117 tank cars in service now. We do not know when a sufficient supply of these tank cars will be available to fulfill the requirement that only those cars be used to transport crude oil to the facility. According to manufacturer National Steel Car N.A. Inc., as of the second quarter 2015, application of the new DOT-117 standard could take longer than scheduled, as there was a backlog of 46,375 orders for new tank cars.

Q: Will that be a problem for timely implementation of the Rule?

A: That is a real possibility, yes.

Q: What can you tell us about the performance of tank cars used to transport crude oil by rail?

A: There is accident history available about the performance of DOT-111 tank cars and CPC-1232 tank cars in HHFT derailments. That history has shown that DOT-111 and CPC-1232 tank cars have poor crashworthiness records. Tank car breaches have resulted from head and sidewall punctures and tears, damaged valves and fittings, and thermal rupture tears after being exposed to large fires. The CPC-1232 tank car has failed on multiple occasions in 2015 - in Gogama, Ontario, in Galena, Montana, and in Mount

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Carbon, West Virginia. In the Mount Carbon, West Virginia accident on February 16, 2015, 27 CPC-1232 tank cars derailed, 20 of those tank cars failed and released 378,034 gallons of crude oil (the equivalent of 42 gasoline cargo tank trucks).

Below is an accident photo from the NTSB Tank Car Performance Factual Report for the Mount Carbon accident.

In a New Brighton, Pennsylvania train derailment on October 20, 2006, 20 of 23 DOT-111 tank cars failed and released 485,278 gallons of ethanol (the equivalent of 54 gasoline cargo tank trucks).

Q: What about DOT-117 cars? If only those are used, how does this impact the risk assessment?

A: The PHMSA estimates that the DOT-117 will only provide a 21% risk reduction over the unjacketed CPC-1232 and only a 10% risk reduction over the jacketed CPC-1232.[14] So,

[14] 47 Draft Regulatory Impact Analysis PHMSA-2012-0082, p. 120.

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there is an improvement, but risks remain present, even if the new requirements can be fully implemented.

Q: The applicant appears to believe - based on the 2016 "Barkan Report,"[15] that the risk of a 92,000 gallon (ten cargo tank trucks) spill in a non-jacketed DOT-111 is once every 13 years, once every 33 years in a jacketed DOT-111, once every 25 years in a non-jacketed CPC-1232, once every 57 years in a jacketed CPC-1232, and once every 110 years in a jacketed DOT-117. They also believe a "worst case discharge" of 840,000 gallons (93 cargo tank trucks) would occur just once in 20,176 years. Is this statistical analysis consistent with what is going on in the real world?

A: No. My review of data found 13 accidents involving DOT-111 and CPC-1232 tank cars releasing more than 92,000 gallons of cargo in the 9 year period of October 20, 2006 to September 19, 2015. Cargo release in these 13 accidents totaled 5,950,603 gallons of cargo, an average of 457,738 gallons per accident. If the Lac Megantic accident is not considered, the remaining 12 accidents had a total release of 4,370,603 gallons of cargo, an average of 364,216 gallons of product per accident. Four of these accidents involved CPC-1232 tank cars: two accidents in Gogama, Ontario and one accident each in Mount Carbon, West Virginia and Galena, Illinois.

Q: Ok. So, significant events are happening, regardless of the tank car.

A: Yes.

Q: What do these events look like on the ground?

[15] Petroleum Crude Oil Unit Train Transportation Risk Analysis: Vancouver Energy Project, by Christopher P.L. Barkan, M. Rapik Saat, and Manuel Martin Ramos (January 21, 2016).

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A: The NTSB accident reports document these accidents by photograph. Excerpts have been incorporated into this testimony above. Based on my own review of accident scenarios, those are reasonable depictions of those types of accidents.

Q: The applicant has stated that these risks are really no different than driving a car or flying in an airplane, and the public generally accepts those risks. Is that a true statement?

A: Well, how much risk the public wishes to tolerate is not my decision. However, what I can say is that I assessed risk associated with HHFTs based on their actual accident history.

An HHFT is distinct from automobiles or planes. An HHFT, unlike a plane or car, is not truly a single unit. It is composed of many linked units, each containing volatile cargo. That linkage changes the risk profile.

Consider the following. A single rail tank car used to transport crude can hold 30,000 gallons. A single HHFT, with its 20 car minimum, would thus carry at least 600,000 gallons, or the equivalent of 67 gasoline cargo tank trucks. That's a minimum, not a maximum. Crude oil trains may transport 100 or more tank cars filled with crude oil (more than 3,000,000 gallons per train) and it is proposed that four trains daily would travel through the City of Vancouver.

Derailments are occurring and tank cars are breaching. Of course, not every derailment is catastrophic, but given the consequences of significant events, risk management agencies should plan accordingly.

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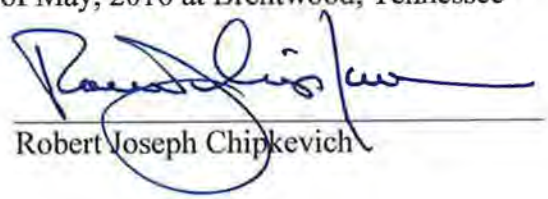
I declare under penalty of perjury of the laws of the State of Washington that the foregoing is true and correct to the best of my knowledge.

DATED this 9th day of May, 2016 at Brentwood, Tennessee



Robert Joseph Chipkevich

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BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	CASE NO. 15-001 **PREFILED TESTIMONY OF ROBERT J. BLACKBURN FILED BY THE CITY OF VANCOUVER**

Q: Please state your name, place of employment and title, and address.

A: Robert J. Blackburn, CPCU, Managing Principal
Blackburn Group, Inc.
1173 Pittsford Victor Road, Ste. 250
Pittsford, New York, 14534

Q: What does Blackburn Group do?

A: I founded Blackburn Group, Inc. in 1991 as a company specializing in marketing products and services for the risk, insurance, and claim management fields.

The company provides enterprise risk management and claim settlement solutions. We assist companies in identifying risks and insuring against those risks. The company maintains and manages over 8,100,000 claims valued at over $550 billion in our proprietary databases.

Q: What types of businesses have you worked with?

A: Energy production and distribution, manufacturing, retail, real estate, construction, etc.

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1 Q: Can you briefly describe your work at Blackburn Group, Inc.?

2 A: Enterprise risk management, claim management and settlement solutions.

3 Q: What other positions have you held?

4 A: Prior to founding Blackburn Group, Inc., I established and managed a risk management
5 and retention company for Jamesport Associates. As Vice President and Chief Operating
6 Officer, I developed and managed the strategies for the combined company assets of over
7 $2.5 billion and $500 million in annual sales in the aviation and real estate industries. I
8 have also held senior management positions at Home Properties, Inc., Deloitte and
9 Touche, LLP, Wilmorite, Inc., Citibank, N.A., Page Avjet Corporation, and Harris
10 Corporation. Additionally, I have served as an advisor and consultant to FM Global
11 Insurance Company and other insurance companies.

12 Q: What is your educational background?

13 A: I graduated from St. John Fisher College in Pittsford, NY in 1978 with a BS in
14 Management, Finance, and Economics, and have completed graduate studies at the
15 University of Rochester Simon Business School. I have served as a risk management
16 guest lecturer at both institutions and as a guest speaker at numerous risk and claim
17 management industry events. I am a Chartered Property Casualty Underwriter, Certified
18 Adjuster, Property and Casualty Insurance Broker (NY Resident License; reciprocal
19 ability in all 50 states); Independent General Adjuster (NY Resident License; reciprocal
20 ability in all 50 states); Life and Health Insurance Broker (NY Resident License;
21 reciprocal ability in all 50 states).

22 Q: What organizations are you a member of related to insurance/risk management?

23

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- Association for Cooperative Operations Research and Development (ACORD), Member, 1985-2001.
- Chartered Property and Casualty Underwriters (CPCU) Society Member, 2011-present.
- Diocese of Rochester, NY, Stewardship Council and Risk Management Committee Chairperson, 2010 - present.
- Hillside Children's Center, Insurance Committee Member, 1992-2004.
- Institute of Management Accountants, Member, 1980-2001.
- Insurance Accounting and Systems Association, Member, 1991-2001.
- New York Self Insurers Association, Member, 2012 - present.
- New York State Center for Advanced Technology in Electronic Imaging Systems, Member, 1996-2001.
- Risk and Insurance Management Society, Member, 1996-2010.
- Risk and Insurance Management Society, Society Director and Officer, 1988-1996.

Q: Have you written on the topic of insurance?

A: Yes. Papers and reports have included:

- Claim and Litigation Management Processes, January 1995.
- Enterprise Risk Management Development, February 1995.
- The Risk Management Program Development Methodology, April 1996.
- The Benefits of Establishing a Captive Insurer or Other Alternative Risk Finance Vehicles, June 1996.
- The Limitations of the Traditional Approach to Risk and Insurance Management, May 1997.
- The Benefits of N-tier Applications in Managing Risk, February 1998.
- The Need for Reduced Risk Costs and Improved Quality, July 1998.

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- The RiskPro Manual for the Enterprise, February 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007.
- Management of Risks for the New Millennium, January 2000.
- The New Insurance Distribution Model, June 2001.
- Global Risk in Today's Business Environment, July 2001.
- The Risk Management Network - Straight through Processing for an Interconnected World, July 2001.
- Biometrics – How they are Changing the World of Operational Risk Management, October 2001.
- September 11th has Changed Everything in the World of Risk Management, November 2001.
- Security Risks – How Organizations are Responding to New Vulnerabilities, November 2001.
- Risk Management for Real Estate and Retail Businesses, December 2001.
- Confronting the Risks – The New Utility Organization, January 2002, September 2003.
- The Risk Report, Home Properties, 2002-2008.
- Six Key Risk Management Strategies for 2009, Various National Newsletters, January 2009.
- The RiskPro Monthly Newsletter, January 2009 to present.
- Various Articles and Presentations for Enterprise Risk Management and Claim Settlement Solutions, January 2010 to present.

Q: What is a Maximum Foreseeable Loss (MFL) estimate?

A: An MFL or Maximum Foreseeable Loss is an estimate of a worst case operational risk scenario. In other words, the financial risk or total dollar amount associated with a worst case incident. An MFL is not limited to one type of cost, but includes costs associated

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with loss of life, injury to persons, destruction of property, loss of use of property, first responder costs, and cleanup expenses.

Q: Did the City of Vancouver ask you to consider: (1) the financial risks; and (2) whether insurance or other financial assurances are available to address those risks, associated with a proposal to transport and handle Bakken crude oil and diluted bitumen, within the City of Vancouver, WA?

A: Yes.

Q: In assessing risk levels, what types of considerations are useful?

A: Well, first the commodity itself. I am not a petrochemical engineer. However, I look at what is being handled and whether catastrophic accidents have occurred elsewhere for similar risk profiles. For purposes of estimating a maximum foreseeable loss, or MFL, the analyst attempts to measure the worst loss that is likely to occur because of a single event. In this case, I was told that the proposal involved the transport and handling of 15 million gallons of Bakken crude oil and diluted bitumen per day or four HHFTs per day. I have been told that "HHFT" stands for "High-Hazard Flammable Train" and is the term used by the federal government (USDOT-PHMSA) to describe freight trains carrying 20 or more tank cars of crude oil in a block.[1] This is a highly volatile compound which has been involved in a number of catastrophic accidents. Another consideration is where the commodity is located. In this instance, the proposal is within the City of Vancouver, which has a population base of about 170,000, making it the fourth largest city in Washington. Another factor is the presence of environmentally sensitive features. That

[1] 49 CFR § 171.8.

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informs estimates of environmental clean-up and infrastructure replacement costs. Here, it is my understanding that the proposal is located proximate to the Columbia River.

Q: What do you believe is a reasonable MFL to remedy damages flowing from a catastrophic accident?

A: It is reasonable to estimate an expected MFL for a catastrophic accident in the region at approximately $5-6 billion. That is a rough figure.

Q: What is the basis for a $5-6 billion rough estimate?

A: This estimate is derived from considering costs associated with other major accidents and insurance reports. As an example, the Lac Megantic incident, involving a small town of roughly 6,000 in Quebec Province, Canada, was a catastrophic accident. It occurred in 2013, killed 47 people, and destroyed the downtown. Damage estimates are now at about $3 billion according to recent media reports. Compensation has been a major issue with that incident. The short-line railroad hauling the crude oil filed for bankruptcy because it didn't have enough insurance to pay the claims.

That the total risk values are into the billions is not surprising. BNSF has been up front that even available railroad liability insurance (apart from the applicant) tops out at "about $1.0 Billion" and "[i]nsurance is not commercially available to sufficiently protect us against catastrophic loss."[2] In a U.S. Dept. of Transportation Report, titled "The Transportation of Hazardous Materials: Insurance, Security, and Safety Costs" (December 2009), this level of insurance was documented as:

[2] Attached is a true and correct copy of excerpts from a BNSF Power Point (Attachment 1).

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> well short of the $5-$6 billion that Class I railroads estimate would be necessary in a 'nightmare scenario,' e.g., an accidental release of TIH gas in close proximity to a large number of people. Once their primary insurance has been exhausted, carriers would be held liable for the balance, forcing even the largest railroad into bankruptcy.[3]

The City of Vancouver, with its considerably larger population, has higher risks for loss of human life and physical injury, along with considerably higher infrastructure values.

Q: Are you aware of other high profile rail accidents involving the release of flammable materials?

A: Of course. The City has retained experts to address those incidents, but they have garnered considerable media attention. True and correct copies of photos of such incidents pulled from media coverage are at Attachment 3.

Q: Could the MFL be calculated with greater precision?

A: Yes. The $5-6 billion figure is, as I have mentioned, a rough estimate. To have greater certainty requires more data on actual investments made within the area, what it would take to reconstruct those investments, along with calculated blast zones and their locations relative to infrastructure and people. To obtain a more precise number is a fact intensive exercise. Of course, even with those factors, insurance risks cannot be quantified with absolute precision for any single event. The costs of any incident would vary, depending on the severity of the incident, number of lives lost, proximity to areas with environmental sensitivity, etc. So, we have to also look at other events which have in fact happened.

[3] Attached is a true and correct copy of report excerpts (Attachment 2), p. 21.

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Q: Based on what you have reviewed so far, assuming an MFL of $5-6 billion, can the applicant look to the commercial markets to provide that insurance, whether through traditional or non-traditional insurance instruments, to cover that risk?

A: No. There is no market to cover that entire risk at present. Further, based on what I have been provided from the application, Draft EIS excerpts, and lease requirements, the proposed financial security is minimal in terms of covering worst case scenarios. It certainly would not cover an MFL event. The lease with the property owner requires the tenant to have $10 million per occurrence and $15 million aggregate liability insurance, coupled with $25 million in environmental pollution coverage. Very little is documented at this point confirming what the applicant is assuming and would pay over to injured parties, in the event of a catastrophic accident. That analysis has been postponed.

Q: What insurance could the applicant obtain?

A: It would be expected that the applicant could, in theory, purchase insurance of up to $1 billion. Thus, a shortfall of $4-5 billion toward the estimated MFL is anticipated. (Of course, how the injured parties would access the funds which may be available is an entirely separate question.)

Q: So, does the proponent have the capability - from a dollars perspective and through the commercial markets - to fully remedy impacts resulting in injury and casualties, natural resource and property damage, emergency responder resource impacts, and infrastructure damage?

A: No. Given how high the MFL is, those products are not commercially available.

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Q: OK. Let's turn to the application and the types of insurance the applicant states will be provided. Can you read from the application at Section 1.3, Assurances, p. 1-7, subsection 1.3.1 - Commercial General Liability Insurance, last paragraph?

A: Yes. "Tesoro Savage Petroleum Terminal LLC will purchase insurance policies to cover liabilities arising from environmental, casualty, and other major incidents. The insurance industry views facilities such as the Tesoro Savage Vancouver Energy Distribution Terminal as low to moderate risk. Therefore, high coverage limits are available at reasonable cost."

Q: Is that an accurate assessment?

A: Only if one assumes there are caps/exclusions on insurance so there is no MFL pay-out exposure. There are various insurance companies with diverse opinions about current risk taking and transfer. With the above assumption in mind, this statement may be true for certain insurers, but untrue for others. An appropriate way to approach the subject would be to complete applications for insurance to multiple insurers to determine the insurers current underwriting appetite for risk taking and premium quotation.

Q: Ok. What about property insurance? Can you read from Section 1.3, Assurances from the application, subsection 1.3.3 - Property Insurance?

A: "Tesoro Savage Petroleum Terminal LLC will obtain and maintain at all times during the term of construction and operation of the Facility, physical damage insurance on the buildings and improvements that are to be erected on the premises on an "all risk" basis, including coverage against damage or loss caused by earth movement and flood in an amount sufficient to cover any expected loss or damages. Upon completion of project

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design, insurance underwriters will evaluate the design and estimate maximum potential damage due to failure. In some cases, design changes may be implemented to reduce the damages. Insurance would then be purchased to cover the maximum expected damages."

Q: What does that language mean?

A: That statement means that insurers will underwrite the facility considering the potential damages. They would take into consideration loss control and safety factors built into the facility. However, there are no “all risk” policies sold for this type of risk at this time. Commercial property insurance in the United States is written in one of two ways: on a “Named Peril” basis or on a “Special Peril” basis. If the risks are covered by a “Named Peril” policy, it will only cover those perils named in the policy. A typical broad form named peril policy would cover fire, windstorm, hail, aircraft, riot, vandalism, explosion and smoke. When coverage is written on a named peril basis, it is up to the insured to prove that one of the named perils caused the loss. Otherwise, if the risks are covered by a “Special Peril” Policy, then the insurance company must prove that the peril causing the damage is not excluded.

Q: Let's turn to Environmental Impairment Liability Insurance, subsection 1.3.5.1 on p. 1-8. Can you read that section?

A: "Tesoro Savage Petroleum Terminal LLC and its operator(s) will be responsible, as required by law, for acts of environmental impairment related to the ownership and operation of the Tesoro Savage Vancouver Energy Distribution Terminal. Such losses may, in some circumstances, be covered by general liability insurance, which Tesoro Savage Petroleum Terminal LLC and the construction contractor will carry. In addition,

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Tesoro Savage Petroleum Terminal LLC and/or its contracted operator(s) will obtain environmental impairment liability insurance to the extent such coverage is available on a commercially viable basis. This insurance will cover the acts of Tesoro Savage Petroleum Terminal LLC and its operator(s) at the site, consistent with or in excess of then-prevailing industry standards for such insurance in the petroleum transportation industry. Commercial viability will be determined by reference to the norm of the industry."

Q: Are there some caveats here? What does it mean to say that the applicant - a Delaware LLC - will obtain "environmental impairment liability insurance" but only to the extent "such coverage is available on a commercially viable basis?" And, what does it mean to determine such viability "by reference to the norm of the industry?"

A: At the time of commencement of the project, Tesoro and its contractors will complete several applications for environmental impairment and other commercially available liability insurance. They will access the worldwide insurance markets through brokers to obtain the most advantageous terms, conditions, and premiums for transferring risks to insurers during a specified period of time, most likely for one year. Thereafter, they will assemble all quotations to determine what is available to them for all liability risks. Similar facilities with a responsibility to maintain insurance for their operations would have previously gone through the same process and obtained the most advantageous terms, conditions, and premiums. Their industry-experienced brokers will be able to report the state of the insurance market at that time for reasonableness of the terms, conditions, and premiums.

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Q: Is the applicant in effect admitting it cannot obtain insurance against an MFL event?

A: At the current time, yes. Presumably for a similar operation, they may be able to obtain $1 billion of coverage. If the MFL is $5-6 billion, then there will be a $4-5 billion insurance shortfall.

Q: Let's turn to subsection 1.3.5.2, p. 1-8 of the application. Can you read that paragraph starting with "In accordance....?"

A: "In accordance with RCW 88.40.025, the Applicant will demonstrate financial responsibility in an amount determined by the Washington State Energy Facility Site Evaluation Council (EFSEC) as necessary to compensate the state and affected local governments for damages that might occur during a reasonable worst-case spill of oil from the Facility into the navigable waters of the state. The amount of financial responsibility will consider such matters as the amount of oil that could be spilled into the navigable waters from the Facility, the cost of cleaning up the spilled oil, the frequency of operations at the Facility, the damages that could result from the spill, and the commercial availability and affordability of financial responsibility. In accordance with RCW 88.40.030, the financial responsibility required may be established by any one of, or a combination of, the following methods acceptable to EFSEC: (1) evidence of insurance; (2) surety bonds; (3) qualification as a self-insurer; or (4) other evidence of financial responsibility."

Q: So, what are we looking at here as a dollar amount for clean up and is there an insurance market to cover that?

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A: It would appear at this time that perhaps Tesoro could obtain $1 billion of insurance. Otherwise, surety bonds, self-insurance, or other financial responsibilities would be required to cover the presumed MFL shortfall of $4-5 billion.

Q: One last question about the application. Can you read the first sentence of subsection 1.3.6, Site Closure Bond (Ch. 463-72 WAC)?

A: "No set-aside from operating funds is anticipated for site abandonment, but Tesoro Savage Petroleum Terminal LLC will obtain a site closure bond in an amount to be determined by EFSEC upon approval of an initial site restoration plan."

Q: Do you have a comment on that?

A: It would appear that the applicant does not intend to fund a site abandonment, but instead provide a site closure bond after a site restoration plan is submitted and approved. The two should be clearly linked, meaning whether abandoned or closed, adequate bonding is provided. I would recommend that their engineer submit a “deconstruction” plan so that the measurement of all known risks and compliances is determined for evaluation. That way at least an engineer would have to consider all of the issues to mitigate risks of adverse events and final compliances back to a pre-operations condition. The idea is to secure sufficient funding guarantees at each step the risk profile changes (i.e., from "existing conditions," through “operation,” back to “existing conditions”).

Q: Turning now to the applicant's lease with the Port, can you summarize insurance levels identified in summary form on pgs. 5-6?

A: Yes. The document provides for: (1) property insurance ($1 million and five percent of values per location); (2) liability insurance ($10 million per occurrence/$15 million

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aggregate, with specific requirements for employer liability and automobile liability of $1 million each); and (3) pollution legal liability insurance ($25 million as an extension of the commercial general liability insurance or a separate policy).

Q: Would these insurance amounts be adequate to cover an MFL event?

A: No, the figures proposed are well short of that. And, as I have explained, such insurance is not available at this time.

Q: Would it be expected, for the type of insurance policies we have been discussing, that there would be exclusions for intentional sabotage or acts of terrorism?

A: Absolutely.

Q: So, for an intentionally caused MFL it is probable that for most, if not all, of the insurance policies the applicant holds there would be no pay-out?

A: Correct.

Q: Turning to Section 1.1, p. 1-3 of the Proponent's Application, can you read: (1) paragraph 1, sentence 2; (2) subsection 1.1.2; (3) subsection 1.1.3, first sentence; (4) subsection 1.1.3, last sentence; and, (5) subsection 1.1.4, first sentence?

A: Yes.

1. The Applicant is Tesoro Savage Petroleum Terminal LLC (Applicant).

2. Tesoro Savage Petroleum Terminal LLC is a Delaware limited liability company that is qualified to do business in the state of Washington. Its members are Savage Companies and Tesoro Refining & Marketing Company LLC.

3. Tesoro Corporation, a Fortune 150 company, is an independent refiner and marketer of petroleum products.

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4. Tesoro Refining and Marketing Company LLC is a subsidiary of Tesoro Corporation.

5. Savage Companies is a privately held operator that provides supply chain management solutions.....

Q: So, in summary, the applicant is a Delaware LLC which includes as members a second LLC and a "privately held operator?"

A: That is what the application states.

Q: What type of financial information is publicly available for this Delaware LLC, the second LLC, and the "privately held operator?"

A: For the applicant, the Delaware LLC, I am not aware of any publicly available information regarding its financial standing. That is the same for Tesoro Refining and Marketing Company, LLC. And, since Savage Companies is a private company, it may have financial statements to verify its income and assets, but that is not publicly available. However, Tesoro Corporation financial information is available from the U.S. Securities and Exchange Commission (SEC) EDGAR System. The information is required to be filed periodically with the SEC depending upon the types of transactions for public corporations. For example, Tesoro Corporation filed its most recent 10K on February 25, 2016.

Q: So, we do not know the assets and liabilities of this Delaware LLC - which is the applicant - or even the location of such assets, assuming they exist?

A: Correct regarding the Delaware LLC, and its two members, a second Delaware LLC and Savage Companies, the private corporation. The Tesoro Corporation assets and liabilities

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are enumerated in its 10K and other reports found at https://www.sec.gov/Archives/edgar/data/50104/000005010416000055/0000050104-16-000055-index.htm.

Q: OK. So if an MFL event occurs, is compensation from what one presumes is the parent company a possibility?

A: I did look at the Tesoro Corporation 2015 10K Financial Statement Risk Factors and Capitalization. The Risk Factors section acknowledges insufficient insurance to cover known risks of their operation. They did report maintenance of $20 million in marine terminal operator's liability coverage, subject to a $150,000 deductible, and an additional $650 million in umbrella coverage for a total of $670 million in coverage for sudden and accidental pollution events and liability arising from marine terminal operations. Copies of insurance policies would verify coverage. As of December 31, 2015, the total equity of the organization is $7,740,000,000, total debt is $4,073,000,000, with combined total capitalization of $11,813,000,000. (This is based on a February 25, 2016 filing, which updated the earlier December 31, 2015 10K Report.)

However, by utilizing the Delaware LLC structure, and without evidence of contractual indemnifications, I do have a question as to whether the applicant can shield the parent company from liability exposure from this project, including an MFL event. I presume they would be required to provide a contractual indemnity for this project, effectively providing their combined capitalization for uninsured obligations.

Q: Are you familiar with the term "black swan event?"

A: Yes.

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Q: How do you interpret that phrase?

A: A black swan event is a large-scale occurrence that is difficult to predict; however it has a huge impact on the region or world. It presents itself when seemingly disparate expected events occur in the same place at essentially the same time. The single black swan event is not within the insurance industry's historical loss experience, nor was it anticipated.

Q: While the insurance markets base risks on average daily events, do they also limit their exposure to what some might refer to as black swan events?

A: They attempt to, certainly. But the MFL outlined in this testimony is not representative of a black swan event, as the insurance markets are already aware of this type of risk. As addressed above, oil train accidents have been covered in the media, with video footage widely available.[4] As the insurance industry is aware of the risks, it has to account for them.

Q: So is it a fair assessment that given the insurance market has to account for the MFL risk by not insuring against it, and the applicant is using a Delaware LLC to also avoid that same risk, that the applicant is effectively asking local citizens here in Washington to shoulder their MFL risks?

A: Yes.

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[4] For example, footage from the derailment in Casselton, North Dakota on December 30, 2013, is posted at https://www.youtube.com/watch?v=CxkUhVswF5U; footage from the derailment in Lac Megantic, Quebec, July 6, 2013, is posted at http://youtube.com/watch?v=tVI6r7tQVeo; and, footage from the derailment in Lynchburg, Virginia, April 30, 2014, is posted at http://youtube.com/watch?v=c15d1JSFQPg.

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I declare under penalty of perjury of the laws of the State of Washington that the foregoing is true and correct to the best of my knowledge.

DATED this 10 th day of May, 2016 at Pittsford, New York.

Robert J. Blackburn, CPCU
Managing Principal, Blackburn Group, Inc.

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Externality Effects on Residential Property Values: The Example of Noise Disamenities

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Externality Effects on Residential Property Values: The Example of Noise Disamenities

DAVID E. CLARK

ABSTRACT Studies conducted by the Federal Railroad Administration in the 1990s reveal that train whistle bans lead to higher accident rates at train crossings. However, advocates of these bans argue that they eliminate noise externalities that have a detrimental effect on residential home values. To assess this latter claim, an event study is conducted and hedonic models are estimated for three different areas in which Conrail unilaterally began ignoring local whistle bans. While the findings consistently show that proximity to rail lines has a negative and statistically important influence on home values, there is little evidence that the Conrail decision had any permanent and appreciable influence on the housing values in these communities. In two of the three study areas, there is no statistically significant impact of the Conrail action, and in the third area, the effects are found to be temporary in duration.

Introduction

In 1992 and 1995, the Federal Railroad Administration (FRA) issued the findings of two separate studies (FRA, September 1992; FRA, April 1995) on the influence of train whistle bans on fatal accidents. The findings revealed substantially lower accident rates at train crossings where whistles are blown as compared to areas where no whistles are blown. In addition to the societal costs resulting from the loss of human life, accidents are also costly to railroads in terms of service disruptions as well as track and crossing repairs. In October 1991, Conrail unilaterally decided to ignore the whistle bans in the cities in which it operates. Critics of this decision contended that residential property markets were detrimentally impacted by Conrail's action. A number of studies in the research literature investigate the influence of noise on annoyance levels of residents. For example, Osada (1991) evaluates community reaction to aircraft noise near Japanese airports. Using

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discriminant analysis, I find that annoyance rates are highly related to noise levels and they depend on personal characteristics of the respondent. In addition, Osada compares the findings on airport noise with that of other studies evaluating road traffic and train noise. Similar responses to noise are found across various sources and different time periods considered. Another study by Björkman (1991) uses a dose-response model to investigate how road-traffic noise levels and event frequency influence annoyance levels. Björkman concludes that the number of noise events increases annoyance rates up to a point, beyond which there is no additional reaction to additional events. It was also determined that annoyance depends on the level of noise, and that this effect is independent of the frequency of noise events. Sörensen and Hammar (1983) find similar results when evaluating train noise. Specifically, they find that the number of noise events and the level of noise both influence the percent of residents who report that they are very annoyed. Residents report no annoyance for less than fifty trains per twenty-four-hour period. Above the fifty-train threshold, the level of annoyance depends on noise levels. These results are similar to a study of aircraft noise by Rylander, et al. (1980). Finally, a recent study by Multer and Rapoza (1998) evaluates community impacts from wayside horns (i.e., horns that are placed in a fixed location as opposed to a moving train) versus train horns. They found lower levels of reported annoyance for wayside horns, which were approximately 13 dB quieter than train horns. In addition, the wayside horn was found to have a severe impact for residents within 100 feet of the track, whereas severe impacts were found for train horns within 1,000 feet of the track.

Although survey research is important in measuring attitudes towards noxious activity, stated levels of annoyance do not necessarily translate into actual economic impacts. For example, Metz (1994) shows that stated preferences on aversion to nuclear waste are inconsistent with actual behavior. That is, individuals typically report that a minimum safe distance for storage of nuclear waste is in excess of the actual distance they live from waste. An alternative approach to valuing local externalities is to examine their impact on residential property values.[1] Under certain circumstances, these impacts can be considered implicit prices for amenities. In a recent study, Strand and Vagnes (2001) find that properties in Oslo, Norway, selling within 100 meters of rail lines are detrimentally impacted. They find that a doubling of the distance within the 100-meter buffer area increases housing values 10 percent. However, this study does not distinguish between proximity to rail lines, and proximity to rail crossings where whistles are blown. Another recent study by Simons and El Jaouhari (2004) evaluated activity levels on railroad tracks in Cuyahoga County in Ohio (a metropolitan county in Cleveland) in the late 1990s and found significant detrimental effects from proximity to freight tracks ranging from 2 percent to 4 percent of the average residential sales price. In a related study, El Jaouhari and Simons (2002) show that proximity to a rapid transit station in Cuyahoga County actually increases property values by 9 percent to 14 percent of the average price for those properties between 750 and 1,000 feet of a rail station. Interestingly, they also find evidence of a nuisance effect for stations. Specifically, households living too close to a rapid transit station (i.e., less than 750 feet) do not experience a significant positive benefit, and the premium for those between 750 and

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1,000 feet is diminished by higher levels of customers at the station. In the current study, the author investigates the extent to which the action taken by Conrail to ignore whistle bans at grade crossings influenced residential property sales prices in the vicinity of railroad crossings in two different cities in Ohio and one city in Massachusetts.

Theoretical Overview of Hedonic Model

The hedonic model treats a unit of housing as a heterogeneous bundle of characteristics. These characteristics include different structural features of the housing unit (e.g., numbers of bedrooms and bathrooms, interior square footage, etc.) as well as features of the neighborhood (e.g., locational attributes such as poverty rates, racial and ethnic characteristics, average commute time, proximity to rail lines, etc.). One advantage of this modeling approach is that it allows one to examine the *ceteris paribus* influence that a particular attribute has on local housing prices. That is, holding constant the impact of structural characteristics of the home as well as other neighborhood attributes, one can examine the independent influence on the sale price of the property of a rail crossing or a decision to ignore a ban on train whistles. The theory, which has its foundations in the works of Lancaster (1966), Rosen (1974) and others (Freeman 1979; Palmquist 1984; Brown and Rosen 1982, Diamond and Smith 1985; Epple 1987; Bartik 1987), has been extensively developed in the literature; hence, it will only be briefly reviewed here. Assuming 1) perfect information about the bundle of attributes embodied in each house, 2) zero transactions costs in market trades of bundles, and 3) a continuous offering of attributes, the market price of a house can be represented as p(z), where $z = z_1, z_2, \ldots, z_n$ is a vector of structural and neighborhood attributes. The hedonic price function p(z) represents a reduced-form equation, which embodies both supply and demand influences in the housing market. The implicit price of attribute j is then given by the partial derivative of p(z) with respect to attribute j, or $p_j(z) = \partial p/\partial z_j$.[2] That is, assuming the above conditions are satisfied, $p_j(z)$ represents the independent influence of attribute z_j on the housing price, holding constant the influence of other attributes. The equilibrium price function, p(z), is assumed to be a nonlinear function because the cost of arbitrage activity that repackages bundles of attributes once a house is built is assumed to be prohibitive.

Many studies have applied the hedonic methodology to value neighborhood externalities and local public goods (Haurin and Brasington 1996; McDougall 1976). Applying this model to a train whistle policy change can shed light on the impact of noxious activity on residential property markets and the dynamic adjustment of property markets after such an event. For example, Kiel and McClain (1995) show that the implicit price, p_j, associated with an incinerator project varied as the project moved from the rumor stage to actual operation of the facility. Thus, it is possible that the influence of the policy change on train whistles has an immediate short-run effect and smaller long-run impacts. Indeed, Galster (1986) argues that even relatively significant events such as the Three Mile Island nuclear accident may have relatively minor long-term property value impacts. This is because the residents most sensitive to the presence of a nuclear power plant had long since moved from the vicinity of the plant when the accident occurred. Those who lived in the region at the

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time of the accident were by definition those who were least concerned with the risks associated with the facility. The same phenomenon may be at work as one considers the influence of whistle bans. Specifically, households who are most sensitive to train noise are unlikely to live close to an established rail line. Hence, long-run adjustments in the composition of local residents may serve to mitigate any property value impacts associated with the policy change. Furthermore, even though the Conrail crossings did not have whistle activity before October 1991, local residents may believe there to be some probability of a policy change in the future. To the extent that they consider this possibility when determining their offer price for the property, this would further diminish any measured housing price impact associated with the policy change. To test whether a change in train whistle activity influences residential home sale prices, hedonic models are estimated for properties selling in three communities. The sales took place both before and after the whistle ban was ignored by Conrail, permitting the development of an event study. The policy change is then evaluated to see whether its impact on properties near rail crossings was temporary or permanent.

Empirical Model

Description of study areas. The study estimates a hedonic model using a sample of properties that sold in three counties; two in Ohio, and one in Massachusetts. The Ohio counties include Butler County in the southwestern part of the state, which contains Middletown, and Trumbull County in northeastern Ohio, which contains Niles. The Massachusetts data include transactions from Middlesex County, which contains Framingham. The choice of study areas was dictated by data availability and by two primary requirements. First, the data needed to span the period of the Conrail decision, and second, whistle bans needed to be in place prior to the Conrail decision. The data sets were obtained from two different sources: The Ohio data were obtained from Dataquick and cover the period January 1988 to January 1997. Of the 4,725 properties sold in Butler County, 3,733 or 65.2 percent sold after the ban was ignored, whereas 61.1 percent of the 4,182 properties in Trumbull County sold after the Conrail action. The Massachusetts data were obtained from Experían and cover the period January 1986 to July 1997. Of the 2,718 observations in Middlesex County, 68.0 percent sold after the Conrail action. All property data are geocoded to the street address of the house,[3] which permits matching of the property to the salient locational attributes in the vicinity of the property. The demographic characteristics of each county are described in Table 1.

Of the three geographic regions, Middlesex County, which is a western suburb of Boston, is the most densely populated. It also has the highest median family income, as well as the highest home values and rents. In Ohio, Butler County is more affluent than Trumbull. All three regions are predominantly white, although there are some differences in minority compositions across the three areas. Minority populations in the Ohio counties are predominantly black, whereas Middlesex has higher concentrations of Asian and Hispanic residents.

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TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF STUDY AREAS.

Demographic characteristic	Butler County Ohio	Trumbull County Ohio	Middlesex County Massachusetts
Median family income	$38,673	$33,313	$52,112
Median housing value	$72,500	$53,200	$192,200
Median gross rent	$415	$346	$671
Percent owner occupied	69.22	73.09	59.63
Population (persons)	291,479	227,813	1,398,468
Population density (persons/square mile)	154.12	91.41	419.69
% Black	4.50	6.68	2.87
% Asian	0.91	0.42	3.70
% White	94.31	92.58	92.05
% Hispanic	0.50	0.64	3.39

Source: County data, 1990 U.S. Census of Population and Housing.

Description of model. To avoid misspecification biases and mitigate problems associated with unmeasured spatially correlated influences, the author controls for numerous housing influences in the model. These variables can be assumed to fall into one of four broad categories; *Structural, Neighborhood, Time Sold,* and *Railroad.* A semilog specification is chosen,[4] and the model is specified by equation (1).

$$\ln\text{RPRICE} = \text{f}\,(\textit{Structure}, \textit{Neighborhood}, \textit{Time Sold}, \textit{Railroad}) \tag{1}$$

All variable definitions, and data sources, are reported in Table 2. The dependent variable lnRPRICE is the log of real sale price of housing and is deflated by the housing component of the Consumer Price Index (CPI) for the month in which the property sold.

Categories of independent variables. The first category of variables, *Structure,* represents structural features of the house. The variables in this category differ slightly between the Ohio and Massachusetts specifications. These include the number of bedrooms, bathrooms (bathrooms for OH; half baths and full baths for MA) and other rooms; the number of fireplaces; the age of the structure; the size of the lot on which the structure is located; and the square footage of the structure itself and the garage (Ohio properties only). Finally, the presence of a pool (Ohio properties only) and the number of stories of the property are also controlled. Note that the age of the house and the measures of building and garage area and lot size are included in both linear and quadratic forms so as to account for potential nonlinear effects of these variables on home sale prices.[5] One would expect that structural features that increase the housing services generated by a property increase the sales price.

TABLE 2. VARIABLE NAME, DEFINITION, AND DATA SOURCE.

Variable Name	Definition	Source
Dependent Variable and Variables in the *Structural* Category		
Real price	Real sale price of the property (1990 dollars)	Dataquick or Experían nominal price divided by the national CPI for housing
Age house	Age of the house in years.	Dataquick or Experían
Bathrooms (OH)	Sum of full and half baths, where each full bath = 1 and each half bath = 0.5.	Dataquick or Experían
Half baths (MA)		
Full baths (MA)		
Bedrooms	Number of bedrooms in house	Dataquick or Experían
Other rooms	Total rooms minus number of bedrooms	Dataquick or Experían
Fireplace	Number of fireplaces in the house	Dataquick or Experían
Number of stories	Number of stories in the property	Dataquick or Experían
Pool	1 = Presence of a pool, 0 = otherwise. (OH only)	Dataquick
Building area	Structure area in square feet.	Dataquick or Experían
Garage area	Garage area in square feet. (OH only)	Dataquick
Lot area	Lot area in square feet.	Dataquick or Experían
Variables in the *Neighborhood* Category		
Airport 3 miles;	1 = Property is within three miles from the edge of an airport, 0 = otherwise.	FAA geocoded airport locations
Distance	Distance in miles to airport if within three-mile buffer.	
Highway quarter mile;	1 = Property is within 0.25 mile of interstate highway, 0 = otherwise	ESRI Data and Maps
Distance	Distance in feet to highway if within 0.25 mile buffer.	
Air quality monitor distance	Distance to closest EPA air quality monitor in miles.	LandView III database

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TABLE 2. (CONTINUED)

Variable Name	Definition	Source
Toxic Release Inventory, three miles;	1 = Property is within three miles of a TRI facility, 0 = otherwise.	LandView III database
Distance	Distance in miles to facility if within three-mile buffer.	
Superfund, three miles;	1 = Property within three miles of Superfund site, 0 = otherwise.	Landview III database
distance	Distance in miles to Superfund site if within three-mile buffer.	
Power plant 3 miles;	1 = non-nuclear power plant within three miles, 0 = otherwise.	Landview III database
distance	Distance in miles to plant if within three-mile buffer.	
% owner occupied	Percent of the housing units in the census block group that are owner occupied.	1990 Census of Population and Housing
% Occupied units	Percent of the housing units in the census block group that are occupied	1990 Census of Pop. and Housing
% Asian	Percent of the persons in the census block group who are Asian/Pacific Islander	1990 Census of Pop. and Housing
% black	Percent of the persons in the census block group who are black	1990 Census of Pop. and Housing
% Hispanic	Percent of the persons in the census block group who are Hispanic	1990 Census of Pop. and Housing
Median household income	Median household income in the census block group	1990 Census of Pop. and Housing
Commute time	Average commuting time in the census block group	1990 Census of Pop. and Housing
Lake/River	1 = Lake or river within 3 miles of the property	ESRI Data and Maps.
Tax rate	Imputed property tax rate	Dataquick or Experían

Median year built	The median year in which the housing units in the census block group were built	1990 Census of Pop. and Housing
Variables in the *Railroad* Category		
Line impact area (LIA)	1 = Rail line within 1,000 feet of the property, 0 = otherwise.	Computed from FRA crossing database.
Distance from rail line	Distance of the property rail line in miles.	Computed from FRA database
Crossing impact area (CIA)	1 = Rail crossing within 2,320 feet of the property, 0 = otherwise.	Computed from FRA database
Severe impact area	1 = Rail crossing within 1,000 feet of the property, 0 = otherwise.	Computed from FRA database
Moderate impact area	1 = Rail crossing between 1,000 and 2,320 feet of the property, 0 = otherwise.	Computed from FRA database
Distance from rail crossing	Distance of the property from the rail crossing in miles.	Computed from FRA database
Ignore	1 = property sold more than 45 days after the decision by Conrail to ignore the whistle ban, 0 = otherwise.	Computed from FRA database
Days since	The number of days since the whistle ban was ignored.	Computed from FRA database

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Neighborhood and time trend variables. Both Dataquick and Experían data are geocoded to the property address thereby permitting a wide range of neighborhood characteristics to be precisely matched to each property. ArcView is used to map each property to a census block group and the characteristics of that block group are then assigned to the property. Among the characteristics included are the percent of the houses that are occupied (*%occupied*), the percent of the occupied units that are owner occupied (*%owner occupied*), and the racial and ethnic mix of the block group (*%Asian*, *%Black*, and *%Hispanic*). Also included in this set of demographic controls is the median household income of the block group (*median HH income*). Finally, the age of housing in the neighborhood (*median year built*) is included to proxy the age of the neighborhood, and the average commute time within the block group (*commute time*) is included to account for enhancements to housing prices that result from reduced travel times. Also included is *population density*, which captures both amenities (e.g., variety in cultural amenities) and disamenities (e.g., congestion, noise, crime, etc.) associated with more densely populated neighborhoods.

Neighborhoods with relatively higher rates of occupied units, owner occupancy, and median income are expected to exhibit higher sale prices since the sample is comprised of single-family homes. In addition, the urban location model predicts that lower commute times should result in higher sale prices, *ceteris paribus*. Finally, the expected impact of the racial and ethnic variables is unknown *a priori* because the race or ethnicity of the buyers, which may proxy individual preferences, are unknown.

ArcView is also used to determine how close each property is to various types of noxious activity, specifically, activity related to the proximity to interstate highways and airports. Because a primary goal of this study is to measure the influence of noise on residential property markets, I measure the airport gradient (i.e., the price–distance relationship) for distances of up to three miles from the airport and distances up to 0.25 miles for highways. These distances are believed to reflect the feasible range for noise impacts associated with these activities, and hence noise levels outside these ranges are assumed to be too low to influence property markets. Air quality in the neighborhood is proxied by distance from the nearest EPA air quality monitor (*air quality monitor distance*). Since monitors are not uniformly dispersed throughout metropolitan areas, but rather are placed in areas that are more likely to have elevated readings, one expects properties located at greater distances from a monitor to experience higher air quality. Proximity to several different types of potentially hazardous activity were modeled with two separate variables. Specifically, a dummy variable was included for a three-mile range around the property, and then distance from the site is interacted with the dummy variable to derive a distance gradient. This was done for Superfund sites in the community,[6] the presence of production facilities on the Toxic Release Inventory,[7] and also proximity to nonnuclear power plants to proxy emissions associated with these facilities (*power plant 3 miles)*. Note that the impact of power plants may be ambiguous. This is because there are potential beneficial impacts (e.g., tax subsidies from the utility, employment effects) as well as detrimental effects (e.g., pollution, congestion) from the facility.[8]

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Next, proximity to streams, lakes, and rivers (*lake/river 3 mile*) is included to proxy access to aesthetic and recreational amenities as well as flooding risks. The *property tax rate* for the residence is included to measure the local property tax burden and dummy variables for the school district to account for housing price differentials related to variations in school quality. The data set also contains information about the political jurisdiction in which each dwelling lies. To account for amenities and disamenities as well as public goods and services associated with the community, dummy variables for the political jurisdiction and the specific school district are also included (*city dummy*).

Variables in the *Time Sold* category include dummy variables for the year in which the property sold. This should control for the influence of long-run trends in housing prices, as well as factors related to the business cycle. The omitted year is 1987 for the Ohio data and 1986 for Massachusetts. In addition, seasonal dummy variables are included to account for whether the property was sold in the spring, summer, fall, or winter, with winter being the omitted dummy variable. There are no sign expectations in any of the time-related variables because both supply and demand for housing will change during each period.

Railroad variables. To account for the influence of railroad noise, several different measures are included in the *Railroad* category. To account for whistle noise, the distance of the property to the closest rail crossing is measured. Rail crossings that are maintained by Conrail are distinguished from other crossing data. Note that a crossing is classified as a Conrail crossing if Conrail maintains it, or if any Conrail trains travel through the crossing. Multer and Rapoza (1998) report that locomotive engineers begin sounding their horn approximately 1,320 feet (i.e., a quarter mile) from the highway-railroad grade crossing. In addition, they report that the impact or severe impact zone for train whistles is, at most, 1,000 feet from the train, so an operational definition of an impact zone of properties within 2,320 feet of a rail crossing is adopted. The impact zone is split into moderate and high impact ranges by defining the area within 1,000 feet as severe impact and the area 1,000 to 2,320 as a moderate impact zone.

In general, homes in Butler County are closer to rail crossings than in the other study areas. Specifically, 23.9 percent of the properties in this sample fall within 2,320 feet of Conrail crossings in Butler County whereas 8.5 percent and 2.7 percent are within that distance of Conrail crossings for Trumbull and Middlesex Counties, respectively. Likewise, the properties in Butler are also closer to crossings of other rail companies on average (i.e., 7.2 percent are within 2,320 feet for Butler County; 1.5 percent are within that impact zone for Trumbull County and 1.6 percent are within that distance for Middlesex County). Noise and vibration may also result from proximity to rail lines, even if the property is not close to a rail crossing. Thus, it is important to control for proximity to both rail lines and rail crossings. A 1,000-foot buffer zone (*Line impact area,* or *LIA*) is constructed around each rail line, and again, the line is classified by the rail company. It is assumed that noise and vibration that is unrelated to whistle noise will dissipate within 1,000 feet. As with the crossing data, Butler properties tend to be closer than those in other counties to rail lines with 17.9 percent within 1,000 feet of Conrail lines, and 7.8 percent within that distance of

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other lines. This is in contrast to the findings for Trumbull County (5.7 percent for Conrail lines and 4.8 percent for other lines) and Middlesex County (7.2 percent for Conrail lines and 1.3 percent for other lines).

Two different specifications are examined for each of the three geographic regions. The first specification uses dummy variables to distinguish between impacts in the moderate and severe impact areas. This is given by equation (2) below.

$$\ln(rprice) = \beta_0 + \beta_1 * \text{Control} + \beta_2 * LIA_j + \beta_3 * XIA_k + \beta_4 * XIA_{k:Conrail} * Ignore + \beta_5 * XIA_{k:Conrail} * Ignore * Days\ since \tag{2}$$

where: ln(*rprice*) = the log of the real sales price

Control = Vector of control variables, and β_1 a vector of coefficients on those variables;

LIA_j = Line impact area (i.e., within 1,000 feet of the rail line) for j = Conrail, Other;

XIA_k = Crossing impact area for k = moderate, severe;

Ignore = A zero-one dummy variable that takes on a value of one if the property sold at least 45 days after the date when Conrail began ignoring the whistle ban.

Days since = the number of days that have passed since 45 days after the Conrail action.

Properties that closed within forty-five days of the Conrail action would not have been influenced by the action for two reasons. First, Conrail did not provide any advanced warning of its decision to discontinue observing the whistle ban. Furthermore, it typically takes four to six weeks to close on a property. Hence, properties selling within forty-five days of the Conrail action would have had an accepted offer before the action to ignore the bans. While it may be possible for the buyer to withdraw the offer once Conrail began blowing their whistles, those transactions would not take place within the forty-five-day period subsequent to the action. The coefficient on *LIA*, (β_2) is expected to be negative if proximity to a train line represents a local disamenity. The coefficients on the crossing dummy variables (i.e., estimates of β_3) would also be expected to be negative, with the coefficient on the XIA_{severe} anticipated to be more negative than the coefficient on $XIA_{moderate}$. If the action by Conrail is detrimental to property values, then the estimate of β_4 should be negative and statistically significant. That is, ignoring the whistle ban would significantly reduce sale prices on property below the baseline level established by the estimates of β_3. Finally, the last term is designed to capture temporal differences in property value impacts, such as those identified by Kiel and McClain (1995). If negative impacts grow over time (i.e., the area is stigmatized), this coefficient could be negative, implying continued declines in property prices after the action. On the other hand, if negative impacts are only temporary, then one would expect a positive estimate of β_5.

The second specification estimates continuous distance gradients (i.e., price–distance relationships) for the entire impact area rather than dividing the crossing impact area (CIA) into moderate and severe ranges with separate dummy variables. It then investigates the

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influence of the Conrail action on the slope of the gradient. The model is given by equation (3).

$$\begin{aligned}\ln(rprice) = \beta_0 + \beta_1 * \text{Control} + \beta_2 * LIA_j + \beta_3 * LIA_j * Distance_j + \\ \beta_4 * XIA_j + \beta_5 * XIA_j * Distance_j + \\ \beta_6 * XIA_{Conrail} * Distance_{Conrail} * Ignore + \\ \beta_7 * XIA_{Conrail} * Distance_{Conrail} * Ignore * Days\ since\end{aligned} \tag{3}$$

where ln(*rprice*), Control, *LIA*, *Ignore* and *Days since* are defined as before.

XIA_j = 2320 foot radius crossing impact area for j = Conrail, Other crossing.

$Distance_j$ = distance from property to rail crossing, or rail line j

The estimate of the coefficient on LIA_j*$Distance_j$ (i.e., β_3) represents the rate at which housing prices change with distance from the rail line. If proximity to rail lines is undesirable, then it would be expected that $\beta_2 < 0$ and $\beta_3 > 0$. That is, prices would be expected to be lower for homes selling within the impact area (i.e., $\beta_2 < 0$) but they would rise with greater distance from the line (i.e., $\beta_3 > 0$). Similarly, the coefficient estimate on XIA_j (i.e., β_4) represents the baseline impact associated with residing within the impact area. In addition, as distance from the crossing increases, property prices should rise if being close to the crossing is undesirable. Hence, the estimate of β_5 is expected to be positive. If the Conrail decision to ignore the ban increases the premium for distance from the crossing, then the estimate of β_6 would be positive, and the expected sign on β_7 depends on whether property impacts decline, or are exacerbated, over time.

Empirical Findings

Separate regressions are estimated for each of the three geographic regions, and a White test reveals evidence of heteroskedasticity in all regressions. White's correction technique is used to generate consistent estimates of standard errors (White 1980). The findings on the two specifications are reported in Tables 3 and 4, respectively. Because the coefficients and the *t*-scores on control variables differ very little between the specifications, they are only discussed for the first specification.[9] In addition, the discussion will focus on coefficients that are statistically significant in a two-tailed test at the 90 percent level of confidence or higher. The regression models explained 64.3 percent of the variation in the log of real sale prices in Butler County; 61.7 percent of the variation in Trumbull County; and 48.8 percent in Middlesex County. While the model specifications are nearly identical, the fit in Middlesex County is significantly lower. Recall that the population density is significantly higher in the Middlesex as compared to the other counties, and this may imply that unmeasured neighborhood externalities are more prominent in that county.

Structural variables. Most structural characteristics are significant and of the anticipated sign. The influence of age on housing price is generally negative although not all coefficients are significant. Treating the coefficients as point estimates, the net effect of the linear and quadratic coefficients is negative in the relevant range of the data for all counties. Holding square footage constant, additional bedrooms, bathrooms, and other rooms

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TABLE 3. HEDONIC REGRESSION EXAMINING EFFECT OF CONRAIL ACTION ON IMPACT ZONES.

Variable	Butler County		Trumbull County		Middlesex County	
	Coefficient	*t*-stat.	Coefficient	*t*-stat.	Coefficient	*t*-stat.
a. *Intercept*	3.03453	1.616	9.509976	5.687***	349.4428	1.524
b. *Structural Characteristics*						
Age house	–0.003341	–3.186***	–2.96E-04	–0.371[m]	–0.175215	–1.513[m]
Age house squared	–5.18E-06	–0.601[m]	–4.42E-05	–5.723***	2.50E-05	3.768***
Bedrooms	0.054248	4.905***	0.048357	4.544***	0.023086	1.471
Bathrooms (OH) Full bath (MA)	0.016989	1.362	0.102802	6.996***	0.043785	2.006**
Half bath (MA)					0.075038	4.484***
Other rooms	0.024233	3.595***	0.033494	4.084***	0.005597	0.542
Fireplace	0.114386	11.134***	0.122876	8.811***	0.045837	3.121***
Garage area	0.000172	6.780***	0.000398	7.314***		
Garage area squared	–6.25E-08	–3.503***	–1.56E-07	–2.262**		
Building area	0.00032	8.391***	0.000441	11.338***	0.000286	4.478***
Building area squared	–2.33E-08	–2.900***	–5.76E-08	–7.513***	–2.82E-08	–2.562**
Lot area	9.01E-07	3.060***	1.43E-06	2.673***	1.60E-06	4.043***
Lot area squared	–3.92E-13	–1.485	–3.81E-12	–2.122**	–1.12E-12	–3.157***
Number of stories	–0.019578	–1.689*	–0.069005	–4.892***	2.02E-02	0.942
Presence of a pool	0.099166	4.186***	0.073518	3.908***		
c. *Neighborhood Characteristics*						
Airport 3 miles	0.264427	6.299***	–0.23352	–1.986**	–3.92E-01	–1.311[m]
Airport 3 miles × distance	–0.071927	–5.365***	0.079275	2.345**	0.177719	1.205[m]

Highway quarter mile	–0.194899	–0.373	–0.111048	–1.502	–2.00E-01	–2.001**
Highway quarter mile × distance	–1.412707	–0.254	0.066272	0.135	0.000205	2.931***
Air quality monitor distance	0.02556	2.042**	–0.012167	–1.402	–0.002489	–0.260[m]
Toxic release inventory 3 miles	–0.016579	–0.241	–0.224346	–3.777***	–0.204782	–3.227***
Toxic rel. inv. 3 miles × distance	0.009512	0.512	0.044404	2.164**	0.054481	2.730***
Superfund 3 miles					0.02598	0.457[m]
Superfund 3 miles × distance					–0.048341	–1.875*
Power plant 3 miles	–0.234856	–4.501***	–0.034007	–0.502[m]		
Power plant 3 miles × distance			0.022193	1.002[m]		
% Owner occupied	0.002935	4.912***	–0.003501	–4.746***	–0.003183	–2.185**
% Occupied units	–0.008693	–4.147***	–0.01032	–3.281***	–0.006517	–1.567
% Asian	0.029628	2.790***	–0.019835	–2.708***	–0.333521	–1.097
% black	–0.001705	–1.183	–0.007608	–7.050***	0.223109	0.418
% Hispanic	0.020736	1.872*	–0.028882	–2.407**	0.018075	0.049
Median Household Income	8.67E-06	7.794***	1.55E-05	10.375***	4.17E-06	4.751***
Commute time	–0.009217	–4.013***	0.003689	1.264	0.002872	0.589
Population density	–2.11E-06	–0.473	1.48E-05	3.373***	–2.82E-06	–0.284
Lake/River	–0.036878	–2.652***	0.044012	2.259**	–0.015118	–0.838
Tax rate	0.104922	2.716***	–0.038323	–3.904***	3.590921	0.591[m]
Median year built	0.003711	3.910***	0.000698	0.817	–0.169896	–1.471[m]
d. *Railroad variables*						
Conrail line and crossing variables						
Line impact area (LIA)	–0.067983	–4.391***	–0.063327	–1.931*	–0.089785	–2.144**
Moderate crossing impact area (CIA)	–0.087112	–3.735***	–0.090096	–2.305**	–0.031596	–0.312

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TABLE 3. (CONTINUED)

Variable	Butler County		Trumbull County		Middlesex County	
	Coefficient	*t*-stat.	Coefficient	*t*-stat.	Coefficient	*t*-stat.
Moderate	–0.017244	–0.469	–4.72E-02	–0.731	–0.041458	–0.258
CIA × Ignore						
Moderate	2.23E-05	0.898	5.37E-05	1.045	2.12E-05	0.198
CIA × Ignore × Days since						
Severe CIA	–0.031365	–0.874	–0.182329	–1.845*		
Severe CIA × Ignore	–0.04221	–0.787	–0.327394	–2.248**		
Severe	6.27E-05	1.891**	0.000209	2.056**		
CIA × Ignore × Days since						
Other railroad line and crossing variables						
LIA	–0.139909	–5.265***	–0.020258	–0.690	–0.274098	–1.447
Moderate CIA	–0.095145	–3.272***	–0.160567	–2.791***	0.182837	1.594
Severe CIA	–0.039456	–0.819	0.002371	0.016	0.474631	1.525
Adjusted R^2	0.642		0.617		0.488	

F-statistic	139.95***	94.49***	35.88***
Number of observations	4725	4182	2718
Log-likelihood	–805.77***	–1359.49***	–1310.86***
e. *Unreported city* control dummy variables (Jointly significant at 95% Conf.–Wald test)	2 ($\chi^2 = 34.78$***)	4 ($\chi^2 = 26.31$***)	14 ($\chi^2 = 31.01$***)
f. *Unreported time* control variables (Jointly significant at 95% Conf.—Wald test)	12 ($\chi^2 = 407.06$***)	12 ($\chi^2 = 301.53$***)	14 ($\chi^2 = 120.01$***)
g. *Unreported school* district dummy variables (Jointly significant at 95% Conf.—Wald test)	4 ($\chi^2 = 1.12$)	12 ($\chi^2 = 54.92$***)	4 ($\chi^2 = 30.34$***)

* Significant at 90% level, 2-tailed test; ** significant at 95% level, 2-tailed test; *** significant at 99% level, 2-tailed test.
[m] Variance inflation factor on insignificant coefficient is greater than 10.

TABLE 4. HEDONIC REGRESSION EXAMINING EFFECT OF CONRAIL ACTION ON HOUSING PRICE DISTANCE GRADIENTS.

Variable	Butler County		Trumbull County		Middlesex County	
	Coefficient	*t*-stat.	Coefficient	*t*-stat.	Coefficient	*t*-stat.
a. *Intercept*	3.003773	1.589	9.34E+00	5.649***	343.3374	1.498
b. *Structural characteristics*						
Age house	–0.003395	–3.244***	–4.07E-04	–0.348[m]	–1.72E-01	–1.487[m]
Age house squared	–4.65E-06	–0.542[m]	–4.32E-05	–3.647***	2.48E-05	3.733***
Bedrooms	0.055002	4.981***	0.049175	4.238***	0.022806	1.447
Bathrooms (OH) Full bath (MA)	0.017924	1.438	0.102252	6.400***	0.045292	2.057**
Half bath (MA)					0.075014	4.478***
Other rooms	0.023969	3.547***	0.035236	3.705***	0.005983	0.580
Fireplace	0.113483	11.041***	0.121941	9.048***	4.92E-02	3.335***
Garage area	0.000171	6.754***	3.97E-04	7.077***		
Garage area squared	–6.36E-08	–3.633***	–1.54E-07	–2.386**		
Building area	0.000318	8.386***	4.42E-04	7.084***	2.85E-04	4.435***
Building area squared	–2.26E-08	–2.825***	–5.79E-08	–3.501***	–2.83E-08	–2.559**
Lot area	9.16E-07	3.146***	1.45E-06	2.210**	1.52E-06	3.845***
Lot area squared	–4.05E-13	–1.546	–3.83E-12	–1.744*	–1.05E-12	–2.977***
Number of stories	–0.02052	–1.773*	–0.069217	–4.487***	0.018726	0.868
Presence of a pool	0.101129	4.277***	0.073974	4.442***		
c. *Neighborhood characteristics*						
Airport 3 miles	0.262504	6.231***	–0.243675	–1.712*	–0.395113	–1.314[m]
Airport 3 miles × distance	–0.073037	–5.451***	0.082418	2.007**	0.179068	1.209[m]

Highway quarter mile	–0.194716	–0.374	–0.126898	–1.309	–0.203131	–2.040**
Highway quarter mile × distance	–1.412739	–0.255	0.172014	0.286	0.000206	2.954***
Air quality monitor distance	0.025269	2.028**	–0.011732	–1.260	–0.002408	–0.252[m]
Toxic release inventory 3 miles	–0.005577	–0.081	–0.215741	–3.490***	–0.252978	–4.218***
Toxic rel. inv. 3 miles × distance	0.005523	0.298	0.040673	1.826*	0.064366	3.280***
Superfund 3 miles					0.022645	0.393[m]
Superfund 3 miles × distance					–0.044653	–1.727*
Power plant 3 miles	–0.242659	–4.707***	–0.02229	–0.299[m]		
Power plant 3 miles × distance			0.017441	0.702[m]		
% Owner occupied	0.002925	4.843***	–0.003508	–4.516***	–3.08E-03	–2.139***
% Occupied units	–0.008632	–4.116***	–0.00977	–3.094***	–0.006538	–1.595
% Asian	0.031016	2.919***	–0.019809	–2.510**	–0.329781	–1.090
% black	–0.001842	–1.253	–0.007692	–6.149***	2.89E-01	0.547
% Hispanic	0.019619	1.752	–2.82E-02	–2.182**	–1.28E-01	–0.348
Median household income	8.61E-06	7.700***	1.53E-05	9.349***	4.05E-06	4.739***
Commute time	–0.008954	–3.872***	3.09E-03	1.015	2.04E-03	0.421
Population density	–2.05E-06	–0.458	1.36E-05	3.028***	–4.57E-06	–0.455
Lake/River	–0.035531	–2.552**	0.044702	2.111**	–0.013579	–0.747
Tax rate	0.105338	2.699***	–0.038117	–3.165***	2.480748	0.410[m]
Median year built	0.003719	3.894***	0.000762	0.911	–0.166792	–1.445[m]

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TABLE 4. (CONTINUED)

Variable	Butler County		Trumbull County		Middlesex County	
	Coefficient	*t*-stat.	Coefficient	*t*-stat.	Coefficient	*t*-stat.
d. *Railroad variables*						
Conrail line and crossing variables						
Line impact area (LIA)	–0.089171	–3.142***	–0.319479	–3.261***	–2.47E-02	–0.180[m]
LIA × Distance	0.284876	1.320[m]	1.715128	2.848***	–0.541454	–0.443[m]
Crossing impact area (CIA)	–0.039341	–1.106[m]	–0.112056	–1.230[m]	–2.35E-01	–1.701*
CIA × Distance	–1.42E-01	–1.269	0.058647	0.223[m]	2.72E-05	2.598***
CIA × Distance × Ignore	–0.014222	–0.136	–0.204594	–0.917	5.49E-07	0.070
CIA × Distance × Ignore × Distance × Days Since	4.60E-05	0.643	0.00022	1.240	–1.19E-08	–1.328
Other Railroad Line and Crossing Variables						
LIA	–2.07E-01	–2.637***	0.015228	0.209	–0.405999	–1.335[m]
LIA × Distance	0.538401	1.012	–0.160558	–0.302	–0.177961	–0.096[m]
CIA	0.010161	0.139[m]	0.065236	0.222[m]	0.843392	1.682*
CIA × Distance	–0.344353	–1.618[m]	–0.611725	–0.700[m]	–1.748785	–1.345[m]

Adjusted R^2	0.642	0.617	0.485
F-statistic	140.26	94.51	37.09
Number of observations	4725	4182	2718
Log-likelihood	–802.353	1359.18	–1310.86
e. *Unreported city* control dummy variables (Jointly significant at 95% Conf.—Wald test)	2 ($\chi^2 = 21.67$***)	4 ($\chi^2 = 8.69$**)	14 ($\chi^2 = 29.4$***)
f. *Unreported city* control dummy variables (Jointly significant at 95% Conf.—Wald test)	12 ($\chi^2 = 437.94$***)	12 ($\chi^2 = 311.73$***)	14 ($\chi^2 = 120.73$***)
g. *Unreported city* control dummy variables (Jointly significant at 95% Conf.—Wald test)	4 ($\chi^2 = 1.26$)	12 ($\chi^2 = 26.54$***)	4 ($\chi^2 = 31.18$***)

* Significant at 90% level, 2-tailed test; ** significant at 95% level, 2-tailed test; *** significant at 99% level, 2-tailed test.
[m] Variance inflation factor on insignificant coefficient is greater than 10.

significantly increase housing values in most of the samples. For Butler County, an additional bedroom increases the sale price by 5.4 percent and other rooms increase the price by 2.4 percent. Additional full bathrooms have a much stronger influence in Trumbull, increasing property values by nearly 10.3 percent, whereas bedrooms and other rooms increased values 4.8 percent and 3.3 percent respectively. In contrast, neither bedrooms nor other rooms are statistically significant for Middlesex County. An additional full bathroom increases the value by 4.4 percent and an additional half bathroom increases home sale prices by 7.5 percent.[10] The presence of a fireplace significantly increases the home sale price by 11.4 percent to 12.3 percent in the Ohio samples, and 4.6 percent in Middlesex County. This is likely serving as a proxy for other qualitative features of a home in addition to the influence of the fireplace. For example, fireplaces may be more likely to be found in homes with family rooms. Each additional story reduces the real sale price by about 6.9 percent in Trumbull, and about 1.9 percent in Butler County. The presence of a swimming pool significantly raises the sale price of the property by about 7.3 percent in Trumbull and 9.9 percent in Butler County. Turning to the square footage measures, consistent with Palmquist (1984), the square footage of the property increases housing prices but at a decreasing rate. Other things equal, the real housing price falls after 6,867 sq. ft. in Butler County, 3,559 sq. ft. in Trumbull County, and 5,071 sq. ft. in Middlesex County. In all areas, this is well beyond the mean building area. Evaluating this relationship at the mean building area value of each sample (i.e., 1,324 sq. ft. in Butler, 1,475 sq. ft. in Trumbull, and 1,863 sq. ft. in Middlesex), an increment of 100 square feet increases housing value by 3.8 percent in Butler County, 2.7 percent in Trumbull County, and 1.8 percent in Middlesex County. Additional garage area also increases values at a decreasing rate with each 100 square foot increment in garage space leading to an increase in value of 1.4 percent in Butler County and 2.9 percent in Trumbull County (again, these are evaluated at the mean values for garage area). This higher impact of garage space in Trumbull is caused by stronger marginal effects resulting from the magnitude of the coefficients in the Trumbull regression, combined with garage sizes that are on average about 46 percent larger in Trumbull. Finally, the size of the lot, which is also included in quadratic form, significantly increases the sale price of the housing unit. Again, evaluating this at the mean acreage level for the properties in the sample, this increases home values by approximately 3.2 percent per acre in the Butler County area, 5.6 percent per acre in Trumbull County, and 6.6 percent per acre in Middlesex County.

Neighborhood characteristics. The influence of neighborhood characteristics varies across locations both in terms of significance and magnitude. For example, being within three miles of the airport in Trumbull County reduces home values by 23.3 percent, but the negative effect is dissipated at 2.9 miles, since values rise 7.9 percent per mile as one moves further away for the airport. In contrast, it increases 26.4 percent within the three-mile buffer in Butler County, and then falls 7.2 percent per mile to eliminate most of the positive effect from proximity to the airport at the edge of the buffer. Proximity to an interstate highway reduces values 20 percent in Middlesex County (which is the most urban of the three areas) but the detrimental influence is completely eliminated within the quarter-mile area (i.e., values increase 27 percent per quarter mile). The real home sale price increases

2.5 percent with each additional mile from air quality monitors in Butler County, but the influence is insignificant in the other two counties. Properties in Trumbull County that are adjacent to a Toxic Release Inventory facility sell for 22.4 percent less on average, but they rise by 4.4 percent for each mile within that region. Thus, the detrimental effect is only partially offset by distance within the impact region. A similar negative impact was found in Middlesex County, but the positively sloped real housing price gradient is steeper (i.e., 5.4 percent per mile). The impact of Superfund sites is counterintuitive in Middlesex County because the real property value drops 4.8 percent per mile further from the site. It is likely that the site is capturing influences other than the perceived risks from the site. Finally, the single property that sold within three miles of a power plant in Butler County, sold for 23.5 percent less than comparable properties in the area.

Turning to the neighborhood measures drawn from 1990 census block group data, it is not surprising to find that real housing prices are higher in neighborhoods that are more affluent. Older neighborhoods, as determined by a smaller value for the *median year built* variable, have significantly lower priced housing in Butler County with an additional 10 years of age reducing the real sale price by nearly 4 percent. Surprisingly, a high percentage of occupied units significantly decreases the sale price of housing in Butler and Trumbull Counties although it should be noted that there is very little variation in this variable, and most neighborhoods have high occupancy rates. This may be capturing the influence of desirable neighborhoods that are experiencing active construction activity in Ohio. Likewise, whereas an increase in the percent of occupied homes that are owner-occupied raises housing prices in Butler County, it actually has the opposite effect in Trumbull and Middlesex Counties. Population density, which can proxy both amenities and disamenities associated with a neighborhood, on net has a positive and significant influence on housing prices in the Trumbull regression model. The racial and ethnic mix of the neighborhood exerts a statistically important influence in all three housing markets. Specifically, increases in the black population are associated with decreases in housing prices in Trumbull County; increases in Asian populations are associated with decreased prices in Trumbull County but an increase in sale prices in Butler County; and an increase in the Hispanic population is associated with decreases in home sale prices in Trumbull County but an increase in Butler County. There are a number of possible reasons for these findings. Race may be serving as a proxy for other unmeasured neighborhood characteristics, or it may be capturing racial preferences and attitudes of the majority population. It should be noted from Table 1 that concentrations of all minority groups are low in all three communities, with white populations at least 92 percent of total population in each county. Finally, consistent with the predictions of the urban location model (e.g., Bender and Hwang 1985), higher average commuting times reduce the real home price, with the coefficient significant in the Butler County regression equation. An increase in commuting time of ten minutes depresses housing prices about 9.2 percent in that city.

Being within three miles of a lake or river significantly increases home prices in Trumbull County (i.e., by 4.4 percent) whereas it significantly decreases them in Butler County (i.e., by 3.7 percent). This latter finding may be reflecting negative consequences

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associated with proximity to rivers, such as flooding. Unfortunately, residence in floodplains is not controlled in the regression models. Turning to fiscal measures, a high property tax burden depresses housing prices in Trumbull County, but it increases them in Butler County. Because the value of public services is only partially controlled in the regressions, tax rates may be capturing both the tax burden and also the benefits of uncontrolled services. Several coefficients were included in the regression models but are not reported in Tables 3 and 4 to conserve space. Specifically, dummy variables for the school district, where the properties are located, are found to have a jointly significant impact on the real price of properties selling in Trumbull and Middlesex Counties. Likewise, the dummy variables for the jurisdiction of the property sold are highly significant in all three counties. These variables partially control for the provision of local public services in the community.

Time and seasonal dummy variables. The time and seasonal dummy variables are jointly significant in all equations. The coefficients on seasonal dummy variables reveal that housing prices in Butler County are significantly higher in the fall than in the winter, which is the omitted category, whereas they are significantly higher in the summer in Middlesex. In addition, real housing prices have risen over the 1988–1997 period, with the real appreciation rate approximately 29.2 percent in Butler County and 26.9 percent in Trumbull. The housing market in Middlesex is substantially stronger, with real price appreciation of 175.4 percent over the 11-year period. This is in spite of a relatively deep recession in New England during the late 1980s.

Railroad related variables: Specification 1. The first specification (shown in Table 3) assumes that there are two distinct impact areas for rail crossings. The severe impact area is the area defined within 1000 feet of the crossing, whereas the moderate impact area is defined as the zone between 1001 and 2320 feet of the crossing.

Proximity to rail lines. Turning to the findings on railroad variables in the first specification, controls for proximity to both Conrail and other rail lines consistently reveal that properties within 1,000 feet of a rail line experience significantly lower home sale prices. The reductions in sale prices for properties along Conrail lines are significant in all areas, with real prices falling between 6.3 percent and 9 percent as compared to properties outside the Conrail line impact area. In the only county showing a significant impact along other lines, Butler County, the impact was more substantial at −14 percent. These findings are slightly larger than those found elsewhere. For example, Simons and El Jaouhari (2004) found negative impacts in the 2 percent to 4 percent range, whereas Strand and Vagnes (2001) found impacts in the −10 percent range within 100 meters of the tracks.

Proximity to crossings. Turning to the impact areas surrounding the crossings, some consistent patterns do emerge although there are some exceptions as well. Specifically, an examination of the baseline effects in the moderate impact area of the Conrail crossings reveal significantly lower home prices in the impact areas for properties selling in the Ohio counties. Indeed, they are 8.7 percent lower in the Butler moderate impact area (as compared to outside the area) and 9 percent lower in the Trumbull County moderate area. For other

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lines, there are somewhat higher negative baseline effects in the Ohio counties (–9.5 percent in Butler and –16 percent in Trumbull). The severe impact areas for Conrail crossings are negative and significant for Trumbull County, and as expected, the negative impact is greater in the severe impact area (i.e., –18.2 percent as compared to –9 percent in the moderate zone). Finally, none of the coefficients in the severe impact area (other) category are statistically significant. Note that activity levels at these crossings are not controlled, which can influence the findings. Although information was collected from the Federal Railroad Administration on activity levels at the crossings, these data were not consistently defined over time. Furthermore, of the three areas considered, only Middlesex County had activity levels that exceeded fifty trains per twenty-four-hour period, which is the threshold activity level identified by Sörensen and Hammar (1983) as they measured annoyance levels among residents.

Effects of Conrail action. Examining the effect of the Conrail action, there is no evidence of a permanent negative impact associated with the Conrail policy. None of the interaction terms between the *Moderate CIA* variables and the *Ignore* variable were statistically significant. Of the two counties with properties selling in the *Severe CIA*, only Trumbull County showed a significant negative effect from the action (i.e., a reduction in sale price of 32.7 percent). However, the impact was significantly diminished over time. That is, the coefficient on the *Days since* interaction term was positive and significant, suggesting that property values rose 7.6 percent for each year that passes after the Conrail action. This suggests the negative effect of the Conrail action would be eliminated in approximately 4.3 years. Note that the log-linear increase in the sale price resulting from the influence of the *Days since* variable would not be expected to continue indefinitely because it is unlikely that the Conrail action would actually increase property values. However, these estimates do suggest that within the relevant range of the data, more than a third of the negative impact of the Conrail decision on local property values was eliminated. That is, at the mean value of *Days since* (548 days), property values would have rebounded by approximately 11.5 percent, and hence, the negative impact of the Conrail action is mitigated over time.

Railroad related variables: Specification 2. The second specification (shown in Table 4) estimates continuous price-distance gradients, which measure the rate at which housing prices change with the distance of the property from the rail line or rail crossing. The findings are similar in many respects to those found in the previous specification, but there are some important differences as well.

Proximity to rail lines. The coefficient estimates on the LIA dummy variables consistently reveal negative and significant property value impacts. For Conrail lines, the price reductions range from about 8.9 percent in Butler County to 31.9 percent in Trumbull County. For other lines, real housing price reductions of 20.7 percent were seen in Butler County. While these values are larger in magnitude than those found in the first specification, there is an important difference in the interpretation. For the first specification, no gradient was estimated. Hence, the coefficient on the LIA variable represented the average impact over the entire impact area. In this specification, the LIA dummy variable is

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included, and it is also interacted with the distance of the property from the line. Thus, the coefficient on LIA is now interpreted as the impact at the closest point to the rail line, rather than the average impact over the entire impact area. The interaction between LIA and *Distance* measures the marginal effect of distance from the rail line, within the LIA. Three of the six gradients are positive, although only one is statistically significant. Specifically, the coefficient on the *LIA * Distance* interaction term in the Trumbull County regression is 1.715, indicating that prices rise 32.5 percent in the 1,000 foot LIA. This suggests that the 32 percent reduction at the edge of the track is eliminated within 1,000 feet of the railroad line. Given the high VIF scores on some of the insignificant coefficients for the other areas, it is possible multicollinearity is partially responsible for the low levels of significance in the Butler and Middlesex regressions.

Proximity to rail crossings. Turning to the analysis of rail crossing measures, there are some interesting results. For other rail lines, the coefficient on the CIA in Middlesex County is positive and significant. That is, real home prices are 84.3 percent higher for properties located at intersection, but they then fall (albeit with a *t*-score of –1.345)[11] at a rate of 43.7 percent per quarter mile from the crossing. It may be that this is capturing in part the possibility that some of these crossings are also commuter rail stations. It should be noted that the non-Conrail Middlesex crossings are the only ones for which train activity levels exceeded fifty trains per day (i.e., there were sixty-two trains per day in one location). Finally, I point out that in Butler County, the coefficient on the interaction term *CIA * Distance* was negative and approaching significance at the 90 percent level of confidence. It is unclear as to the reason for a negatively sloped gradient in this county because there is no commuter rail in the county. Again, multicollinearity may be contributing to the insignificance of some of the rail crossing gradients in this specification.

Examining the coefficients on the Conrail *CIA* variables, the only coefficients that are statistically significant are found in Middlesex County although the findings in Trumbull County may be insignificant because of multicollinearity. Here, the coefficient on *CIA* was negative (–23.4 percent at the track edge). Furthermore, the gradient had only a very slight positive slope changing less than 0.1 percent over the quarter-mile range of the impact area. Both of these effects can be viewed as having been in existence before the Conrail action to ignore the local whistle ban. To consider the impact of the Conrail action, one must evaluate the interaction terms with the *Ignore* variable. All of the coefficients on *CIA * Distance * Ignore* were statistically insignificant, as were all of the coefficients on the *CIA * Distance * Ignore * Days since* interaction term. These findings suggest that the decision by Conrail to ignore the whistle bans did not significantly change the shape of the housing price gradients in the neighborhoods around the crossings, either immediately after the Conrail action or in the months that followed their decision.

Conclusions and Policy Implications

The findings consistently show that proximity to rail lines has a negative and statistically important influence on residential property values. In addition, there is evidence that

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proximity to rail crossings can also reduce the real sale price of homes. In fact, all of these impacts existed before the point at which Conrail began ignoring the train whistle bans in these three areas. However, the overall weight of data reveals little evidence that the decision by Conrail to begin ignoring whistle bans had any permanent and appreciable influence on the housing values in these communities. For two of the three study areas, there was no statistically significant influence of the Conrail action. Furthermore, in the only area where a negative effect was identified (i.e., Trumbull County), one model suggested the effects were minor and temporary (i.e., property prices rebounded within about 4 years).

This is not necessarily surprising. Individuals buying properties within the potential audible range of a rail crossing likely consider at least the possibility that train whistles will be blown at the crossing in the future. Thus, when Conrail began ignoring the ban, it may have only confirmed their initial suppositions. Furthermore, it is likely that the Conrail action generated dynamic changes in the composition of residents that served to mitigate the initial impact of the action. Residents most sensitive to train whistle noise would be expected to eventually move away from the impacted area, and they would be replaced with those less bothered by train whistles. This is because the residents most tolerant of train noise would have the highest willingness to pay for the property when it is on the market. This transition from more sensitive to less sensitive residents would reduce and possibly eliminate any long-run impacts from the Conrail decision that could explain the insignificant coefficients in two of the three study areas.

This study has important implications for policy makers. In a cost-benefit analysis of the impacts of lifting of whistle bans, one component of the costs of such a policy would be the reduction in property values for properties in the vicinity of rail crossings. These costs would then be weighed against the benefits of the policy change (i.e., reduced societal costs from accidents). These findings suggest that for communities with low to moderate train activity (i.e., less than seventy-five trains per day), the costs in terms of property value reductions appear in most cases to either be negligible, or minor in magnitude and temporary in duration. Thus, it is likely that removal of train whistle bans results in positive net-benefits to society. These findings, while enlightening, are just first steps in understanding how train whistles influence local property markets. More complete data is needed to achieve a thorough understanding of the factors leading to residential property price impacts of train whistles. This includes continuously defined data on train activity levels. Next steps should also investigate the relationship between distance, terrain, and the presence of other factors such as tall buildings that can serve as barriers to noise. Moreover, the analysis could be extended to study areas in other geographic regions. For example, all of the study areas in this study were in the Northeast or North Central regions. In more moderate climates, residents likely spend more time outdoors year round. This may influence their sensitivity to train whistle noise. Note also that this study has focused on property impacts from train whistles. There are other whistle impacts that could also be investigated, including the effect on residential mobility. That is, does a change in policy regarding train noise motivate some residents to move out of the audible range of trains?

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Although this study suggests that this dynamic process may be at work, more direct measures of mobility are needed before strong conclusions can be drawn. Finally, this study focused exclusively on residential property. Train whistle noise may also influence the value of commercial property, and an empirical investigation of commercial impacts is needed to understand more fully the impacts of a policy change regarding train whistles.

NOTES

1. There are a number of reasons why stated preferences and revealed preferences derived from hedonic approaches may differ. One of the assumptions of the hedonic model is that homebuyers know the true level of the local amenity bundle. This is not always the case, however. For example, Bernknopf, Brookshire, and Thayer (1990) document that earthquake and volcano hazard risk notices influence local property markets. Homebuyers who are unaware of such risks pay more for housing than those who are notified of their presence. Likewise, Clark and Allison (1999) show that the visual cues and media coverage about stored nuclear waste influence housing price gradients for nuclear power plants.
2. Rosen (1974) shows that this implicit price does not represent an individual's willingness to pay for the attribute. The implicit price can be used, however, to derive the demand for an attribute in a second stage estimation process. Brown and Rosen (1982), Diamond and Smith (1985), Epple (1987), Bartik (1987), and others, however, have noted the existence of identification problems that make estimation of these demand functions difficult. The current study need only focus on the single stage model.
3. The ArcView 3.1 GIS software with the Streetmap was used to geocode each property. Only properties with complete address information were geocoded, and the author required an average score of 80 out of 100 on the geocoding index reported by ArcView to keep the observation.
4. The issue of functional form has been investigated extensively in the hedonic literature. Although some authors (Rasmussen and Zuehlke 1990) advocate flexible functional forms, others have voiced concerns about the accuracy of implicit prices from such forms (Cassel and Mendelsohn 1985). Cropper, Deck, and McConnell (1988) argue that the semilog model is preferred when the possibility of a misspecification exists. While I have been careful in the choice of specification, such a possibility exists with spatially defined data.
5. Older homes are expected to include more dated technology (e.g., some may not include central air conditioning), and hence, may be less desirable. However, older homes may also include features such as hardwood floors, crown molding, and so on that are less likely to be found in newer homes. In addition, Palmquist (1984) has argued that building area should be included nonlinearly because construction costs increase nonlinearly with the size of the house. Hence, the author includes area measures in linear and quadratic form. Overall, linear terms for the age and area variables are expected to have a positive influence on sale prices, and the quadratic terms are expected to negatively impact prices.
6. Note that only Middlesex County had a site on the National Priorities (a.k.a. Superfund) list that matched to a property that was within three miles. There were Superfund sites in the other counties, but all of the properties fell outside the three-mile impact area.
7. The Toxic Release Inventory is a publicly available database of firms that emit toxic chemicals into the environment. It was created in response to the 1984 Bhopal accident in which a Union Carbide

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plant accidentally released methyl isocyanate gas. Some estimates indicate that more than half million people were exposed to the gas, and more than 20,000 eventually died from their exposures. Given that some of these properties sold during the late 1980s and early 1990s, it is possible that knowledge of TRI sites could affect their bid prices.

8. The definition of impact areas for environmental goods is admittedly arbitrary. It should be noted that the dummy variable definitions and/or the distance variables interacted with those variables are all significant in at least one of the regression equations reported in this article.
9. Nearly identical specifications are included in all three regressions so that the findings across locations can be compared without fear of a specification bias. As long as a variable is found to be significant in at least one regression, the variable is retained in all three regressions. Because multicollinearity can lead to insignificant coefficients, Variance Inflation Factor (VIF) scores were computed for all insignificant coefficients. When the VIF > 10, this is denoted in Tables 3 and 4.
10. It may initially seem odd that a half bathroom is valued more highly than an additional full bathroom. However, note that all homes have at least one full bathroom, and thus an incremental bathroom is the second bathroom. Indeed, 50.2 percent of the homes in Middlesex County had one and 42.9 percent had two bathrooms. In contrast, about half of the homes do not have a half bathroom.
11. Note again that the coefficient on *LIA * Distance* has a VIF score that exceeds 10.

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Attachment D
Exhibit 4005-000030-CWF
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The Economic Impact of a Transient Hazard on Property Values: The 1988 PEPCON Explosion in Henderson, Nevada

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Abstract

This article investigates the effect of the May 1988 explosion of a chemical plant in Henderson, Nevada on residential property values (1) before the explosion (anticipation), (2) between the time of the explosion and an announcement of relocation, and (3) subsequent to an announcement in July 1988 that the plant would be rebuilt 100 miles away in Cedar City, Utah. This article uses the conventional hedonic model wherein the real prices of residential houses are related to the characteristics of the property (age, size, and amenities); the timing of the sale; and distance from the site of the explosion, rounded to the nearest mile. A quadratic specification of the model showed that the model was sensitive to the mean distance from the hazard. In a sample of properties throughout the Las Vegas Valley, property values decreased with distance from the explosion, indicating the presence of other hazards. The quadratic specification was stable only for properties within six miles of the explosion site, which included the communities of old Henderson (to the east) and the master planned community of Green Valley (to the west). A discontinuous specification of the model, in which distance was measured by a set of dummy variables (i.e., within two miles, within three miles, etc.) proved to be much more stable. Property within two miles of the hazard were depressed both before and after the explosion, although after the relocation announcement, property values rebounded to reflect the reduction in the number of hazardous plants. This article lends weight to the accumulating body of evidence that real estate markets do behave efficiently.

Key Words: hedonic, hazard, housing, market efficiency

1. Introduction

On May 4, 1988, a welder's torch set off an explosion of a vat of ammonium perchlorate, a volatile ingredient in solid rocket fuel. Within minutes the Pepcon plant in Henderson, NV, disappeared. The explosion, which rocked the Las Vegas valley, killed two employees, leveled an adjacent marshmallow manufacturing factory, and caused extensive but repairable damage to residential and commercial property. The blast did not harm the Kerr-McGee facility two-thirds of a mile away, the only other manufacturer of ammonium perchlorate

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in the U.S.A. Two areas most affected: the residential neighborhoods of old Henderson, an industrial town about 15 miles from the Las Vegas strip, and the rapidly growing master planned community of Green Valley, which had been annexed by the city of Henderson in the early 1980s. Figure 1 shows the location of the Pepcon plant (triangle) in the southeast corner of the Las Vegal valley between Green Valley (to the west) and Henderson (to the east). Figure 2 magnifies the map of the Green Valley and Henderson, showing the Pepcon plant site midway between zip code 89014 (Green Valley) and zip code 89015 (Henderson).

As homeowners replaced broken windows and garage doors and filed insurance claims, Pepcon's parent corporation negotiated with community leaders about the rebuilding. On July 27, 1988, 84 days after the explosion, corporate officials announced that the Pepcon plant would not be rebuilt in heavily populated southern Nevada, but would be relocated in Cedar City, Utah, approximately 100 miles to the northeast.

The events of May through July of 1988 present a unique opportunity to investigate the impact of a transient hazard on property values in a rapidly growing community. The city of Henderson is the fastest growing city in Nevada, the fastest growing state in the U.S.A. Using an extensive record of residential housing sales, this article explores both the spatial and temporal impacts of the explosion on the Henderson and Green Valley residential housing markets. Analyzing nearly 8,000 housing sales, we relate housing prices to the distance between each house and the Pepcon plant, and link significant changes in this relation, before and after the explosion, and after the relocation announcement. Our large sample size (in comparison to other studies) allows us to test the hypothesis of market efficiency by looking at daily, as opposed to monthly or annual, housing transactions. Our investigation shows that home buyers in Henderson appeared to be better informed about the hazard both before and after the explosion, perhaps because of the older, settled nature of that community. Before the explosion, property values significantly increased as distance from the plants increased in both old Henderson and Green Valley. After the plant explosion, the impact of distance from the plant on housing prices increased. After the relocation announcement, the price-distance relation returned to pre-explosion levels in Henderson, but disappeared in Green Valley.

In the next section, we present a review of the literature, followed by a discussion of the incident and a description of the hypotheses to be tested. The fourth and fifth sections present the model and data, respectively. The sixth section contains the empirical results, followed by a concluding section.

2. The literature

2.1. Do nuisances affect property values?

There is an emerging consensus in the literature on the effect of neighborhood nuisances on residential property values: to varying degrees, the existence of such nuisances *does* significantly reduce property prices. Colwell (1979) established that overhead electrical power transmission lines reduced property prices up to 200 feet away, but such lines had no discernible impact farther away. Later he (1990) also demonstrated that the price-reducing effect of overhead power transmission lines declined with time; Colwell cited the growth

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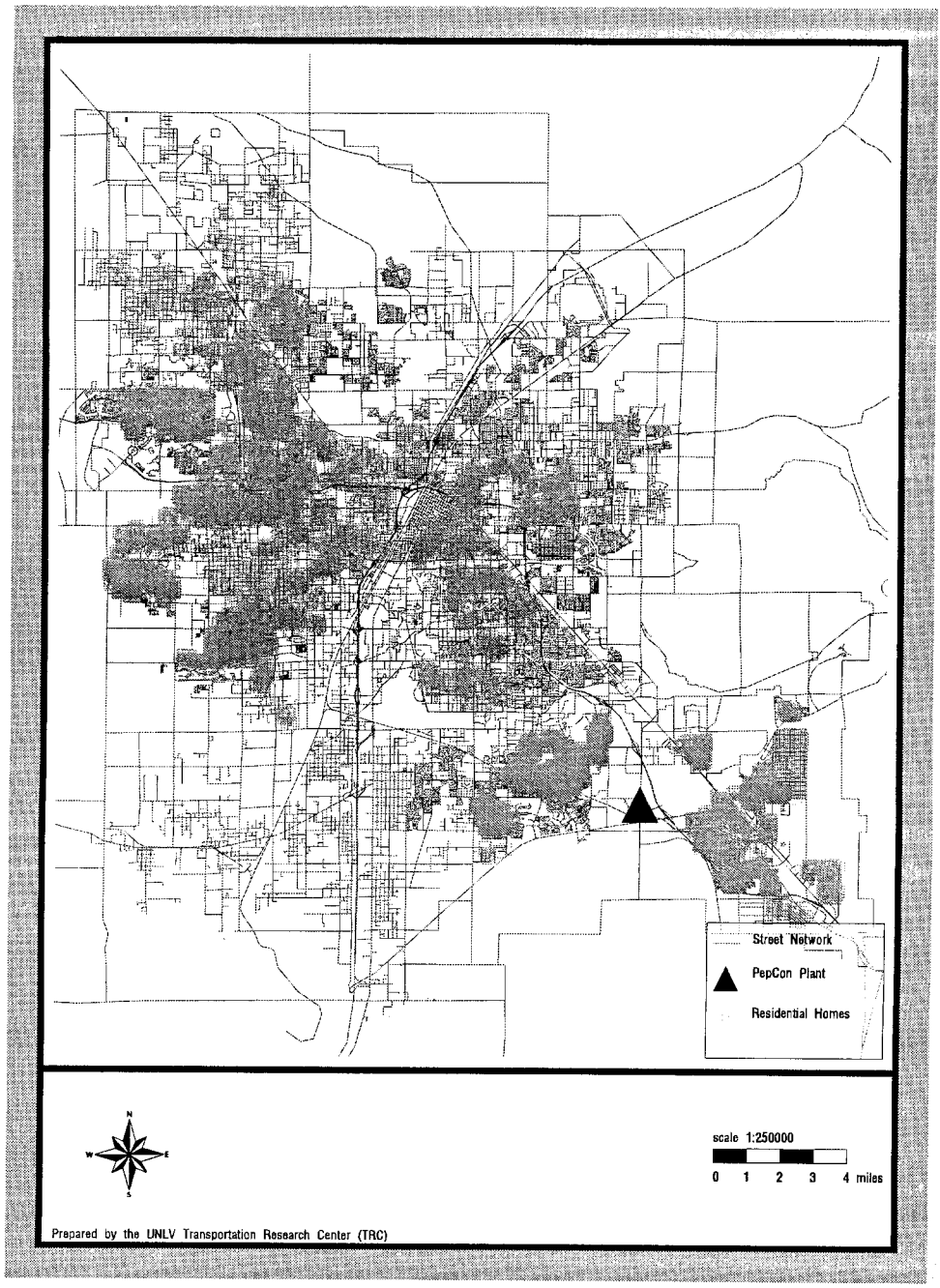

Figure 1. Location of residential homes and the Pepcon plant in Las Vegas, Nevada.

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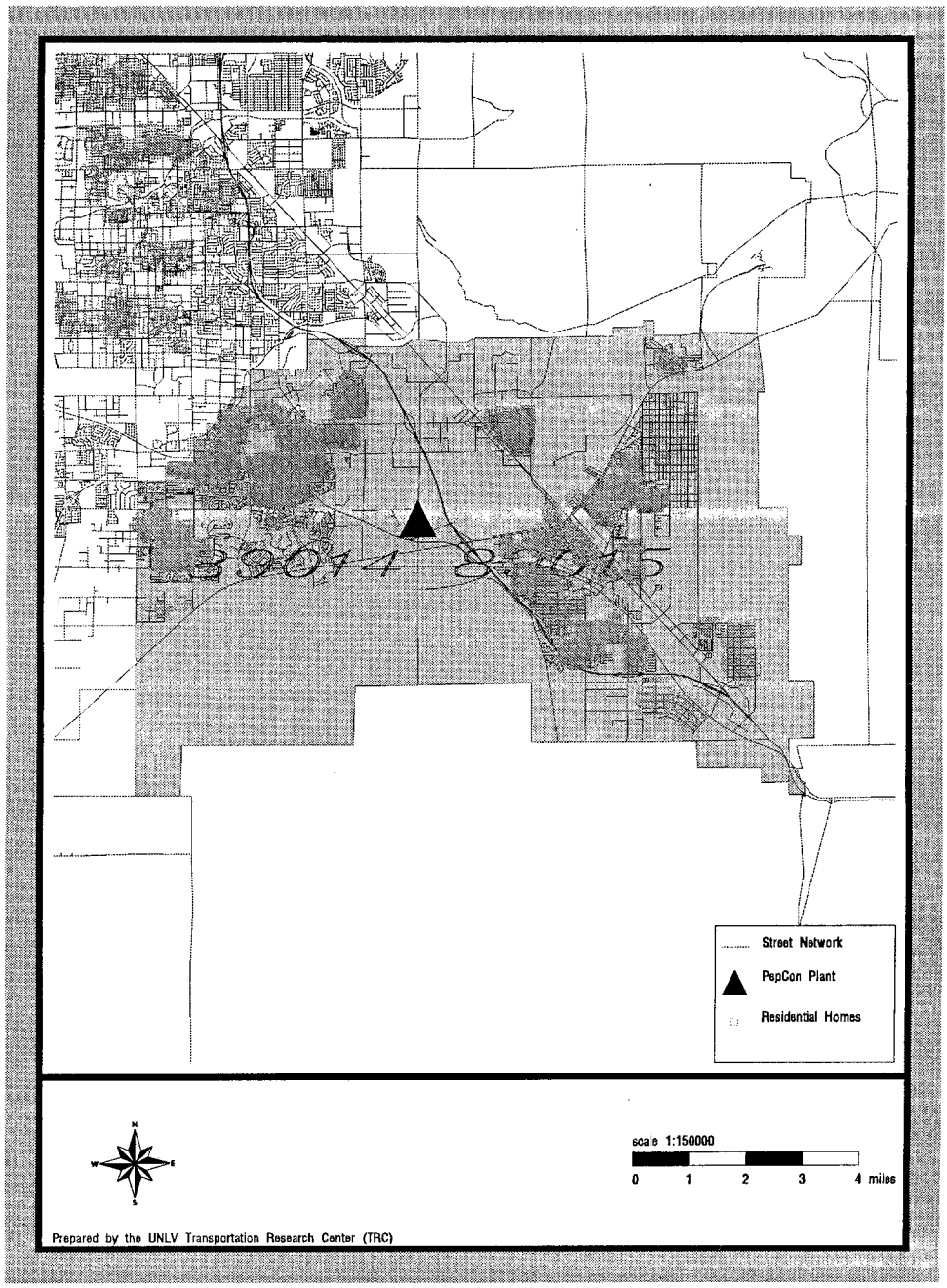

Figure 2. Location of residential homes and the Pepcon plant in Green Valley (zip 89014) and old Henderson (zip 89015).

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of trees as one explanation. Delaney (1992) surveyed 219 appraisers and found that they believed that there was a 10% discount on property values in proximity to overhead power lines. The most cited reason for the discount was the unsighly nature of the lines (93.9%), but concern for health was also an important reason given (59.9%). Kung and Seagle (1992) concluded that the most serious impact on property values would result from knowledge by the public of the possible health effects.

Thibodeau (1990) examined the effects of a high-rise office building in neighboring residential properties. He found that nearby houses decreased in value by 15%. However, there was a 5% premium on houses located over 1,000 meters from the structure. Frankel (1992) investigated the effects of aircraft noise on property values. Through a survey of 2,000 realtors and 70 appraisers, he found a significant discount for noise levels above 65–70 Ldn.[1] While discounts approximating 5% occur in the 65–70 Ldn range, those discounts reach 15% when Ldns reach the 75–80 range.

Carter (1989) found evidence that nonhazardous landfills depress property prices. Reichert et al. (1992) found the negative effect to be between 5.5% and 7.3%, depending on the distance from the site. In older, less expensive neighborhoods, the effect was smaller—between 3 and 4%. Thayer et al. (1992) estimated the effect of nonhazardous landfills in dollars. They concluded that housing prices in the Baltimore area rose by $1,300 to $1,700 for each mile distant from a waste disposal site. On the other hand, Bleich et al. (1991) employed a sample of 1,628 transactions over a ten-year period to show that if a landfill was well-designed and well-managed, the effect on property prices would be minimal. Do et al. (1994) measured the effect of neighborhood churches on residential property values in Chula Vista, California. They document a $4,000 price reduction for houses 50 feet from a church, relative to the value of a similar house 850 feet away.

Gamble and Downing (1982) study two effects of nuclear power plant proximity on residential properties before and after the Three Mile Island incident in 1979. They found that before the accident property values increased by $163 for each mile distant from the plant. They found no change in values subsequent to the accident. Galster (1986) studied the appreciation of prices for houses located near the Three Mile Island plant. He found that houses located within five miles of the plant rose more slowly in value than those located five to 25 miles away.

Hazardous waste facilities seem to depress property values by a greater magnitude. Smolen et al. (1992) found that in Toledo, Ohio there was a $12,000 premium for each mile distant from a toxic chemical waste dump, up to 5.75 miles, with no effect beyond that range. McClelland et al. (1990) used a hedonic regression model to determine the effect of risk perception of a hazardous waste landfill on house values in the Los Angeles area. They discovered that a 10% increase in respondents' indicating a high risk lowered property prices by $2,084. Closing the landfill reduced the number of respondents who thought there was a high level of risk by 25%, leading to a $5,000 increase in property values. Kohlhase (1991) looked at the effect of an EPA announcement that a site contained hazardous waste material. She discovered a premium for distance from the site of $3,310 per mile. The premium disappeared after the site was cleaned up and pronounced safe by the EPA.

On the high end of the risk perception spectrum, residents appear to be unhappy with the prospect of nuclear respositories. Hoyt et al. (1992) found a statistically significant difference in the level of concern between those who were knowledgeable about the facility

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and those who were initially ignorant, but informed of the facility. Hoyt et al. found that those with more knowledge of the facility tended to be less concerned. Smolen et al. (1992) found that the announcement of a low-level radioactive landfill near Toledo caused property prices to drop quickly near the proposed site. After the announcement that the facility would not be located in that area, property values rebounded "quickly." When one uses annual data, as did Smolen, it is difficult to determine precisely how quickly property values rebound, and, consequently, how efficient the housing market is. Indeed, few studies investigate how quickly property values react to the commencement or the termination of a neighborhood nuisance. This stems from the general reliance on annual or quarterly data with small sample sizes, making it difficult to track the timing of nuisance changes on property values. But this is precisely the question that should most interest economists and real estate specialists: do markets respond efficiently to the presence and removal of neighborhood hazards? To answer this question a large sample size with numerous daily sales is required.

2.2. Should the housing market be considered efficient?

Gau (1985) tested the weak form version of market efficiency using data from apartment and commercial property sales from Vancouver, British Columbia. He found support for the hypothesis that real estate markets are weak-form efficient. Gau also tested the semi-strong version of the hypothesis by analyzing the effect of new publicly available information on real estate asset prices. Here, too, he found support for market efficiency. Jones et al. (1981) also found support for the hypothesis that housing markets function efficiently, by demonstrating that housing prices reflected energy use as measured by annual fuel bills. On the other hand, Krantz et al. (1982) argued that housing markets are inefficient because only about 60% of property tax changes are capitalized in property prices. However, their finding does not necessarily contradict the efficiency hypothesis. If approximately 40% of property taxes were used to fund local public services (e.g., parks, schools, fire and police stations), whose positive value to residents would also be capitalized in property values, then housing markets would indeed be efficient.

3. The incident

American Pacific Corporation operated the Pepcon plant that manufactured ammonium perchlorate, a highly volatile ingredient in solid rocket fuel. The plant was located in Henderson, Nevada, an industrial town of 50,000 approximately 15 miles from the city of Las Vegas. Residential property in old Henderson (zip code 89015) sold between 1986 and 1990 (the span of our sample) averaged 3.51 miles from the Pepcon plant, with a range from 2 miles to 7 miles from the plant. Residential property in Green Valley (zip code 89014) is located at an average distance of 3.2 miles from the Pepcon plant, with a range of 2 to 15 miles. Green Valley accounts for about 64% of property sales in the two zip code areas between 1986 and 1990. On July 27, 1988, the American Pacific Corporation announced that the Pepcon plant would not be rebuilt on the original site, but would instead be relocated in Cedar City, Utah, about 100 miles northeast of Las Vegas.

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Thus, we have the existence of a hazardous activity upon which a thriving residential community is growing; that is, moving to the nuisance. The hazard dramatically erupts, and then, within three months, is lessened from two to one, reducing the probability of a future explosion by 50%. If the housing market operates efficiently, several factors should be revealed:

1. Property values should have been depressed prior to the explosion, relative to what they would have been had the hazard not existed. That is, as distance from the hazard increased, property values should have increased, ceteris paribus.
2. If the market had underestimated the hazard, property values should have responded quickly and significantly to the explosion as market agents reevaluated the probability of a chemical explosion. The rate of increase of property values with respect to the distance from the hazard should have increased after the explosion.
3. Property values should have responded to the removal of the hazard, also quickly and significantly. After the announcement that the hazard was removed, property values should have increased slightly, due to the reduction from two hazardous chemical plants to one.

4. The model

We use a hedonic model of housing prices, employing several housing characteristics and a time trend to represent the rate of appreciation of housing values. Dummy variables are introduced to indicate (a) the explosion ($P = 0$ before May 4, 1988, $P = 1$ on and after May 4, 1988, and (b) the announcement that the plant would be relocated ($C = 0$ before July 27, 1988, and $C = 1$ on and after July 27, 1988).[2]

Since the explosion caused no injuries to people in their homes, but only damaged property, we take potential losses by property owners to be proportional to the value of their house.[3] The appropriate functional form to test this specification is a double-log form, wherein coefficients measure the percentage change in the real price due to a 1% change in (continuous) regressors. We expect that the elasticity of value with respect to size should be positive, but smaller than one, for both building size (B^2) and lot size (L^2). The smaller than unitary elasticity with respect to building size reflects economies of scale in construction. Doubling the square footage of a house would increase its perimeter by only 50%. Holding the size of the building constant, a larger lot means more yard work and higher irrigation costs, so that diminishing returns prevail. Also, since block walls are ubiquitous in the Las Vegas Valley, the cost of enclosing a lot is a function of perimeter, rather than area, so the contribution of lot size to residential value should be inelastic. We hypothesize that the value of a house will vary with age and distance from the hazard in quadratic form; hence, age (A) and distance (d) are entered as a quadratic function.[4]

$$\ln p_{idt} = \ln \beta_0 + \beta_1 A_i + \beta_2 A^2 + \beta_3 \ln(B^2) + \beta_4 \ln(L^2) + \beta_5 t + \beta_6 Pl + \beta_7 FP + \beta_8 d + \beta_9 d^2 + \ln \epsilon_{it} \quad (1)$$

where:

$\ln p_{idt}$ = the natural logarithm of property real price of property i at time t (January 1, 1986 = 0), and distance d from hazard. The reported selling price was deflated by the monthly consumer price index for housing (1982–1984 = 100).
A = age of house at the time of sale in years[5]
$\ln(B^2)$ = natural logarithm of square feet of house
$\ln(L^2)$ = natural logarithm of lot size (in square feet)
t = time trend (number of months after 1/1/86)
Pl = 1 if house has a pool; 0 if there is no pool
FP = 1 if house has at least one fireplace; 0 if the house has no fireplace[6]
d = distance between house and the site of the Pepcon plant in miles[7]
$\ln \epsilon_{it}$ is the natural logarithm of the random disturbance term (mean 1, constant variance σ^2)

If the market is efficient, the coefficient on d should be positive, and the coefficient on d^2 should be negative, with $|\beta_8| > 4\beta_9$. That is, as distance from the plant(s) increases, housing prices should increase at a decreasing rate, with the effect falling to zero when $d^* = |\beta_8|/2\beta_9$.[8] Note that the efficient market hypothesis is the *alternative* hypothesis.[9] If any of the following three outcomes occur, we should accept the *null* hypothesis that the market is not efficient.

1. $\beta_8 \leq 0$. That is, property values do not increase significantly as distance from the Pepcon/Kerr-McGee plants increases.
2. $\beta_9 \geq 0$. That is, property values continue to increase as distance from the hazard increases, implying either irrational behavior on the part of home buyers, or the influence of another, potentially stronger hazard further removed from this hazard site.
3. $|\beta^8| \leq 4\beta_9$. That is, property values achieve their maximum value less than two miles from the chemical plants, which is irrelevant to our data, since the minimum distance between residential property and the plants is two miles.[10]

Otherwise, we expect the usual hedonic results. Property values should increase with the size of the home ($\beta_3 > 0$) and with lot size ($\beta_4 > 0$), and should decline with the age of the home ($\beta_1 < 0$), while increasing with the square of age ($\beta_2 > 0$).[11] Both the presence of a pool ($\beta^6 > 0$) and the presence of a fireplace ($\beta_7 > 0$) should increase the price of the house.

To test the timing of property value responses to both the explosion and the removal of one of the hazards, additional indicator variables are introduced:

P = dummy variable for Pepcon explosion; P = 1 after May 4, 1988 and 0 before May 4, 1988.

C = dummy variable for relocation of plant to Cedar City, Utah. C = 1 after July 27, 1988 and 0 before July 27, 1988.

Introduction of these terms allows us to test whether the market responds quickly to each event. We also introduce interaction terms between the two events and the distance between each house and the plant:

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Pd = a slope shifter to detect change in parameter β_8 due to the Pepcon explosion. If the actual explosion increases risk perception, we would expect that the (absolute value) of the percent change in value due to an extra mile of distance should increase in the wake of the explosion.

Cd = a slope shifter to identify change in parameter β_8 due to the relocation announcement. By reducing the number of plants from two to one, parameter β_8 should have fallen in absolute value after the relocation decision.

We introduce similar slope dummies for squared distance:

Pd^2 = a slope shifter to measure change in parameter β_9 due to the Pepcon explosion. If the actual explosion increases risk perception, we would expect that the optimal distance from the plant should increase, which may imply that β_9 decreases.

Cd^2 = a slope shifter to measure the change in parameter β_9 to to the relocation announcement.

This yields the second test equation:

$$\ln p_{idt} = (\beta_0 + \beta_{10}P + \beta_{11}C) + \beta_1 A_i + \beta_2 A^2 + \beta_3 \ln(B^2) + \beta_4 \ln(L^2) + \beta_5 t + \beta_6 Pl + \beta_7 FP + (\beta_8 + \beta_{12}P + \beta_{13}C)d + (\beta_9 + \beta_{14}P + \beta_{15}C)d^2 + \ln \epsilon_{it}. \quad (2)$$

Note that the six intercept and slope shifter variables are likely to be collinear, given the brief time period between the explosion and the relocation announcement. Accordingly, an *F*-test is used to measure the joint significance of all six indicators.

Despite the fact that quadratic functions are ubiquitous in real estate econometrics literature, there is some concern that such functions may create phony results as the function strains to return to the data beyond the distance of any effects. Accordingly, we estimate a more generalized value-distance function which allows for discontinuous results. This discontinuous distance specification allows for abrupt changes in the relation between residential property values and the distance from the hazard. We define an *MI2* as the dummy variable set equal to 1 for all houses with two miles[12] of the plant site; *MI2* = 0 for all other properties in the sample. The variable *MI3* is coded as 1 for all properties within three miles of the plant site; *MI3* is coded as zero for all remaining properties. Note that all properties for which *MI2* = 1, *MI3* = 1. We coded properties up to ten miles from the plant site in the Las Vegas Valley sample; the reference group for this sample is all properties more than ten miles from the hazard. Nearly all properties in Green Valley and Henderson are within six miles of the plant site. Our distance indicators are restricted to *MI2*, *MI3*, *MI4*, and *MI5*. The reference group for Green Valley and Henderson includes properties more than five miles from the plant site.

With this specification, the new version of (1) becomes:

$$lp_{idt} = \beta_0 + \beta_1 A_i + \beta_2 A^2 + \beta_3 \ln(B^2) + \beta_4 \ln(L^2) + \beta_5 t + \beta_6 Pl + \beta_7 FP + \sum_{d=3}^{d_{\max}} \gamma_d MI_d + \ln \epsilon_{it}. \quad (1a)$$

Coefficient γ_d measures the effect of being d miles from the hazard, as compared to being $d - 1$ miles from the hazard. Accordingly, we expect γ_2 to be negative, since two miles is the closest proximity to the plant site. The coefficient γ_3 should be *positive*, indicating an increase in property values with distance from the hazard. The plant has no further effect on property values at distance j where

$$\sum_{d=3}^{j} \gamma_d MI_d = 0.$$

Interaction terms between distance indicators and the date of the Pepcon explosion (P) and the relocation announcement (C) measure temporal changes on the property value-distance relation:

$$-lp_{idt} = (\beta_0 + \beta_{10}P + \beta_{11}C) + \beta_1 A_i + \beta_2 A^2 + \beta_3 lB^2 + \beta_4 lL^2 + \beta_5 t + \beta_6 Pl$$

$$+ \beta_7 FP + \sum_{d=2}^{n} (\gamma_{1d} + \gamma_{2d}P + \gamma_{3d}C)MI_d + \ln \epsilon_{it}. \tag{2a}$$

A negative size on γ_{22} (on interaction term $PMI2$) either implies an increase in the perceived hazard two miles from the explosion site or perhaps the effect of transitory damage on home prices between May 8 and July 27, 1988. Negative coefficients on other γ_2 terms imply a diminished recovery of property values with distance from the explosion. We expect positive signs for γ_3 (on interaction term CMI_d), as home buyers absorb the information that the number of hazardous plants has decreased by one.

5. The data set

The data used to test market efficiency were taken from a computerized database (*Metroscan*) of the files of the Tax Assessor's office of Clark County, Nevada. The database consists of 319,451 properties including 196,000 single family residences. For each residence, the files contain information on approximately 30 physical characteristics, in addition to the location (street address and zip code), sales date, and sales price. From the database, we selected a sample of 3,084 properties located within zip code 89014 (Green Valley), 1,764 properties located in zip code 89015 (old Henderson), and a random sample of 2,922 properties located to the north and west of Green Valley.[13] All sales occurred between January 1, 1986 and December 31, 1990.[14] Descriptive statistics for the variables selected are shown in Table 1. Note that for each variable selected, there are significant differences in the mean among the three subsamples. The greatest difference rests with the distance from the chemical plant complex. The mean distance from Green Valley homes is 3.2 miles; the mean distance from Henderson homes is 3.5 miles; while the mean distance from the rest of the valley is 14 miles. Another notable difference is in the age of homes: average age in Green Valley is only 1.6 years as compared to 9.5 years for Henderson, and 6.5 years for the rest of the Vegas Valley. As such, we would expect buyers of older houses to be better

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Table 1. Descriptive statistics.

	RPRICE	AGE	SQFTL	SQFTB	MONTH	FP	POOL	MILES	P	C	Z89014	Z89015
Entire Sample												
Mean	84190.99	6.46	7769.50	1720.22	37.69	0.78	0.21	7.34	0.04	0.67	0.40	0.23
Median	79307.18	1.00	6630.00	1612.00	41.80	1.00	0.00	4.00	0.00	1.00	0.00	0.00
Maximum	220458.55	57.00	162000.00	7571.00	60.83	1.00	1.00	22.00	1.00	1.00	1.00	1.00
Minimum	30400.63	0.00	2304.00	380.00	0.07	0.00	0.00	2.00	0.00	0.00	0.00	0.00
Standard deviation	28206.18	9.84	5122.05	562.72	16.48	0.42	0.40	5.68	0.20	0.47	0.49	0.42
Observations	7780	7780	7780	7780	7780	7780	7780	7780	7780	7780	7780	7780
Henderson												
	RPRICE	YAGE	SQFTL	SQFTB	MONTH	FP	POOL	MILES	P	C		
Mean	66123.23	9.49	8884.59	1483.17	34.09	0.59	0.11	3.51	0.04	0.58		
Median	64232.04	6.00	6863.00	1415.00	35.63	1.00	0.00	4.00	0.00	1.00		
Maximum	157853.81	55.00	162000.00	4591.00	58.77	1.00	1.00	7.00	1.00	1.00		
Minimum	30400.63	0.00	3468.00	384.00	0.17	0.00	0.00	2.00	0.00	0.00		
Standard deviation	18851.89	11.52	7130.29	477.99	17.04	0.49	0.31	1.12	0.19	0.49		
Observations	1764	1764	1764	1764	1764	1764	1764	1764	1764	1764		
Green Valley												
	RPRICE	AGE	SQFTL	SQFTB	MONTH	FP	POOL	MILES	P	C		
Mean	94980.87	1.62	7025.15	1888.22	40.59	0.92	0.25	3.20	0.03	0.75		
Median	89067.85	1.00	6537.00	1788.00	45.10	1.00	0.00	3.00	0.00	1.00		
Maximum	220458.55	16.00	66066.00	7571.00	58.77	1.00	1.00	15.00	1.00	1.00		
Minimum	32992.93	0.00	3200.00	888.00	0.40	0.00	0.00	2.00	0.00	0.00		
Standard deviation	25243.35	2.52	2969.89	552.31	14.97	0.27	0.43	1.17	0.18	0.43		
Observations	3084	3084	3084	3084	3084	3084	3084	3084	3084	3084		
Rest of Las Vegas Valley												
	RPRICE	AGE	SQFTL	SQFTB	MONTH	FP	POOL	MILES	P	C		
Mean	83675.02	9.73	7884.15	1685.54	36.79	0.74	0.22	14.02	0.05	0.63		
Median	77047.85	4.00	6600.00	1593.00	40.33	1.00	0.00	15.00	0.00	1.00		
Maximum	214776.63	57.00	54886.00	5222.00	60.83	1.00	1.00	22.00	1.00	1.00		
Minimum	33990.15	0.00	2304.00	380.00	0.07	0.00	0.00	5.00	0.00	0.00		
Standard deviation	30140.22	11.40	5337.13	563.33	17.13	0.44	0.42	3.44	0.22	0.48		
Observations	2932	2932	2932	2932	2932	2932	2932	2932	2932	2932		
F-stat	694.55	736.55	76.67	324.90	97.07	417.25	73.13	19831.81	6.36	82.32		

RPRICE real price of house (1982–1984 = 100)
AGE age of house in years (year purchased minus year built)
SQFTL square feet of lot
SQFTB square feet of building
MONTH month sold (January 1, 1986 = 0)
FP dummy variable for presence of fire place
PL dummy variable for presence of pool
D distance from house to PEPCON plant, in miles
P dummy variable for PEPCON explosion (0 before 5/4/88, 1 after 5/4/88)
C dummy variable for relocation announcement (0 before 7/27/88, 1 after 7/27/88)

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informed, typically because new home buyers rely on builder warrantees and have less of an incentive to investigate potential defects with properties. This moral hazard is likely to carry over into knowledge of environmental hazards.

Table 2 presents the correlation coefficients for the entire sample of 7,780 properties, as well as the correlation coefficients for the three subsamples. In each case, all regressors tend to be positively correlated with the real price of the house except age (in all cases), and distance (in the case of Green Valley). However, the correlation between value and age is weakest for Green Valley, which also has the youngest housing stock. Correlations between regressors tend to be weak (below 0.5) in all cases except between the six indicators of the explosion and relocation announcement dates, portending a multicollinearity problem.

6. The results

For completeness, we estimated eight regressions, relating real housing prices (deflated by the monthly CPI for housing) to age, building size, time, amenities, and distance from the hazard, with and without regard to the explosion and relocation announcement dates for the entire sample, for the combined samples from Henderson and Green Valley, and for the samples from Henderson and Green Valley alone. Results are reported for a cubic relation between price and age for the Green Valley properties and for the combined Green Valley–Henderson sample. These results are reported in Table 3.

In all cases, real housing price is positively related to building and lot size, indicators for fireplace(s) and a pool, and with respect to time. Housing prices in the Las Vegas area consistently increase faster than the consumer price index for housing, indicative of a booming economy. For the entire sample, houses in Henderson (Z89015 = 1) have significantly lower prices than houses in the rest of the Las Vegas Valley. However, there is no significant difference between homes in the Las Vegas Valley sample and the Green Valley sample. In the combined sample for Green Valley and Henderson, housing prices decreased with age and the square of age, and increased with the cube of age, implying that housing prices decrease to approximately 40 years. The quadratic model implies that Green Valley housing prices increase with age up to about 4.5 years, then begin to decrease in value to 40 years. The cubic model implies that Green Valley housing prices increase with age until they are 3.5 years old, then decline in value until 12.5 years of age.

The first equation for each set treats the Pepcon/Kerr-McGee chemical complex as a "timeless" hazard. The Las Vegas Valley sample implies that property values *decrease* in value with distance up to 8.36 miles, then begin increasing. This result contradicts the hypothesis that the Pepcon plant was a hazard with a wide diameter and points up the problem in the quadratic functional form.[15]

For the combined sample from Henderson and Green Valley, and for the sample from Green Valley, property values are not significantly related to distance from the hazard in (1). For the Henderson sample, property values increase up to 4.55 miles from the hazard.[16] These results seem to imply that only in Henderson is the relation between property values stable with respect to the Pepcon explosion and the announcement of relocation to Cedar City.

For the entire Las Vegas Valley, introduction of terms for the Pepcon explosion (P) and the relocation announcement (C) render all distance coefficients statistically insignificant.[17]

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Table 2. Correlation coefficients.

Entire Sample (n = 7780)

	LRPRICE	AGE	$\ln(L^2)$	$\ln(B^2)$	MONTH	FP	POOL	D	D^2	P	PM	C	CM
LRPRICE	1.0000	-0.4793	0.3232	0.8115	0.1962	0.5258	0.3284	0.0542	0.0921	0.1599	0.1316	0.1672	0.1389
AGE	-0.4793	1.0000	0.1306	-0.2798	-0.0554	-0.4411	0.0115	0.0885	0.0214	-0.0420	0.0340	-0.0562	0.0211
$\ln(L^2)$	0.3232	0.1306	1.0000	0.3832	-0.0669	0.0476	0.2085	0.0000	-0.0128	-0.0581	-0.0321	-0.0613	-0.0369
$\ln(B^2$	0.8115	-0.2798	0.3832	1.0000	0.0970	0.4658	0.3254	-0.0083	0.0126	0.0863	0.0453	0.0882	0.0489
MONTH	0.1962	-0.0554	-0.0669	0.0970	1.0000	0.0497	-0.0477	-0.0061	0.0208	0.8604	0.4876	0.8707	0.5197
FP	0.5258	-0.4411	0.0476	0.4658	0.0497	1.0000	0.1297	0.0006	0.0223	0.0467	0.0239	0.0477	0.0253
POOL	0.3284	0.0115	0.2085	0.3254	-0.0477	0.1297	1.0000	0.0029	-0.0097	-0.0402	-0.0291	-0.0369	-0.0280
D	0.0542	0.0885	0.0000	-0.0083	-0.0061	0.0006	0.0029	1.0000	0.9828	-0.0098	0.7058	-0.0242	0.6650
D^2	0.0921	0.0214	-0.0128	0.0126	0.0208	0.0223	-0.0097	1.0000	0.0139	0.7143	0.0024	0.6770	
P	0.1599	-0.0420	-0.0581	0.0863	0.8604	0.0467	-0.0402	-0.0098	0.0139	1.0000	0.5628	0.9099	0.5313
PM	0.1316	0.0340	-0.0321	0.0453	0.4876	0.0239	-0.0291	0.7058	0.7143	0.5628	1.0000	0.4974	0.9429
C	0.1672	-0.0562	-0.0613	0.0882	0.8707	0.0477	-0.0369	-0.0242	0.0024	0.9099	0.4974	1.0000	0.5839
CM	0.1389	0.0211	-0.0369	0.0489	0.5197	0.0253	-0.0280	0.6650	0.6770	0.5313	0.9429	0.5839	1.0000

Henderson (Zip = 89015; n = 1764)

	LRPRICE	AGE	$\ln(L^2)$	$\ln(B^2)$	MONTH	FP	POOL	D	D^2	P	PM	C	CM
LRPRICE	1.0000	-0.4689	0.4986	0.7427	0.1548	0.5276	0.2949	0.4644	0.4634	0.1142	0.2796	0.1329	0.2828
AGE	-0.4689	1.0000	-0.0204	-0.2440	0.0583	-0.4278	-0.0115	-0.2839	-0.2774	0.0646	-0.0697	0.0511	-0.0705
$\ln(L^2)$	0.4986	-0.0204	1.0000	0.5178	0.0389	0.0944	0.1728	0.3869	0.4367	0.0187	0.1627	0.0305	0.1688
$\ln(B^2$	0.7427	-0.2440	0.5178	1.0000	0.0495	0.4253	0.2500	0.3890	0.3930	0.0413	0.1775	0.0517	0.1784
MONTH	0.1548	0.0583	0.0389	0.0495	1.0000	-0.0005	0.0020	0.0737	0.0728	0.8720	0.7779	0.8769	0.7880
FP	0.5276	-0.4278	0.0944	0.4253	-0.0005	1.0000	0.1003	0.3001	0.2866	-0.0116	0.1106	-0.0004	0.1132
POOL	0.2949	-0.0115	0.1728	0.2500	0.0020	0.1003	1.0000	0.1106	0.1111	-0.0098	0.0285	0.0131	0.0488
D	0.4644	-0.2839	0.3869	0.3890	0.0737	0.3001	0.1106	1.0000	0.9828	0.0723	0.4199	0.0704	0.3982
D^2	0.4634	-0.2774	0.4367	0.3930	0.0728	0.2866	0.1111	0.9828	1.0000	0.0675	0.4129	0.0680	0.3949
P	0.1142	0.0646	0.0187	0.0413	0.8720	-0.0116	-0.0098	0.0723	0.0675	1.0000	0.8920	0.9237	0.8309
PM	0.2796	-0.0697	0.1627	0.1775	0.7779	0.1106	0.0285	0.4199	0.4129	0.8920	1.0000	0.8260	0.9356
C	0.1329	0.0511	0.0305	0.0517	0.8769	-0.0004	0.0131	0.0704	0.0680	0.9237	0.8260	1.0000	0.8995
CM	0.2828	-0.0705	0.1688	0.1784	0.7880	0.1132	0.0488	0.3982	0.3949	0.8309	0.9356	0.8995	1.0000

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Table 2. Continued.

Green Valley (Zip = 8901; n = 3094)

	LRPRICE	AGE	$\ln(L^2)$	$\ln(B^2)$	MONTH	FP	POOL	D	D^2	P	PM	C	CM
LRPRICE	1.0000	-0.0717	0.5551	0.8602	0.0925	0.3278	0.3433	-0.0431	-0.0092	0.0676	0.0313	0.0703	0.0398
AGE	-0.0717	1.0000	0.0992	-0.1074	0.0057	-0.1044	0.0753	0.0183	0.0043	-0.0009	0.0243	-0.0070	0.0225
$\ln(L^2)$	0.5551	0.0992	1.0000	0.5102	-0.1062	0.1764	0.2990	0.1007	0.0835	-0.0965	-0.0198	-0.1026	-0.0343
$\ln(B^2$	0.8602	-0.1074	0.5102	1.0000	0.0004	0.3480	0.3154	-0.0594	-0.0160	0.0022	-0.0369	0.0009	-0.0340
MONTH	0.0925	0.0057	-0.1062	0.0004	1.0000	-0.0671	-0.0950	-0.1123	-0.0535	0.8499	0.6284	0.8628	0.6632
FP	0.3278	-0.1044	0.1764	0.3480	-0.0671	1.0000	0.0835	0.0330	0.0116	-0.0429	-0.0229	-0.0598	-0.0383
POOL	0.3433	0.0753	0.2990	0.3154	-0.0950	0.0835	1.0000	0.0107	0.0047	-0.0824	-0.0623	-0.0858	-0.0678
D	-0.0431	0.0183	0.1007	-0.0594	-0.1123	0.0330	0.0107	1.0000	0.8871	-0.1041	0.5000	-0.1206	0.4562
D^2	-0.0092	0.0043	0.0835	-0.0160	-0.0535	0.0116	0.0047	0.8871	1.0000	-0.0478	0.5076	-0.0565	0.4781
P	0.0676	-0.0009	-0.0965	0.0022	0.8499	-0.0429	-0.0824	-0.1041	-0.0478	1.0000	0.7721	0.9135	0.7215
PM	0.0313	0.0243	-0.0198	-0.0369	0.6284	-0.0229	-0.0623	0.5000	0.5076	0.7721	1.0000	0.6876	0.9267
C	0.0703	-0.0070	-0.1026	0.0009	0.8628	-0.0598	-0.0858	-0.1206	-0.0565	0.9135	0.6876	1.0000	0.7897
CM	0.0398	0.0225	-0.0343	-0.0340	0.6632	-0.0383	-0.0678	0.4562	0.4781	0.7215	0.9267	0.7897	1.0000

Random Sample of Las Vegas and Unincorporated Clark County (n = 2931)

	LRPRICE	AGE	$\ln(L^2)$	$\ln(B^2)$	MONTH	FP	POOL	D	D^2	P	PM	C	CM
LRPRICE	1.0000	-0.5026	0.3358	0.7741	0.1798	0.4996	0.2882	0.3135	0.3501	0.1469	0.2537	0.1536	0.2524
AGE	-0.5026	1.0000	0.1846	-0.2367	-0.0341	-0.4096	0.0832	-0.5259	-0.5469	-0.0208	-0.2123	-0.0335	-0.2071
$\ln(L^2)$	00.3358	0.1846	1.0000	0.3841	-0.0631	0.0605	0.2275	-0.0723	-0.0443	-0.0430	-0.0684	-0.0536	-0.0745
$\ln(B^2$	0.7741	-0.2367	0.3841	1.0000	0.0982	0.4577	0.3231	0.1545	0.1769	0.0884	0.1400	0.0870	0.1357
MONTH	0.1798	-0.0341	-0.0631	0.0982	1.0000	0.0412	-0.0742	0.1719	0.1833	0.8549	0.8044	0.8671	0.8190
FP	0.4996	-0.4096	0.0605	0.4577	0.0412	1.0000	0.1198	0.2400	0.2517	0.0416	0.1172	0.0439	0.1100
POOL	0.2882	0.0832	0.2275	0.3231	-0.0742	0.1198	1.0000	-0.1239	-0.1210	-0.0572	-0.0947	-0.0537	-0.0872
D	0.3135	-0.5259	-0.0723	0.1545	0.1719	0.2400	-0.1239	1.0000	0.9892	0.1528	0.4615	0.1557	0.4368
D^2	0.3501	-0.5469	-0.0443	0.1769	0.1833	0.2517	-0.1210	0.9892	1.0000	0.1622	0.4733	0.1677	0.4512
P	0.1469	-0.0208	-0.0430	0.0884	0.8549	0.0416	-0.0572	0.1528	0.1622	1.0000	0.9209	0.8938	0.8316
PM	0.2537	-0.2123	-0.0684	0.1400	0.8044	0.1172	-0.0947	0.4615	0.4733	0.9209	1.0000	0.8322	0.9125
C	0.1536	-0.0335	-0.0536	0.0870	0.8671	0.0439	-0.0537	0.1557	0.1677	0.8938	0.8322	1.0000	0.9304
CM	0.2524	-0.2071	-0.0745	0.1357	0.8190	0.1100	-0.0872	0.4368	0.4512	0.8316	0.9125	0.9304	1.0000

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Table 3. Regression results (dependent variable: log of real price): quadratic distance specification.

	Las Vegas Valley	Las Vegas Valley	Henderson Green Valley	Henderson Green Valley	Henderson	Henderson	Green Valley	Green Valley
Log	5.91[1]	5.89[1]	5.91[1]	5.74[1]	6.68[1]	6.61[1]	5.16[1]	5.03[1]
Intercept	113.85	112.18	99.32	85.15	60.31	57.39	69.68	59.41
AGE	-0.0128[1]	-0.0128[1]	-0.0020	-0.0020	-0.0088[1]	-0.0088[1]	0.0350[1]	0.0363[1]
	-22.04	-21.97	-1.66	-1.68	-8.34	-8.37	7.87	8.14
AGE^2	0.000119[1]	0.000119[1]	-0.0003[1]	-0.0003[1]	0.000054[1]	0.000056[2]	-0.0064[1]	-0.0068[1]
	8.17	8.17	-3.94	-4.09	2.27	2.34	-6.29	-6.69
AGE^3			5.35E-06[1]	5.59E-06[1]			0.000266[1]	0.0003[1]
			3.91	4.10			4.27	4.68
$\ln(L^2)$	0.1287[1]	0.1294[1]	0.1176[1]	0.1214[1]	0.1322[1]	0.1307[1]	0.1607[1]	0.1352[1]
	26.66	26.86	19.02	19.60	13.54	13.42	16.37	16.50
$\ln(B^2)$	0.5704[1]	0.5679[1]	0.5747[1]	0.5709[1]	0.4096[1]	0.4094[1]	0.6585[1]	0.6523[1]
	79.59	79.22	67.49	66.95	26.08	26.16	68.42	67.52
MONTH	0.0022[1]	0.0028[1]	0.0021[1]	0.0027[1]	0.0022[1]	0.0030[1]	0.0020[1]	0.0026[1]
	21.08	12.98	17.50	10.68	11.06	6.73	13.83	8.75
FP	0.0577[1]	0.0591[1]	0.0722[1]	0.0736[1]	0.0912[1]	0.0921[1]	0.0347[1]	0.0362[1]
	11.67	11.96	12.00	12.29	10.34	10.48	4.09	4.29
PL	0.0793[1]	0.0796[1]	0.0654[1]	0.0642[1]	0.1127[1]	0.1144[1]	0.0425[1]	0.0416[1]
	17.93	18.04	12.79	12.62	9.79	9.95	8.09	7.97
D	-0.0117[1]	-0.0006	0.0045	0.1110[1]	0.0773[1]	0.1296[1]	0.0008	0.1141[1]
	-4.88	-0.17	1.16	5.45	4.48	4.66	0.20	3.42
D^2	0.0007[1]	0.000010	-0.0004	-0.0166[1]	-0.0085[1]	-0.0164[1]	-0.0002	-0.0181[1]
	6.71	0.06	-1.06	-5.82	-3.63	-4.31	-0.48	-3.74
Z89014	-0.0067[1]	-0.0032[1]						
	-0.58	-0.28						
Z89015	-0.1321[1]	-0.1294[1]	-0.1541[1]	-0.1535[1]				
	-12.39	-12.07	-29.61	-29.57				

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Table 3. Continued.

	Las Vegas Valley	Las Vegas Valley	Henderson Green Valley	Henderson Green Valley	Henderson	Henderson	Green Valley	Green Valley
Eog		-0.0031		-0.1940		-0.2519		-0.0931
		-0.10		-1.51		-1.20		-0.59
C		0.0095		0.3231		0.3592		0.2179
		0.32		2.60		1.73		1.48
PD		-0.0070		0.0954		0.0753		0.0623
		-0.80		1.24		0.59		0.67
PD^2		0.0004		-0.0127		-0.0030		-0.0117
		0.94		-1.16		-0.16		-0.89
CD		-0.0075		-0.2018[1]		-0.1637		-0.1723[2]
		-0.88		-2.71		-1.29		-1.98
CD^2		0.0004		0.0291[1]		0.0158		0.0296[2]
		1.01		2.75		0.86		2.41
Observations	7780	7780	4848	4848	1764	1764	3084	3084
Adjusted R^2	0.7962	0.7972	0.8249	0.8267	0.7317	0.7341	0.7813	0.7838
Durbin-Watson	1.77	1.78	1.97	1.98	1.98	1.99	1.93	1.94
Multiple F	2763.5[1]	1799.3[1]	2081.5[1]	1363.8[1]	535.3	325.5	1106.0	701.9
F-to-include		7.22[1]		9.24[1]		3.63[1]		6.95[1]
SSE	164.60	163.68	83.46	82.51	35.57	35.13	41.89	41.33

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In the combined sample for Henderson and Green Valley, introduction of the event indicators renders the coefficients on distance and distance squared both statistically significant, implying that property values increased at a decreasing rate with distance from the plant site *before* the explosion ($P = C = 0$). The explosion itself decreased property values in the combined sample by 17.6%, a result that is significant at the 10% level for a *one-tail* test. After the explosion, property values rebounded by 38%, implying some discount in value prior to the incident. Between the time of the explosion and the relocation announcement, the change in value with respect to distance is given by: $\partial \ln(p)/\partial d = 0.206 - 0.0293d$. This implies a maximum value at a distance of 3.5 miles. After the relocation announcement, the value-distance relation becomes: $\partial \ln(p)/\partial d = 0.0046 - 0.0002d$, which, for all intents and purposes, is no relationship at all.[18]

In the Henderson sample, introduction of the interaction terms between the explosion (P), the relocation announcement (C), and distance (D) increases the absolute value on both distance and distance squared. Before the explosion, property values were maximized approximately four miles from the plant site. Although none of the interacttion terms are significant,[19] the picture which they paint indicates a decline in property values by 22.3% in the wake of the explosion, and a recovery by 43.2% after the relocation announcement. After the relocation announcement, the property value reaction function becomes: $\partial \ln p/\partial D = 0.412 - 0.0036D$, implying no effect from the remaining chemical plant at 5.7 miles.

The situation in Green Valley is somewhat different. If the timing of the explosion is ignored, property values in Green Valley appear independent of the distance from the plant site. Introducing the date of the explosion indicates that, prior to the explosion, property values increase at the rate of 4.17% at a distance of two miles from the chemical plant. After the explosion, but prior to the relocation announcement, property values increase at a rate of 12% at a distance of two miles from the plant site(s).[20] After the relocation announcement, property values increase by 0.33% per mile two miles from the hazard. Two explanations suggest themselves: (1) that new home buyers in Green Valley are unaware that some hazard still exists after the relocation announcement; (2) that the "bandwagon effect" of the growth in Green Valley is nearly as strong as the fear of the remaining hazard, causing the two to cancel.

7. Discontinuous distance function

For reasons mentioned above, there are reasons to question the validity of the quadratic relation between property values and distance from the hazard. Assuming a continuous relation means that the function can be pulled out of shape by the existence of other hazards some distance away from the hazard in question. Table 3a presents the results of the discontinuous distance specification introduced as (1a) and (2a) above. Variable MI_d is coded as one for all properties within d miles of the plant site, and coded as zero for all properties more than d miles away. The reference group for each equation consists of properties $d_{max} + 1$ miles removed. For the Las Vegas Valley, we include indicators for *MI2* through *MI*10; the reference group consists of properties more than ten miles distant from the plant.

First, we note that the coefficients on *MI2* are consistent across the eight regression results. Properties within two miles of the Pepcon plant are depressed 6.3% for the Las Vegas Valley

Table 3a. Regression results (dependent variable: log of real price): discrete distance specification.

	Las Vegas Valley	Las Vegas Valley	Henderson Green Valley	Henderson Green Valley	Henderson	Henderson	Green Valley	Green Valley
Log intercept	5.98[1]	5.97[1]	5.99[1]	5.98[1]	6.95[1]	6.93[1]	5.41[1]	5.43[1]
	117.25	116.85	91.20	90.20	60.32	60.13	63.07	62.35
AGE	-0.0151[1]	-0.0151[1]	-0.0013	-0.0012	-0.0088[1]	-0.0089[1]	0.0363[1]	0.0367[1]
	-27.17	-27.07	-1.08	-1.05	-8.32	-8.36	8.36	8.43
AGE^2	0.000162[1]	0.000161[1]	-0.000436[1]	-0.000435[1]	0.000046[1]	0.000049[2]	-0.006727[1]	-0.006817[1]
	11.15	11.09	-5.42	-5.41	1.93	2.04	-6.75	-6.83
AGE^3			7.31E-06[1]	7.92E-06[1]			0.00028[1]	0.00028[1]
			5.40	5.39			4.62	4.68
$\ln(L^2)$	0.1329[1]	0.1327[1]	0.1224[1]	0.1215[1]	0.1281[1]	0.1259[1]	0.1328[1]	0.1324[1]
	27.10	27.07	19.32	19.18	13.04	12.80	16.47	16.38
$\ln(B^2)$	0.5551[1]	0.5549[1]	0.5564[1]	0.5566[1]	0.3985[1]	0.3991[1]	0.6351[1]	0.6342[1]
	77.24	77.15	65.54	65.44	25.18	25.29	66.82	66.74
MONTH	0.0024[1]	0.0030[1]	0.0022[1]	0.0027[1]	0.0023[1]	0.0030[1]	0.0020[1]	0.0025[1]
	23.14	13.96	18.28	10.85	11.46	6.95	13.99	8.82
FP	0.0503[1]	0.0507[1]	0.0693[1]	0.0699[1]	0.0899[1]	0.0904[1]	0.0276[1]	0.0283[1]
	10.25	10.32	11.70	11.79	10.24	10.32	3.33	3.40
POOL	0.0746[1]	0.0745[1]	0.0618[1]	0.0616[1]	0.1105[1]	0.1113[1]	0.0398[1]	0.0401[1]
	17.03	17.04	12.26	12.24	9.64	9.71	7.78	7.87
MI2	-0.0649[1]	-0.0792[1]	-0.0649[1]	-0.0816[1]	-0.0627[1]	-0.0748[1]	-0.0675[1]	-0.0922[1]
	-11.38	-7.05	-12.41	-8.01	-5.91	-4.74	-12.39	-7.22
MI3	0.0497[1]	0.0629[1]	0.0494[1]	0.0651[1]	0.0161	0.0172	0.0608[1]	0.0915[1]
	8.84	6.18	9.60	7.07	1.65	1.16	10.90	8.31
MI4	0.0125	0.0167	0.0092	0.0147	-0.0445[1]	-0.0080	0.0136	-0.0075
	1.66	1.69	1.34	1.28	-3.19	-0.41	1.82	-0.55
MI5	0.0249	0.0252	0.0124	0.0128	0.0525[1]	0.0516[1]	-0.0792[2]	-0.0818[2]
	1.66	1.68	0.86	0.89	2.80	2.72	-2.15	-2.21
MI6	-0.0155	-0.0160						
	-0.69	-0.72						

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Table 3a. Continued.

	Las Vegas Valley	Las Vegas Valley	Henderson Green Valley	Henderson Green Valley	Henderson	Henderson	Green Valley	Green Valley
MI7	0.0150	0.0153						
	0.68	0.70						
MI8	0.1121[1]	0.1120[1]						
	5.54	5.54						
MI9	0.0070	0.0076						
	0.42	0.45						
M10	-0.0747[1]	-0.0747[1]						
	-6.10	-6.11						
Z89014	-0.1083[1]	-0.1081[1]						
	-5.71	-5.71						
Z89015	-0.2307[1]	-0.2313[1]	-0.1524[1]	-0.1524[1]				
	-12.35	-12.38	-29.47	-29.41				
P		-0.0176		-0.0148		0.0527		-0.0780[2]
		-1.46		-0.57		1.14		-2.65
C		-0.0038		0.0037		-0.0394		0.0432
		-0.32		0.15		-0.87		1.53
PMI2		-0.0442		-0.0471		-0.0877		-0.0056
		-1.25		1.49		-1.60		-0.15
PMI3		0.0231		0.0147		-0.0223		0.0202
		0.78		0.55		-0.47		0.68
PMI4		-0.0131		-0.0141		-0.0641		0.0409
		-0.57		-0.45		-1.19		1.15
CMI2		0.0665		0.0725[2]		0.1144[2]		0.0383
		1.95		2.37		2.11		1.10
CMI3		-0.0433		-0.0382		0.0195		-0.0632[2]
		-1.52		-1.49		0.42		-2.23

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Table 3a. Continued.

	Las Vegas Valley	Las Vegas Valley	Henderson Green Valley	Henderson Green Valley	Henderson	Henderson	Green Valley	Green Valley
CMI4		0.0064		0.0053		0.0081		-0.0138
		0.29		0.17		0.15		-0.40
Observations	7780	7780	4848	4848	1764	1764	3084	3084
Adjusted R^2	0.8009	0.8014	0.8310	0.8315	0.7345	0.7365	0.7945	0.7959
Durbin-Watson	1.87	1.88	1.88	1.95	1.93	1.93	1.92	1.93
Multiple F	1739.9[1]	1208.0[1]	1833.9[1]	1139.8[1]	444.4[1]	260.3[1]	994.2[1]	602.0[1]
F-to-include		3.05[1]		2.84[1]		2.64[1]		3.60[1]
SSE	164.5979	163.684	83.45809	82.51262	35.56699	35.13274	41.8905	41.33016

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and the combined sample of Henderson and Green *before* the explosion. The consistency of this result is heartening, since the only properties within two miles of the Pepcon plant site are within Green Valley and Henderson. Prior to the explosion, Henderson properties prices were depressed by 6%, while Green Valley properties were depressed 6.5%. Introducing the event interaction terms consistently increases the coefficient on *MI2*, indicating that property values were depressed by a greater amount before the explosion then afterwards. Only in Green Valley was the coefficient on *P* significantly negative; in no case was the coefficient on *C* significantly positive.

The coefficient on *PM2*, while consistently negative, is never significant. The coefficient on *CM12* is significantly positive in the Henderson–Green Valley combined sample, and for Henderson.

The coefficient on *MI3* is consistently positive in all eight regressions, and consistently smaller than the coefficient on *MI2*. This implies that houses between 2.5 and 3.5 miles from the hazard typically sell for more than houses within 2.5 miles of the site. The sample of Green Valley properties shows coefficients equal in absolute value, indicating that the adverse effects of the hazard are neutralized at three miles. Henderson properties show only minor recovery at three miles and a significant decrease at four miles. Introduction of the indicators for the explosion and the relocation announcement render the coefficient on *MI4* insignificant. The coefficient on *MI5* is positive and significant for the Henderson sample, implying that the effect of the hazard was felt over a larger distance in Henderson than in the rest of the valley (effectively, Green Valley).

Table 4 presents evidence that the discontinuous distance specification is consistently better, as measured by the sum of the squared errors (SSE). The sum of the squared errors of the quadratic specification is broken down into two components, the sum of squared pure error (SSPE), which is equal to the sum of squared errors for the discontinuous specification, and the sum of squares due to lack of fit (SSLF), equal to the difference between the sum of squares of the two specifications. By construction, the discontinuous model will result in a smaller sum of squares, because the fit is not forced to follow a continuous curve. Because a set of discrete distance dummy variables is required, the question is whether the smaller sum of squares gained by the discontinuous specification is worth the loss of degrees of freedom. The mean squared errors due to lack of fit (MSLF) equal the SSLF divided by the difference in the number of regressors. This is then divided by the mean square pure error (MSPE) to yield the *F*-statistic. In each case, we reject the null hypothesis that the discontinuous specification is not superior to the continuous (quadratic) one.

8. Conclusion

The dramatic explosion of the Pepcon chemical plant in Henderson, Nevada, on May 4, 1988 and the announcement of the removal of the hazard on July 27, 1988 provide a unique opportunity to investigate the dynamic effect of a transient hazard on residential property values. This article has shown that, prior to the explosion, property values in both older Henderson (zip = 89015) and booming Green Valley (zip = 89014) varied significantly with distance from the hazard. After the explosion, property values became more sensitive (although insignificantly so) to the distance from the site of the explosion. This could be

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Table 4. Lack of fit test: Quadratic vs. general surface estimate.

	Entire Sample		Henderson Green Valley		Henderson		Green Valley	
	Without Event Indicators	With Event Indicators	Without Event Indicators	With Event Indicators	Without Event Indicators	With Event Indicators	Without Event Indicators	With Event Indicators
				Quadratic Distance Specification				
SSE	164.5979	1673.6838	83.45809	82.51262	35.5699	35.13274	41.8905	41.33016
dfn	11	19	11	17	9	15	10	16
dfd	7768	7760	4846	4840	1754	1748	3083	3077
				Discontinuous Distance Specification				
SSE	160.6085	160.1045	80.55949	80.17327	35.16172	34.74175	39.41269	39.03247
dfn	18	26	13	21	11	19	12	20
dfd	7761	7761	4844	4836	1752	1744	3081	3073
MSLF	0.569914	0.511329	1.4493	0.584837	0.20409	0.097748	1.238905	0.574423
MSPE	0.020694	0.020629	0.016631	0.016578	0.020069	0.019921	0.012792	0.012702
F	27.53967	24.78644	87.14565	35.27702	10.16917	4.906824	96.84866	45.2239
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

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explained by residents underestimating the probability of the hazard, or because of adverse selection: buyers might feel that property sold soon after the explosion had unrepaired damage. After the announcement that the plant was not to be rebuilt in southern Nevada, property prices in old Henderson and Green Valley became less sensitive to the distance from the remaining producer of ammonium perchlorate.

We contrasted a continuous and discontinuous specification of the relation between real housing prices and distance from the hazard and found the latter model to be consistently superior. The discontinuous model showed a suppression of housing prices within two miles of the hazard and was insensitive to the mean distance from the hazard in the sample. This is a feature not shared by the quadratic specification. We also found that property values were higher for properties between 2.5 and 3.5 miles of the hazard, relative to properties that are closer. Only in Henderson were property values depressed as far as 5.5 miles from the plant site. We highly recommend that future articles on the impact of hazardous locations on residential property values at least consider the discontinous specification attempted here.[21]

Most importantly, our results support the emerging consensus that real-estate markets are informationally efficient. There is clear evidence that home buyers discounted properties close to the hazard site *prior to* the explosion. Property values generally declined after the explosion, perhaps reflecting price concessions by sellers hoping to close in a market suddenly vulnerable to price renegotiation and higher search costs. After the announcement that one of the hazards would be relocated, rather than rebuilt, property values rebounded. So, even in a market where prices were contracted some time before the close of the deal, we have shown that such prices were sensitive to dramatic information about a hazard, in the form of an explosion, and to the reassurance that the hazard had been removed.

Notes

1. Ldn is a decibel measure whose weighting contains a penalty for nighttime noise.
2. Although exchange prices on a transaction day are generally set several weeks earlier, events such as the Pepcon explosion, which might have caused even superficial damage, will provide the buyer with an opportunity to force a renegotiation of price. For instance, buyers may refuse to close on the scheduled date without price concessions. Rather than voiding the sales contract and searching for a new buyer in a now troubled market, the seller may acquiesce to the lower price. Thus, although institutional rigidities should lead one to expect little price reaction within a day or so of the event, we nonetheless test the model as though the market were so efficient as to allow quick renegotation of contractually agreed-upon prices.
3. Even if homeowners feared personal injury, the greatest loss would be income loss, which would also be proportional to the value of the home.
4. A set of variables measuring the condition fo the housing market (varying monthly) were also tried. These variables included the log of the mortgage interest rate (*LMORT*), the change in the housing stock (*DH*), the county unemployment rate (*CCUE*), and the percent change in population (DPOP). Since these variables were uniformly insignificant, the results of the regressions are suppressed here, but will be provided upon request.
5. Several observations were dropped because the year sold preceded the year built (e.g., the owner built a custom home), so that the transfer price reflected only the price of the land, and not the structure.
6. An indicator variable for the presence of one or more fireplaces was used instead of the number of fireplaces, because the latter variable was more highly correlated with the size of the building.
7. The distance measure in feet was computed in feet by the Transportation Research Center at UNLV. Because of the proximity of the Pepcon plant to the Kerr-McGee plant, which also manufactures ammonium perchlorate (they are approximately 2/3 of a mile apart), the distance variable was divided by 5,280 feet and rounded to the nearest mile.

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8. Taking the partial derivative of the equation with respect to d and setting the result equal to zero, we have: $\beta_8 + 2\beta_9 d = 0 \rightarrow d^* = -(\beta_8/2\beta_9)$.
9. It is typical in the literature for the efficient market hypothesis to be the *null* hypothesis. The investigator hypothesizes that current price cannot be predicted from past prices, then "proves" this hypothesis by showing the lack of a significant relation between current and past prices. Appropriate use of the scientific method requires that the hypothesis which one wishes to support should bear the burden of proof, and therefore should be the *alternative* hypothesis.
10. As explained below, we also estimate a model that uses dummy variables for discrete distances from the hazard. This model fit the data significantly better than the quadratic model discussed here. This finding has implications for future hazard models.
11. For very new homes, value may actually increase with age due to an adverse selection. Buyers would infer that resales of nearly new homes indicate a seller trying to unload a lemon. With time, the probability that defects had been repaired would increase and, accordingly, the house's value. For this reason, a cubic model of price and the age of the house was fit for Green Valley, whose median age at the time of sale was one year. We also employ a cubuc age specification for the combined sample of Green Valley and Henderson.
12. Actually, this is 2.5 miles, due to rounding.
13. The random sample was selected by picking sellers whose last names began with the letters A, B, and Ca.
14. *Metroscan* reports data on the most recent sale of each home in the data set. This rules out the investigation of repeat sales for the same property, so we are unable to investigate arbitrage activity on individual properties.
15. A *cubic* distance specification is a positive sign on miles (significant at 5% level), a negative sign on miles squared, (significant at .01 level), and a positive sign on distance cubed (also significant at the .01 level). This specification implies that property values increase up to 2.7 miles from the hazard, then decrease up to 12.3 miles, which is the approximate distance from the plant site to downtown Las Vegas, Nellis Air Force Base, and about one mile west of the Las Vegas Strip.
16. $\frac{\partial lP}{\partial d} = 0.0773 - 2(.0085)d = 0 \rightarrow d^* = \frac{0.0773}{0.017} = 4.547.$
17. The same thing happens in the cubic distance specification.
18. There is a 36% probability that neither distance nor distance squared has any impact on real price on observations restricted to after the relocation announcement.
19. The F-statistic for inclusion of the set of interaction variables is significant at the 1% level for each sample. However, the F-statistic for Henderson is the smallest of the four samples.
20. Restricting the regression to the 101 observations on Green Valley when $P = 1$ yields the equation:

$$\frac{\partial lp}{\partial d} = .166 - .058d \rightarrow d^* = \frac{.166}{0.058} = 2.86.$$

21. The only drawback to the discontinuous model is that it requires breaking distance into discrete units. It was natural for this study to specify distance in integer miles, given the proximity of a continuing hazard (the Kerr-McGee plant) and a transient one (the Pepcon plant). Other investigators may have to experiment with the optimal discrete distance units.

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Attachment E
Exhibit 4006-000025-CWF
Columbia Waterfront LLC

The Effect of Freight Railroad Tracks and Train Activity on Residential Property Values

by Robert A. Simons, PhD, and Abdellaziz El Jaouhari, PhD

abstract

This study evaluates the impact of freight railroad tracks on housing markets. A hedonic price model is used to estimate reduction in the sale price of residential properties near freight railroad tracks in Cuyahoga County, Ohio for 1996 and 1999. The findings indicate an average loss in value between $3,800 and $5,800 (5%–7%) for houses under 1,250 square feet located within 750 feet from a railroad track. Larger houses showed mixed results. After substantial publicity about a freight train company merger, freight trip counts showed a negative and statistically significant impact on the sale price of smaller houses, and some larger houses, for each additional daily freight train trip.

The benefits of transportation in linking markets and generating positive externalities are well established in economic theory. Access to transportation links, such as highway interchanges, airport hubs, train stations, and boat landings, is a positive factor. However, being too close to transportation uses that are far away from access links can have a negative effect on property values due to the nuisance and potential problems of accidents. This is particularly true for railroads that crisscross the country carrying freight and have very few access points. For freight railroads, the access points are not directly used by residential property owners. In addition, there is train noise and whistle blowing as the trains pass by, the fear of accidents exists, and potential for other related nuisances. The main questions addressed by the research here are how much markets discount houses near railroad tracks and whether the discount decreases with distance from the track and less freight trip volume.

Variables Related to Railroad Freight Lines

Periodically, train companies merge and consolidate track activity; sometimes this can lead to changes in trip volumes on specific segments. Because proximity to train tracks is considered a nuisance, nearby property values can be affected. The effect could be related solely to proximity or to the volume of activity (e.g., freight train cars passing by the property). Effects may also be more pronounced on properties adjacent to where the freight lines cross streets. Also, if trip counts change due to rerouting, would there be any differential effect on property values? This study finds that rail traffic, as opposed to simply proximity to tracks, makes a difference in the sale price of residential properties. Further, publicity is found to increase public awareness of this issue.

In the Cleveland, Ohio area in the mid- to late-1990s, CSX Corporation (CSX) and Norfolk Southern Corporation (Norfolk Southern) decided to reorganize and acquire another railroad, Consolidated Rail Corporation (Conrail). An environmental impact statement (EIS) was done to determine track

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reconfiguration. Freight trip counts on various segments were scheduled to change. Beginning in 1997, there was a lot of publicity regarding the reconfiguration, and the railroad lines negotiated with various cities about the impacts of the train reconfiguration on property values. Cities received millions of dollars, but none of the money went toward property damage awards. By 1999, the EIS process had been completed and changes to track volumes had been implemented.

This study examines the "before" and "after" of the reconfiguration in freight railroads in Cuyahoga County, Ohio, and comments on the inclusion of property damage awards in a process of this type. The study focuses on the effect of freight-carrying railroad tracks on single-family housing in Cuyahoga County, Ohio, which includes a total of 15 rail segments with over 50 miles of track. After a review of the extant literature, this article discusses the study area, data collection, and variables. Size-stratified hedonic regression models of the county residential real estate market are developed, and the proximity to railroad tracks is tested in various forms. The results are presented, as well as conclusions and implications for appraisers.

Overview and Literature Review

This study was inspired, in part, by a project done in a graduate urban planning class on the factors affecting the desirability of an urban neighborhood. A questionnaire was administered in person to 105 prospective homebuyers of inner-city homes on the near-west side of Cleveland, Ohio, during the summer of 2000. The questions mainly related to neighborhood characteristics that could have a positive or a negative effect on housing values. Residents were asked to weigh their willingness to live close to various urban factors (e.g., an auto junkyard, interstate, railroad tracks, city park) on a seven-point scale, where -3 was strongly negative and +3 was very desirable. The results of the questionnaire are shown in Table 1.

The least desirable site characteristics were junkyard (-2.81), leaking underground storage tank (LUST) (-2.71), and factory (-2.60). Living next to a train track had the next most negative score of -2.07, closely followed by proximity to a highway and main street (both about -1.9). Scores ranged up to +2.2 for lake views.[1]

Table 1 Survey of Prospective Homebuyers in Cleveland, Ohio: Urban Disamenities and Amenities

Site Characteristics	Scale of the Results
Next to an auto junkyard	-2.810
Next to a gas station with a tank leaking petroleum	-2.709
Next to a factory	-2.600
Next to a train track with about 15 trains per day	-2.067
Next to an interstate highway	-1.990
On a main 4-lane street	-1.933
Has no basement	-1.598
On a former brownfield; cleaned to state risk-based standards	-1.231
Next to a retail complex	-1.019
Next to a grade school	-0.567
Ohio City, south of Lorain Avenue	-0.388
Next to a new cemetery	-0.320
On a former brownfield; cleaned "clean enough to eat the dirt"	-0.192
Next to a secure and historic water tower park	-0.019
Has affordable housing mixed in	0.010
Next to old cemetery with trees	0.590
Next to a city park	0.683
View of downtown skyline	1.733
View of Lake Erie	2.229

n = 105

Effects of Other Linear Urban Uses on Residential Property

Roads are a linear land use similar in some ways to railroad tracks. Hughes and Sirmans found a significant 1% negative change in residential property values for each 1,000 annual average daily traffic (AADT) in city areas, and a 0.5% change per 1,000 AADT in suburban areas in Baton Rouge, Louisiana.[2] A related study by the same authors showed an 11% decrease in value for houses on high traffic streets, compared with low traffic streets.[3] However, this study did not explicitly control for street design. This same research also showed an average reduction of 0.8% in property values per 1,000 AADT.[4] For a typical collector street with 5,000 to 10,000 more trip counts per day than a purely residential street, this would equate to a 5%–10% reduction in property values, holding all else constant.

1. Some of these items have been empirically tested. Leaking underground storage tanks, for example, have been linked to a 13%–17% reduction in residential property value in the same Cuyahoga County, Ohio area. See Robert A. Simons, William Bowen, and Arthur Sementelli, "The Effect of Underground Storage Tanks on Residential Property Values in Cuyhoga County, Ohio," *Journal of Real Estate Research* 14, no. 1/2 (1997): 29–42. Because this score was worse than for the railroad tracks, the expected result should be less than this amount.
2. William T. Hughes Jr. and C.F. Sirmans, "Traffic Externalities and Single-Family House Prices," *Journal of Regional Science* 32, no. 4 (1992): 487–500.
3. William T. Hughes Jr. and C.F. Sirmans, "Adjusting House Prices for Intra-Neighborhood Traffic Differences," *The Appraisal Journal* (October 1993): 533–538.
4. Ibid.

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Another linear and visible type of land use that is somewhat similar to railroad tracks is high-voltage overhead electrical transmission lines (HVOTL). Studies by Colwell, and Kinnard and Dickey showed a significant reduction of 5%–8% in residential property values within a few hundred feet of the transmission lines.[5] Another use similar to trains in its linearity is pipelines. In a study of the effect of a pipeline rupture on non-contaminated residential property on the pipeline easement in Fairfax County, Virginia, Simons estimated that single-family housing experienced a loss in value of 4%–5% after the rupture.[6]

Rail Impact Studies

Noise, especially from train horns, is the primary negative externality generated by train traffic. A study by Rapoza, Rickley, and Raslear[7] found that residents living within 1,000 feet of a railroad track were severely annoyed by train horns.Consistent with this unsurprising finding, many communities have enacted regulations to ban the use of train horns especially during nighttime hours to reduce the interference of train noise with the comfort of local residents. However, numerous studies funded by the Federal Railroad Administration (FRA) have proven that banning train horns increases fatalities and that the bans are costly to both residents and railroad companies.[8]

The FRA's numerous studies on the impact of noise on communities have also evaluated the effectiveness of warning systems, specifically the wayside train horn at crossing sections. A study conducted by the U.S. Department of Transportation and the FRA indicated that the use of railroad horns in addition to wayside horns could reduce accidents by 69%. The same study surveyed actions taken by residents to reduce the interference of noise with their daily activities. While most residents, as reported by the study, would stop talking or close windows, 14% considered moving.[9]

Most studies measure the frequency and level of noise to assess their impact on residents or property values. Few studies have examined the effect of proximity to a railroad track in terms of distance. Clark used distance from a railroad track to measure loss in property values for the mostly rural districts of Middletown and Niles in Ohio.[10] The findings indicate property values decreased by 2.1% in Middletown and 2.8% in Niles for every additional rail line within a buffer of ¼ mile. The loss is even higher for properties located near a crossing section where the use of train horns is more frequent. Another study in Oslo, Norway, looked at the relationship between tracks and residential sale price, based on pure proximity. Residential sale price decreased by up to 7%–10% within 100 meters (about 330 feet) of a railroad track.[11] These results were derived from both hedonic modeling and a type of contingent valuation analysis done by real estate salespeople.

To summarize, the benefits of railroad transportation in connecting markets are well established in economic theory but there is still a tension between the need for safety and the need to reduce the level of annoyance generated by railroad activities. Based on previous train studies and the negative effect on property values from other similar urban land uses, property value decreases in the single digits are expected from trains and train traffic.

Railroad Merger in Cleveland

Railroads sometimes merge and consolidate. As previously noted, in Cleveland this began in 1997 as CSX and Norfolk Southern sought to combine operations, acquire Conrail, and streamline and consolidate track utilization in Cuyahoga County. The negotiations were accompanied by an environmental impact statement that examined reconfiguring lines and train volumes. Trip counts on various segments ranged from 0–75 trips per day before the

5. Peter Colwell, "Power Lines and Land Value," *Journal of Real Estate Research* 5, no. 1 (Spring 1990): 117-127; William Kinnard and Sue Ann Dickey, "A Primer on Proximity Impact Research: Residential Property Values Near High Voltage Overhead Transmission Lines," *Real Estate Issues* 20, no. 1 (1996): 23–29.
6. Robert. A Simons, "The Effect of Pipeline Ruptures on Noncontaminated Residential Easement-Holding in Property in Fairfax County," *The Appraisal Journal* (July 1999): 255–263.
7. Amanda S. Rapoza, Edward J. Rickley, and Thomas G. Raslear, "Railroad Horn Systems Research," prepared for U.S. Department of Transportation, Federal Railroad Administration, Report No. DOT-VNTSC-FRA-98-2, 1998.
8. John P. Aurelius and Norman Korobow, "The Visibility and Audibility of Trains Approaching Rail-Highway Grade Crossings," prepared for U.S. Department of Transportation, Federal Railroad Administration, Report No. FRA-RP-71-2, 1971 (available through National Technical Information Service, Springfield, VA); Amanda S. Keller and Edward J. Rickley, "The Safety of Highway-Railroad Grade Crossings: Study of the Acoustic Characteristics of Railroad Horn Systems," prepared for U.S. Department of Transportation, Federal Railroad Administration, Report No. DOT/FRA/ORD-93/25, 1993.
9. Jordan Multer and Amanda Rapoza, "Field Evaluation of a Wayside Horn at a Highway-Railroad Grade Crossing," prepared for U.S. Department of Transportation, Federal Railroad Administration, Report No. DOT/FRA/ORD-98/04, 1998.
10. David E. Clark, "Ignoring Whistle Bans and Residential Property Values: A Hedonic Housing Price Analysis" (working paper).
11. Jon Strand and Mette Vagnes, "The Relationship Between Property Values and Railroad Proximity: A Study Based on Hedonic Prices and Real Estate Brokers' Appraisals," *Transportation* 28 (2001): 137–156.

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merge, with 15–30 trains per day being typical. The reconfiguration was finalized and operational by 1998. As a result, some lines experienced substantial reductions in traffic (e.g., from 50 per day down to 5 per day), some increased (10 to 45 per day), while other segments remained the same.[12]

Beginning in 1997, there were many news reports regarding the impact of the merger, and the railroad lines negotiated with various cities about the impacts of the train reconfiguration on property values. Cities received considerable sums of money. For example, East Cleveland, with a population of about 33,000 in the year 2000, received $4 million; Cleveland, population 493,000, received over $20 million; and Lakewood, population 50,000, also received a multimillion-dollar award. These funds went toward noise mitigation and safety improvements; no monies were allocated to reductions in property values. By 1999, the EIS process had been completed and changes to track volumes had been implemented. This article examines the "before" (1996) and "after" (1999) of this decision in the Cuyahoga County, Ohio, residential resale market.

Model and Research Questions

The initial research question examines whether railroad tracks have the expected negative effect on nearby, single-family house prices. The second question examines whether the negative effect declines with distance from railroad tracks. It is expected that the loss in value of properties within 250 feet from the railroad tracks would be higher than the loss in value of properties located within 750 feet from the railroad tracks. If this holds true, it supports the notion of a gradient effect from the tracks. If there were negative effects but not decreasing with distance, then a zonal effect would be evident. Third, trip volumes (instead of pure proximity) are tested for their effect on sale prices, and whether this effect is stable over time when trip volumes change and the changes are publicly known. Proximity to railroad crossings, where noise and fear of accidents are expected to negatively impact sale prices, is also examined.

The hedonic regression model states that single-family housing sale price is a function of structural characteristics of the house, neighborhood characteristics, and its distance from railroad tracks. With respect to the model presented below, we expect β_3 (sale within several hundred feet of a freight line), β_4 (freight train traffic), and β_5 (gated railroad crossing) to be negative.

A reduced form of the hedonic model is used and is expressed as:

$$P = \beta_0 + \beta_1 S + \beta_2 Z + \beta_3 BUFF + \beta_4 TTRIPS + \beta_5 CROSSING + \varepsilon$$

where:

P = Sale price of the house
S = Vector for structural characteristics of the house
Z = Vector that consists of dummy variables for zip codes; a proxy for neighborhood characteristics
$BUFF$ = Dummy variables attached to properties located within 250, 500, and 750 feet from railroad tracks
$TTRIPS$ = Number of daily freight trains passing in both directions for the segment nearest each house within a railroad track's buffer
$CROSSING$ = Proximity to gated railroad crossing
ε = Error term

Because of potential market stratification issues, the data set is divided into three approximately equal parts based on building square footage. Parallel analyses are run for each market segment and compared.[13]

Study Area and Data Collection

The study area for this research is Cuyahoga County, Ohio; Cleveland is the main city in the county. The population of the city and county in the year 2000 was about 0.5 million and 1.6 million, respectively.

Data Collection

The data used for this research is from the Northern Ohio Data Information Service (NODIS) of the Maxine Goodman Levin College of Urban Affairs at Cleveland State University. House sale prices were obtained from Amerestate, Inc. data, based on county records, and were collected for all transactions that occurred during 1996 and 1999. The county data set included a set of variables related to the characteristics of the house and lot, similar to those included in standard hedonic price studies. Table 2 presents a description of the structural variables included in the hedonic model with descriptive statistics for year 1999. Overall, the typical house sold for $108,800, contained 1,600 square feet of living area, 1.6 garage spaces, and 1.5 bathrooms. It was 61 years old, had a basement of 800 square feet, and sat on a lot of 8,700 square feet. The mean values for the three sizes of units are detailed in Table 2. The data set was split into three parts based on square footage of the units: under 1,250 square feet; 1,251 to 1,700 square feet; and over 1,700 square feet.

The smaller units had an average size of 1,050 square feet, and a sale price of $81,000; the me-

12. Surface Transportation Board, Section of Environmental Analysis, Finance Docket No. 33388, Proposed Conrail Acquisition, 1998.

13. The authors would like to thank the reviewers for suggesting this analysis.

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dium-sized units averaged 1,450 square feet and sold for $97,900; and the largest group averaged 2,200 square feet and sold for $138,500.

Dummy variables were also included for style and construction type. Only single-family residential units were included. Zip codes were employed to account for neighborhood characteristics and to capture the effect of distance from the central business district. A total of 38 dummy variables for the zip codes (with a minimal number of residential sales) were used. Because the zip code variables cannot be generalized, their results are of little interest and are not included (but are available upon request).

The data set contained over 33,000 house sale transactions that occurred in 1996 and 1999. The data cleaning process consisted of deleting all records that had data missing for the following variables: sale price, parcel number, zip code, building square footage, number of rooms, lot square footage, style and construction type specification, and age of the property.

Records clearly outside of a reasonable range that could be considered outliers were deleted. For sale price, only sales between $5,000 and $400,000 were retained for the analysis. Building square footage ranged from 500 square feet to 4,500 square feet. Properties with fewer than three rooms and those with more than 15 rooms were removed, as were properties with lot square footage of less than 2,000 square feet or more than 55,000 square feet. Finally, parcels with lot frontage of less than 20 feet or greater than 140 feet were excluded from consideration. The data set ended up with about 14,900 sales for the year 1996 and 17,800 sales for the year 1999.

Train Variables

Information on train activities was added to the real estate data set. A geographical information system (GIS) was used to link neighborhood and structure information to data on properties located within 250 feet, 500 feet, and 750 feet from railroad tracks. A buffer for the specified distance was created from both sides of the track to include only parcels located within that distance, allowing creation of the dummy variables BUFF250, BUFF500, and BUFF750. The number of annual sales of smaller-sized units, within the distance buffer was 92, 201, and 269, respectively, for BUFF250, BUFF500, and BUFF750. Variables were also created for average daily freight train traffic, based on the number of freight train trips in 1996 and 1999 for each of about 15 different rail segments within Cuyahoga County. Trip data was unavailable for a few freight lines, and these were treated with a dummy variable. We also included buffers of up to 750 feet for proximity to gated train crossings. Because a few freight segments also serve rapid transit, the models also controlled for proximity to rapid transit lines and transit stations.

Regression Diagnostics

The variance inflation factor (VIF) index was used to check for the multicollinearity problem in the larger data set. Some variables such as number of rooms and bedrooms, and lot depth and width had a high VIF and were discarded from the model. For other variables, the multicollinearity was not severe, but for some cases like the fireplace variable, it generated a coefficient with a sign that was not consistent with theory. It also was removed from the model.

Table 2 Descriptive Mean Statistics for 1999

Variable	Small Units Under 1,250 Sq. Ft.	Medium Units 1,251–1,700 Sq. Ft.	Large Units Over 1,700 Sq. Ft.
Sale price	$ 81,007	$ 97,851	$ 138,510
Building sq. ft.	1,049	1,454	2,205
Garage capacity	1.38	1.54	1.75
Number of baths	1.03	1.18	1.80
Basement sq. ft.	682	745	913
Lot front feet	46.80	50.14	59.01
Lot sq. ft.	6,591	7,500	9,707
Age in years	60.79	65.30	59.53
Valid sample size	6,068	5,804	5,917

n = 17,789

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For heteroscedasticity, scatter plots of the dependent variable and model residuals were examined for fanning. None appeared to be present.

Empirical Findings

The initial models (not shown here due to space considerations) were prepared for the large data set.[14] The use of dollars per square foot ($/SF) as the dependent variable was investigated, but results were much less satisfactory than the linear form used in later runs.[15] Table 3 shows the results of the structural variables for 1999 along with train buffers, without freight train trip counts or crossings, for the size-stratified sales data. Overall, the models fit the data well for 1999. The independent variables included in the model explain 62% of the variation in the dependent variable for the smallest units, and 77% for the largest units. The *F*-statistics were 133 to 265, and significant at the 99% level or better. The signs of the coefficients are as expected for the structural variables and are consistent with the findings of previous research in the Cleveland area.[16]

The statistical significance, the sign, and the magnitude of the coefficient for structural variables are as expected and consistent with theory. For example, for the building square footage variable, every additional square foot will increase the sale price by $21 for the smaller units and by $35 for the largest units. Every additional year in the age of the house will decrease the sale price by $367 for the smallest units and by $678 for the largest units. Garage space adds $4,630 to $4,770, and a square foot of lot size adds $0.48 for smaller units and up to $1.86 for the largest ones. All these are significant at well over a 90% confidence level.[17]

The train variables (BUFF250, BUFF500, and BUFF750) are generally consistent with theory and had the right sign. However, statistical significance was only apparent at the 95% level for the units under 1,250 square feet. For this group the results show that for 1999, houses located within 250 feet of railroad tracks sold for $4,400 less than other houses in the reference category. The loss changed somewhat with distance from the tracks, and decreased to about $3,800 less for houses located 251–500 feet away. However, the loss then increased to $5,800 for houses within 501–750 feet of a railroad track. These losses average 5%–7% of the average sale price. Hence, the diminution in property values appears to flatten out because the results for sales within both 500 feet and 750 feet from a track (before consideration of trip counts) did not monotonically decrease. This suggests the markets perceive a zonal effect rather than a gradient effect for freight tracks.

For the medium-sized units, all zones had negative signs, but only the middle ring (251–500 feet away) was statistically significant at 95%. The magnitude of this discount was $4,700 (about 5%). The same negative signs were apparent for the larger units, but no results were significant, even at an 85% level of confidence. Hence, it cannot be said that freight train tracks had a statistically significant effect on these units.[18]

A variable was also inserted to reflect proximity to a rapid transit station (Station RTA 1000 Feet). For smaller units, proximity to a station yielded a positive value from $10,300 to $12,500 (13%–15%) that was statistically significant at a 99% level of confidence. This indicates a value premium among those most likely to use rapid transit. Among the medium units, signs were negative but statistically insignificant. Among the larger units, they were positive but only statistically significant at about an 85% level of confidence, and barely at that level.

Moving along to the "before" and "after" effects of the information about the reorganization of freight train traffic, recall that the changes were announced in about 1997, that 1996 represents the "before" sce-

14. As with Table 3, the large model was run with structural variables and only a buffer around freight train lines. Overall, the model fits the data well for 1999. The independent variables included in the model explain 76% of the variation in the dependent variable. The *F*-statistics were over 750 and significant at the 99% level. The sign of the coefficients is as expected for the structural variables and is consistent with the findings of previous research in the Cleveland area. Of the 54 nongeneralizable variables that were included in the model (38 zip codes and other dummy variables for style and construction), about 40% were statistically significant at the 90% confidence level.

15. We also reran the basic 1999 model with train distance buffers and all ring configurations with the dependent variable as $/building square foot. This means we eliminated building square foot from the right side of the model. The resulting models had a much lower *R* squared: .52 to .72 compared with .62 to .77 in the comparably configured models. The parameter estimates for smaller units were -$4.30, -$3.30, and -$5.20, all significant at a 95% confidence level. Other results mirrored the model with the dependent variable using sale price. When the revised results are transformed into sale price at the average square footage of 1,050, the resulting price drops are $3,500-$5,500, almost identical to those found in Table 3.

16. Simons, Bowen, and Sementelli.

17. A 1996 baseline model for the large data set with the same variables was also run. The *R* squared was 0.80, and the *F*-statistic was over 810. The variable parameter estimates were consistent with theory and with the 1999 results.

18. The results over space should in theory decrease monotonically, but this is not always observed in practice. One explanation is that there is model misspecification, and this may be partly the case here, as evidenced by the superior and more logical results obtained by the model shown later in Table 4b which uses freight trips, as opposed to pure distance, to gauge impacts. Alternatively, results could be attributable to influential outlier sales. Finally, it could be that nuisance from track activity has a zonal (in or out of an affected area) rather than gradient (decreasing over distance within an impact zone) effect on property values. We have ruled out insufficient observations and multicollinearity as potential sources of difficulty on this issue.

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Table 3 Effect of Proximity to Railroad Tracks, 1999

Small units under 1,250 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	Sig.	Coefficients	Sig.	Coefficients	Sig.
(Constant)	45,571.41	0.00	45,687.44	0.00	49,375.77	0.00
Bldg. sq. ft.	20.99	0.00	20.91	0.00	20.89	0.00
Garage capacity	4,630.00	0.00	4,649.48	0.00	4,594.30	0.00
Bath number	3,069.35	0.04	2,940.55	0.55	2,833.87	0.06
Basement sq. ft.	14.75	0.00	14.79	0.00	14.73	0.00
Lot frontage	0.19	0.00	0.19	0.00	0.19	0.00
Lot sq. ft.	0.48	0.00	0.47	0.00	0.48	0.00
Age of house	-366.58	0.00	-365.55	0.00	-366.68	0.00
Station RTA 1,000 ft.	10,576.51	0.01	10,291.85	0.01	12,495.16	0.00
BUFF250	-4,384.95	0.03				
BUFF500			-3,816.25	0.00		
BUFF750					-5,809.50	0.00
Adjusted *R* Square	0.62		0.62		0.62	
Degrees of freedom	5,992.00		5,992.00		5,992.00	
F-statistic	133.17		133.29		133.87	
Durbin-Watson	1.75		1.76		1.76	

Medium units 1,251 to 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	Sig.	Coefficients	Sig.	Coefficients	Sig.
(Constant)	84,888.26	0.00	84,958.68	0.00	84,951.02	0.00
Bldg. sq. ft.	30.83	0.00	30.79	0.00	30.86	0.00
Garage capacity	4,762.51	0.00	4,727.63	0.00	4,768.08	0.00
Bath number	4,538.45	0.00	4,516.23	0.00	4,521.53	0.00
Basement sq. ft.	8.34	0.00	8.32	0.00	8.36	0.00
Lot frontage	0.15	0.00	0.15	0.00	0.15	0.00
Lot sq. ft.	0.70	0.00	0.70	0.00	0.70	0.00
Age of house	-498.98	0.00	-497.07	0.00	-498.93	0.00
Station RTA 1,000 ft.	-5,586.79	0.33	-4,570.52	0.43	-5,447.28	0.35
BUFF250	-2,840.92	0.35				
BUFF500			-4,661.28	0.02		
BUFF750					-385.71	0.82
Adjusted *R* Square	0.64		0.64		0.64	
Degrees of freedom	5,728.00		5,728.00		5,728.00	
F-statistic	135.95		136.10		135.92	
Durbin-Watson	1.56		1.56		1.56	

Large units over 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	Sig.	Coefficients	Sig.	Coefficients	Sig.
(Constant)	48,814.89	0.00	48,616.56	0.00	48,818.87	0.00
Bldg. sq. ft.	35.42	0.00	35.49	0.00	35.42	0.00
Garage capacity	4,771.95	0.00	4,768.55	0.00	4,766.54	0.00
Bath number	16,216.11	0.00	16,209.55	0.00	16,198.56	0.00
Basement sq. ft.	10.13	0.00	10.12	0.00	10.11	0.00
Lot frontage	0.28	0.00	0.28	0.00	0.28	0.00
Lot sq. ft.	1.86	0.00	1.85	0.00	1.85	0.00
Age of house	-677.67	0.00	-676.75	0.00	-676.61	0.00
Station RTA 1,000 ft.	5,670.17	0.17	5,241.39	0.22	6,021.75	0.15
BUFF250	-4,735.30	0.24				
BUFF500			-882.21	0.76		
BUFF750					-3,385.17	0.17
Adjusted *R* Square	0.77		0.77		0.77	
Degrees of freedom	5,840.00		5,840.00		5,840.00	
F-statistic	265.42		265.34		265.45	
Durbin-Watson	1.51		1.51		1.51	

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nario, and that 1999 represents "after" the information became known. Tables 4a and 4b present results for 1996 and 1999, respectively. These models were run with the same structural and zip code variables, but without the train buffers. The new train variables FREIGHT TRIP 250 FEET, FREIGHT TRIP 500 FEET, and FREIGHT TRIP 750 FEET are of particular interest and reflect the number of train trips per day on each segment. Other new train variables include CROSS250, CROSS500, and CROSS750, which indicate distance from a gated train crossing, and RTA1000, which indicates proximity to a rapid transit track (but not station) carrying a number of shorter train trips (2–5 cars).

With respect to the volume of daily freight train trips (FREIGHT TRIP 250 FEET), the 1996 and 1999 models showed quite different results, as expected by theory. For 1996 (Table 4a), only smaller- and medium-sized unit sales had the expected negative sign, and only one cell (smaller units, 501–750 feet away, with a parameter estimate of $80 loss per additional freight train trip) was statistically significant at a 90% or better level of confidence. One parameter estimate (largest units, 501–750 feet away) was positive and statistically significant.

For 1999 (Table 4b), however, after much publicity, the market was able to distinguish the effects of freight trips quite clearly. It was found that per average daily freight trip, sale prices of smaller units within 250 feet (TRIP250) went down by $194. Sale prices of units between 251-500 feet dropped by $85 and by $94 on units between 501-750 feet per average daily freight trip.

All results were statistically significant at a 95% or better level of confidence.[19] This generally reflects a gradient rather than zonal pattern.

For medium-sized units, it was found that per average daily freight trip, sale prices of units within 250 feet dropped by $262. Sale prices of units between 251-500 feet fell by $107 and by $72 on units between 501-750 feet.

All results were statistically significant at 85% or better level of confidence, and the closest result was significant at a 95% level of confidence. This demonstrates a gradient pattern of impact.

For larger-unit sales within 250 feet, a price reduction of $264 was evident, but it was only significant at an 85% level of confidence. Other results were not statistically significant. Thus, the results with freight train trips per day were improved in terms of statistical significance, especially for small- and medium-sized units.

These models also address the effects of gated railroad crossings (CROSS250, CROSS500, and CROSS750) with freight trip counts in the models. For 1996, proximity to a railroad crossing is negative and mostly significant only for the group of smaller units, where units 251–750 feet from a gated crossing experienced negative results of about 5%, holding all else constant. They were not significant for most other categories of units. For 1999, all the losses associated with gated train crossings evaporated, except for the largest units 501–750 feet from a gated crossing. Hence, the overall results for gated crossings were mixed.

Finally, these same models also had a variable if a sale was within 1000 feet of a rapid transit track without a transit station (RTA1000). For 1996, only medium-sized sales showed negative and significant losses for this variable (about 10% of sale price). For 1999, the significant and negative losses (about 5%) associated with RTA1000 were confined to the sales of the smallest units. Hence, the overall results for proximity to rapid transit tracks were also mixed.

Conclusion

The results generated by the hedonic models for 1996 and 1999 are consistent with previous results in the literature. The structural variables are generally of the expected sign. For railroad-related variables, smaller houses of up to 1,250 square feet and located within 250 feet, 500 feet, or 750 feet of a railroad track experienced a statistically significant loss in sale price of $4,300 within 250 feet, $3,800 within 500 feet, and $5,800 within 750 feet from a freight track line; this is equivalent to losses of 5%–7% of sale price. For the medium and larger units, many had negative signs, but only the middle ring (251–500 feet away) was statistically significant at a 95% confidence level, with a discount of about 5%. The lack of a consistent declining pattern implies that markets perceive a zonal rather than gradient effect for this negative amenity when modeled with pure proximity.

Proximity to a gated railroad crossing at grade was associated with a reduction in sale price of about 5% under some circumstances, but results were not robust over all subcategories of sales.

Results improved substantially when freight train trip counts, separate from simple proximity to a

19. A model with all rail variables with the larger data set of all sizes together was run, and the pure proximity buffers performed the most consistently. However, they also had the highest multicollinearity problems. Therefore, these results are considered not very reliable.

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Table 4a Effect of Freight Train Trip Counts on Property Values, 1996

Small units under 1,250 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	40,806.72	0.00	40,538.76	0.00	40,678.68	0.00
Building sq. ft.	19.45	0.00	19.52	0.00	19.46	0.00
Garage capacity	3,915.99	0.00	3,914.75	0.00	3,918.24	0.00
Bath number	1,948.19	0.19	2,004.96	0.17	2,158.74	0.14
Basement sq. ft.	13.16	0.00	13.15	0.00	12.99	0.00
Lot frontage	0.16	0.00	0.16	0.00	0.16	0.00
Lot sq. ft.	0.41	0.00	0.40	0.00	0.40	0.00
Age of house	-365.87	0.00	-363.15	0.00	-362.40	0.00
Station RTA 1,000 ft.	8,603.06	0.05	8,309.17	0.06	9,472.28	0.03
RTA track 1,000 ft.	-2,356.82	0.32	-1,588.63	0.53	262.67	0.92
Crossing 250 ft.	-2,265.19	0.62				
Freight trips 250 ft.	**-116.28**	**0.19**				
Crossing 500 ft.			-6,029.84	0.03		
Freight trips 500 ft.			**-39.63**	**0.20**		
Crossing 750 ft.					-4,197.31	0.04
Freight trips 750 ft.					**-80.45**	**0.06**
Adjusted *R* Square	0.68		0.68		0.68	
Durbin-Watson	1.90		1.89		1.90	
Degrees of freedom	5,191.00		5,191.00		5,191.00	
F-statistic	148.96		149.25		149.81	

Medium units 1,251 to 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	56,488.09	0.00	56,538.94	0.00	56,397.24	0.00
Building sq. ft.	26.49	0.00	26.43	0.00	26.50	0.00
Garage capacity	4,478.43	0.00	4,478.38	0.00	4,528.09	0.00
Bath number	2,701.08	0.01	2,727.01	0.01	2,697.55	0.01
Basement sq. ft.	9.31	0.00	9.42	0.00	9.37	0.00
Lot frontage	0.10	0.00	0.10	0.00	0.10	0.00
Lot sq. ft.	0.91	0.00	0.91	0.00	0.91	0.00
Age of house	-523.31	0.00	-525.11	0.00	-524.87	0.00
Station RTA 1,000 ft.	10,441.52	0.11	9,276.93	0.16	9,661.90	0.14
RTA track 1,000 ft.	-10,393.28	0.01	-10,930.67	0.01	-10,213.85	0.01
Crossing 250 ft.	2,207.11	0.66				
Freight trips 250 ft.	**-164.92**	**0.24**				
Crossing 500 ft.			1,741.49	0.58		
Freight trips 500 ft.			**-27.61**	**0.63**		
Crossing 750 ft.					2,814.19	0.24
Freight trips 750 ft.					**-35.52**	**0.61**
Adjusted *R* Square	0.70		0.70		0.70	
Durbin-Watson	1.99		1.99		1.99	
Degrees of freedom	4,775.00		4,775.00		4,775.00	
F-statistic	147.54		147.61		147.52	

Large units over 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	42,628.11	0.00	42,833.68	0.00	42,036.57	0.00
Building sq. ft.	39.38	0.00	39.29	0.00	39.40	0.00
Garage capacity	6,301.06	0.00	6,268.31	0.00	6,262.75	0.00
Bath number	12,914.22	0.00	12,928.01	0.00	12,980.06	0.00
Basement sq. ft.	9.63	0.00	9.62	0.00	9.59	0.00
Lot frontage	0.19	0.00	0.19	0.00	0.19	0.00
Lot sq. ft.	1.52	0.00	1.53	0.00	1.52	0.00
Age of house	-744.37	0.00	-744.51	0.00	-740.95	0.00
Station RTA 1,000 ft.	1,722.10	0.79	-2,615.66	0.70	-667.42	0.93
RTA track 1,000 ft.	376.34	0.94	-1,602.79	0.75	-3,951.61	0.45
Crossing 250 ft.	5,360.47	0.56				
Freight trips 250 ft.	**-42.74**	**0.88**				
Crossing 500 ft.			1,200.04	0.80		
Freight trips 500 ft.			**30.48**	**0.64**		
Crossing 750 ft.					-4,562.12	0.19
Freight trips 750 ft.					**227.57**	**0.01**
Adjusted *R* Square	0.81		0.81		0.81	
Durbin-Watson	1.97		1.97		1.97	
Degrees of freedom	4,927.00		4,927.00		4,927.00	
F-statistic	267.59		267.85		268.16	

Signif. = statistical significance level. For example, .04 = 96% confidence level

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Table 4b Effect of Freight Train Trip Counts on Property Values, 1999

Small units under 1,250 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	46,203.13	0.00	46,277.68	0.00	46,479.72	0.00
Building sq. ft.	20.85	0.00	20.80	0.00	20.88	0.00
Garage capacity	4,623.29	0.00	4,597.04	0.00	4,579.06	0.00
Bath number	3,107.99	0.04	3,034.27	0.04	2,850.52	0.06
Basement sq. ft.	14.64	0.00	14.69	0.00	14.62	0.00
Lot frontage	0.19	0.00	0.19	0.00	0.19	0.00
Lot sq. ft.	0.48	0.00	0.48	0.00	0.48	0.00
Age of house	-369.09	0.00	-369.17	0.00	-365.27	0.00
Station RTA 1,000 ft.	18,183.18	0.00	16,751.99	0.00	17,259.53	0.00
RTA track 1,000 ft.	-8,152.28	0.00	-6,749.18	0.02	-3,946.57	0.18
Crossing 250 ft.	-4,183.39	0.48				
Freight trips 250 ft.	**-193.87**	**0.02**				
Crossing 500 ft.			884.50	0.78		
Freight trips 500 ft.			**-84.92**	**0.05**		
Crossing 750 ft.					-2,363.30	0.27
Freight trips 750 ft.					**-94.17**	**0.00**
Adjusted *R* Square	0.62		0.62		0.62	
Durbin-Watson	1.75		1.76		1.76	
Degrees of freedom	5,989.00		5,989.00		5,989.00	
F-statistic	128.39		128.23		128.77	

Medium units 1,251 to 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	84,403.28	0.00	84,794.33	0.00	85,017.69	0.00
Building sq. ft.	31.10	0.00	30.90	0.00	30.91	0.00
Garage capacity	4,753.83	0.00	4,709.66	0.00	4,734.70	0.00
Bath number	4,575.45	0.00	4,553.61	0.00	4,523.77	0.00
Basement sq. ft.	8.45	0.00	8.34	0.00	8.36	0.00
Lot frontage	0.15	0.00	0.15	0.00	0.15	0.00
Lot sq. ft.	0.69	0.00	0.70	0.00	0.69	0.00
Age of house	-499.04	0.00	-498.42	0.00	-498.39	0.00
Station RTA 1,000 ft.	-5,510.36	0.40	-5,683.83	0.39	-5,162.14	0.44
RTA track 1,000 ft.	843.34	0.81	905.54	0.81	1,726.68	0.65
Crossing 250 ft.	311.96	0.97				
Freight trips 250 ft.	**-262.01**	**0.04**				
Crossing 500 ft.			-4,487.92	0.19		
Freight trips 500 ft.			**-107.15**	**0.15**		
Crossing 750 ft.					-511.54	0.83
Freight trips 750 ft.					**-71.87**	**0.15**
Adjusted *R* Square	0.64		0.64		0.64	
Durbin-Watson	1.56		1.56		1.56	
Degrees of freedom	5,725.00		5,725.00		5,725.00	
F-statistic	131.09		130.81		130.71	

Large units over 1,700 square feet	Within 250 feet		251–500 feet		501–750 feet	
	Coefficients	**Sig.**	**Coefficients**	**Sig.**	**Coefficients**	**Sig.**
(Constant)	48,622.51	0.00	48,540.41	0.00	47,957.39	0.00
Building sq. ft.	35.54	0.00	35.55	0.00	35.61	0.00
Garage capacity	4,717.35	0.00	4,748.98	0.00	4,790.22	0.00
Bath number	16,186.00	0.00	16,198.41	0.00	16,227.67	0.00
Basement sq. ft.	10.06	0.00	10.05	0.00	9.99	0.00
Lot frontage	0.28	0.00	0.29	0.00	0.28	0.00
Lot sq. ft.	1.85	0.00	1.85	0.00	1.85	0.00
Age of house	-675.69	0.00	-675.32	0.00	-671.90	0.00
Station RTA 1,000 ft.	9,888.68	0.10	9,783.25	0.11	9,969.80	0.10
RTA track 1,000 ft.	-6,750.15	0.16	-6,768.64	0.17	-7,124.08	0.17
Crossing 250 ft.	-2,950.71	0.73				
Freight trips 250 ft.	**-264.38**	**0.14**				
Crossing 500 ft.			-4,837.08	0.30		
Freight trips 500 ft.			**4.46**	**0.96**		
Crossing 750 ft.					-9,701.36	0.00
Freight trips 750 ft.					**0.82**	**0.99**
Adjusted *R* Square	0.77		0.77		0.77	
Durbin-Watson	1.51		1.51		1.51	
Degrees of freedom	5,837.00		5,837.00		5,837.00	
F-statistic	255.51		255.31		255.83	

Signif. = statistical significance level. For example, .04 = 96% confidence level

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track, were modeled. In 1996, prior to announced track reconfigurations, trip counts had little effect on prices, with only one cell having results indicating market awareness of trip counts. In 1999, after the announced changes, among smaller units each trip count was associated with a reduction in sale price of around $194 per additional average daily freight train trip within 250 feet. The reduction in sale price decreased to about $85 and $94 per trip within 500 feet and 750 feet away, respectively. Medium-sized units exhibited a gradient-type effect ranging from $262 to $72, at generally lower significance levels. Larger units also had a drop in sale price of $264 per trip at the closest distance. Thus, adding trip counts substantially improved pricing effects of train trips. It also represents more of a gradient, rather than zonal, pattern of impact.

To put this into perspective, for example, if a $100,000 house were located near a freight train track, and the daily train count were to go from 10 trains per day to 30 trains per day, this would imply a reduction in value of $5,000 (20 trips times $250/trip), or 5%. This is a new finding and represents a contribution to the literature.

In a recent financial settlement related to the train reorganization in the Cleveland area, the railroads negotiated with communities for mitigation of noise and safety concerns, but no funds were provided specifically to compensate residents for losses in property value. Of course, this research has not calculated the net effect (some lines gained trips, some lost), so there is no statement made here about the fairness of these payments, but loss in property values should be included in future negotiations of this type. The train-trip count impact was insignificant before the merger talks and accompanying newspaper publicity. After the publicity, significant modest price reductions were evident and these were consistent with theory. This is evidence that the markets were able to price the train volume data reasonably well, and that the talk of train line reorganization did have a substantial effect on the parameter estimates after the change in trip volumes.

The models appear to work better for smaller-sized units, regardless of distance from the tracks. One possible explanation could be that a higher percentage of the larger units are located in affluent suburbs outside the central city, where other locational amenities outside the model (e.g., school districts) may be affecting value. Smaller sales tended to be in the central city or in a few, inner-ring working-class suburbs.

The implication of this research for appraisers is that they should include proximity to rail lines, train trip counts, and potentially gated crossings in determining the value of residential property.

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Working Paper

The Impact of Rail Transport on Real Estate Prices: An Empirical Analysis of the Dutch Housing Market

Tinbergen Institute Discussion Paper, No. 06-031/3

Provided in Cooperation with:
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The impact of rail transport on real estate prices: an empirical analysis of the Dutch housing market

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Abstract:

A hedonic pricing model is estimated to analyse the impact of railways on house prices in terms of distance to railway station, frequency of railway services and distance to the railway line. Correcting for a wide range of other determinants of house prices we find that dwellings very close to a station are on average about 25% more expensive than dwellings at a distance of 15 kilometres or more. A doubling of frequency leads to an increase of house values of about 2.5%, ranging from 3.5% for houses close to the station to 1.3% for houses far away. Finally we find a negative effect of distance to railways, probably due to noise effects. Two railway station references were used in the analysis: the nearest and most frequently chosen station in the post code area. This distinction indicates that railway station accessibility is a more complex concept than one might think. It involves competition between railway stations.

Key words: property value, railway station, accessibility, hedonic pricing method.

1. INTRODUCTION

Hedonic pricing methods explain the value of real estate in terms of the features of the property. This approach treats a certain property as a composite of characteristics to which value can be attached. The sum of the value of the individual characteristics makes up the value of the property as a whole. Studies on real estate prices generally categorise the value bearing features of properties into three types namely: physical, accessibly and environmental (Fujita 1989; Bowes and Ihlanfeldt 2001). Several studies have been conducted focusing on different features of interest. Accessibility as provided by different modes of transportation and railways in particular also received attention. In order to single out the effect of railway stations on property values, it is suggested in the literature that stations should be seen as nodes in a transport network and places in an area (Bertolini and Spit 1998). Based on this framework, recent empirical studies treat the node feature and the place feature of a station separately. The former characteristic accounts for the accessibility effect, which is generally positive. The latter feature accounts for externalities of the station and can have both positive and negative effects. Bowes and Ihlanfeldt (2001) pointed at the retail employment and crime that stations attract in addition to the accessibility feature of a station. By including the three categories of property features mentioned above this paper examines the effect of railway stations on Dutch house prices. There are three types of rail service in the Netherlands: light rail services (trams), heavy rail services (metro lines) and commuter rail services. The services of the first two are limited within the main cities. However, the third type serves the whole country. This paper assesses the effect of accessibility provided by these commuter railway stations on the prices of these houses. As a main accessibility competitor to railways, highway accessibility is represented in our analysis by means of distance to points of highway entry and exits.

The accessibility and nuisance effects of a railway station are functions of distance between the station and the house under consideration. As the distance increases, the impact of both features on the house price declines. The level of accessibility at a railway station is measured by the quality of the railway network: the number of destinations that can be reached from the station, the frequency of services at the station, and other departure station related facilities. Stations with higher network quality (i.e. a larger number of destinations and a higher frequency of trains) have a higher accessibility index, and are expected to have a relatively high positive effect on the

house prices. Railway stations at the same time impose localised negative environmental effects on house prices due to noise nuisance. An important difference between the two effects is that the accessibility effects are concentrated around nodes (railway stations) whereas the negative noise effects take place everywhere along the railway line.

In this paper we determine the impact of the three railway features namely: railway station proximity and rail service levels and proximity to railway line on prices of residential properties. The data for the analysis in this paper includes the sales and prices of residential properties in the Netherlands. Due to the transportation cost and time savings made possible, households are expected to be willing to pay higher prices to living close to the station compared with other locations. This is because the commuting (time) costs are relatively low when one lives near a station. Furthermore, leisure activities that involve rail transport are more accessible. This paper only covers the sales of residential properties. In a follow up paper we intend to cover the effect of railway station on commercial property values.

2. LITERATURE REVIEW

Most land value theories have their root in the work of Von Thünen (Von Thünen 1830), who tried to explain variations in farmland values. According to Von Thünen, accessibility to the market place explains the value difference of farmlands for agricultural lands having similar fertility. In subsequent studies, economists like Alonso and Muth refined this line of reasoning into a bid-rent analysis (Alonso 1964; Mute 1969). The basic idea behind the bid-rent model is that every agent is prepared to pay a certain amount of money, depending on the location of the land. This leads to a rent gradient that declines with distance from the central business district (CBD) for sites that yield equal utility. Thus far in the analyses, the dominant factor explaining the difference between land (property) values was the accessibility as measured by the distance to the Central Business District (CBD) and the associated transportation costs. The physical characteristics of the land (fertility in the case of Thünen) were assumed given.

Thus the basic theory on real estate prices can be put forward as follows: as a location becomes more attractive, due to certain characteristics, demand increases and thus the bidding process

pushes prices up. In most cases CBDs are the centres of many activities. Therefore, proximity to the CBD is considered as an attractive quality that increases property prices. However, investments in transport infrastructure reduce this demand friction around the CBD to some degree (Fejarang 1994) by attracting households to settle around the stations. Properties close to the investment area (railway stations) enjoy benefits from transportation time and cost saving as a result of the investment. It may be expected that a price curve will have a negative slope; when we move away from the station, prices decrease.

The introduction of the hedonic pricing methodology by Rosen (1974) led to an easier way of attributing value to the properties' features. Therefore, in subsequent studies we observe the integration of physical, accessibility and environmental characteristics of the property in models trying to explain the differences in property values. Accessibility remains an important feature for urban properties. However, earlier attempts to account for it by using transportation cost have been narrow. Attempts have been made to introduce a broader concept of accessibility by including all features that contribute to the potential of opportunities of a location for economic and social interactions (Hansen 1959; Martellato et al. 1998*)*. Though a comprehensive definition of the concept is available, the lack of data and appropriate measuring techniques usually implies that simple measures are used. Thus, in the literature we see a focus on a limited number of factors only, especially a CBD oriented interaction related to employment and shopping. In most property value studies, the other trip purposes are missing from the model.

The main focus of this paper is the analysis of the impact of railway accessibility on residential house prices. However, as Voith (1993) pointed out, highway accessibility is an important competitor to rail accessibility. 'The presence of other facilities that increase accessibility like highways, sewer services and other facilities influence the impact area in the same fashion.' The benefits of these facilities and services are also capitalised into urban property values (Damm et al. 1980). Thus, to single out the effect of railway accessibility, competing modes of accessibility need to be included along with it.

The motivations for the studies on the impact of railway accessibility are diverse. The larger part of the literature on railways focuses on it as a feasible solution to the rising congestion posed by automobile traffic and urban sprawl. Railway investment is expected to support a more compact

urban structure and therefore it serves the urban planning purpose (Goldberg 1981). Apart from reasons of showing that railway investments do result in compact urbanisation, most studies in the area were conducted to provide evidence for the implementation of value capture schemes for financing rail investments (Cervero and Susantono 1999). This was based on the assertion that the value of proximity to accessibility points is capitalised on the value of properties around these stations.

In general, the empirical studies conducted in this area are diverse in methodology and focus. Although the functional forms can differ from study to study, the most common methodology encountered in the literature is hedonic pricing. However, no consistent relationship between proximity to railway stations and property values is recorded. Furthermore, the magnitudes of these effects can be minor or major. One of the earliest studies, Dewees (1976) analysed the relationship between travel costs by railway and residential property values. Dewees found that a subway station increases the site rent perpendicular to the facility within a one-third mile to the station. Similar findings confirmed that the distance of a lot from the nearest station has a statistically significant effect on the property value of the land (Damm et al. 1980). Consistent with these conclusions, Grass (1992) later found a direct relationship between the distance of the newly opened metro and residential property values. Some of the extensively studied metro stations in the U.S., though ranging from small to modest impact, show that properties close to the station have a higher value than properties farther away (Giuliano 1986; Bajic 1983; Voith 1991). However, there are studies which have also found insignificant effects (Lee 1973; Gatzlaff and Smith 1993). On the other hand, contrary to the general assumption, Dornbusch (1975) and Landis et al. (1995) traced a negative effect of station proximity. Evidence from other studies indicates little impact in the absence of favourable factors (Gordon and Richardson 1989; Giuliano 1986). For a detailed documentation of the findings, we refer to (Vessali 1996; Smith and Huang 1995; NEORail 2001;NICS 2002). In general, some studies indicate a decline in the historical impact of railway stations on property values. This was attributed to improvements in accessibility, advances in telecommunications, computer networks, and other areas of technology that were said to make companies “footloose” in their location choices (Gatzlaff and Smith 1993).

The impact of railway stations on property values varies due to several factors. First, railway stations differ from each other in terms of the level of service provided explained terms of frequency of service, network connectivity, service coverage etc. The meta analysis in Debrezion et al. (2006) shows that different types of railway stations have different levels of impact on property value. Commuter railways have a relatively high impact on property value (Debrezion et al. 2006; Cervero and Duncan 2001; NEORail 2001; Cervero 1984). Railway stations also differ in the level and quality of facilities. Stations with higher level and quality of facilities are expected to have greater impact on the surrounding properties. The presence and number of parking lots is one of the many station facilities that got attention in the literature. Bowes and Ihlanfeldt (2001) found that stations with parking facilities have a higher positive impact on property values. In addition, the impact a railway station produces depends on its proximity to the CBD. Stations which lie close to the CBD produce a greater positive impact on the property value (Bowes and Ihlanfeldt 2001). In another study, Gatzlaff and Smith (1993) claim that the variation in the findings of the empirical work is attributed to local factors in each city.

Second, railway stations affect residential and commercial properties differently. Most studies have treated the effect of railway stations on the different property types separately. The range of the impact area of railway stations is larger for residential properties, whereas the impact of a railway station on commercial properties is limited to immediately adjacent areas. Generally, it has been shown that the impact of railway stations on commercial properties is greater than the impact on residential properties within short distance of the stations (Cervero and Duncan 2001; Weinstein and Clower 1999). This finding is in line with the assertion that railway stations - as focal, gathering points - attract commercial activities, which increase commercial property values. However, contrary to this assertion, Landis et al. (1995) determined a negative effect on commercial property values.

Third, the impact of railway stations on property value is subject to demographic segmentation of neighbourhoods. Income and social (racial) divisions are common. Proximity to a railway station is of higher value to low-income residential neighbourhoods than to high-income residential neighbourhoods (Nelson 1998; Bowes and Ihlanfeldt 2001). The reason is that low-income residents tend to rely on public transit and thus attach higher value to living close to the station. Because of the fact that this group of people mostly depend on slow modes (walking and

bicycle) to access the stations, railway station adjacent locations are expected to constitute poor segments. On the other hand, the high population movement in the immediate location gives rise to the development of retail activities which eventually capitalize on commercial properties, but it may at the same time attract criminality (Bowes and Ihlanfeldt 2001). Bowes and Ihlanfeldt outlined that a significant relation was observed between stations and crime rates. However, no proximity variable shows a significant effect on retail employment. In this model, the immediate neighbourhood is affected by the negative impact of the station. Thus the most immediate properties (within a quarter of a mile of the station) were found to have an 18.7% lower value. Properties that are situated between one and three miles from the station, however, are more valuable than those further away.

3. DATA AND DESCRIPTIVES

(A) HOUSE CHARACTERISTICS

The data used in the analysis of this paper covers sales transactions of the Dutch residential housing market for a period of seventeen years from 1985 to 2001. These transactions are recorded by the Dutch Brokers Association (NVM). The data incorporate information related to price of the dwellings, characteristics of the dwellings and some environmental features. To further enrich the data set, each of the houses sold is geo-coded separately to enable us to compute the distances to the railway stations and highway entry/exit points. Some houses are geo-coded at the precise house address level and the rest are geo-coded at the six digit (e.g. 1234XX) post code level, which is an area comprising up to about 50 houses. Apart from the house characteristics, a number of accessibility and neighbourhood features are used. The land use data were acquired from the central office of statistics for the Netherlands (the CBS). These data are available at the four-digit postal code level. Moreover, population related data are available at this level of aggregation. Income levels of the population in the post code area, the density and population composition in particular the share of foreigners in the area, are used in our analysis.

The accessibility data relate to two transport modes: railway and highway. The locations of all railway stations and highway entry/exit points are identified. The distance from the houses to these points was determined by GIS methods. The distance to the nearest highway entry/ exit points is expected to account for the car based accessibility. This paper uses two references for a railway station: the nearest railway station and the most frequently chosen railway station. The nearest station is easily determined using GIS methods. The identification of the most frequently chosen station was based on the survey study of the Dutch National Railway Company (NS). It is given at the 4-digit post code area level.

Tables:

Table 1: Descriptive statistics of house characteristics

	Minimum	Maximum	Mean	Std. Deviation
Dependent variable				
Transaction price in Euros	9076	5,558,800	123,187	95,678
Independent variables				
1. House features				
Surface area in sq. meters	11	99,998	443	1890
Building age in years	0	996	38	40
Total number of rooms	1	39	4.47	1.34
Number of bathrooms	0	4	0.87	0.58
Dummy variables				
Monument			0.009	
Gas heater			0.136	
Open fireplace			0.186	
Garage			0.335	
Garden			0.783	
2. accessibility features				
Distance to nearest railway station (m)	3	25,498	3,486	3441
Distance to most frequently chosen railway station (m)	10	35,643	4,245	5064
Frequency (trains/day at the most frequently chosen station)	18	788	268	217
Frequency (at the nearest station)	18	788	169	151
Distance to highway entry/exit (m)	0	39,541	3,978	4711
3. environmental				
Household income in Euros (4 digit postcode level)	3136	26200	11480	1805
Population composition (percentage of foreigners)	0.010	.890	.642	0.918

In Table 1 above some descriptive statistics on the three categories of factors affecting property values are given. For the physical features of the houses we use a large number of relevant items. Examples are surface area of the house (that includes the built up and non-built up part of the property), age of the house, the number of rooms and number of bathrooms; all these variables are continuous. The rest of the physical characteristics, such as monumental status of the dwelling, the availability of gas heater, the presence of open fire place, the presence of garden and garage are indicated by dummy variables. The mean values for some of these features are given in Table 1. The descriptive statistics are based on 663,024 houses sold in the time period considered. The features in the accessibility category include distance to the railway station, the frequency of trains and the distance to the nearest highway entry/exit point (both with respect to the most frequently chosen station for residents in the post code area and the nearest station to the house). The analysis also includes the perpendicular distance to railway lines in an effort to capture the noise effect of railways.

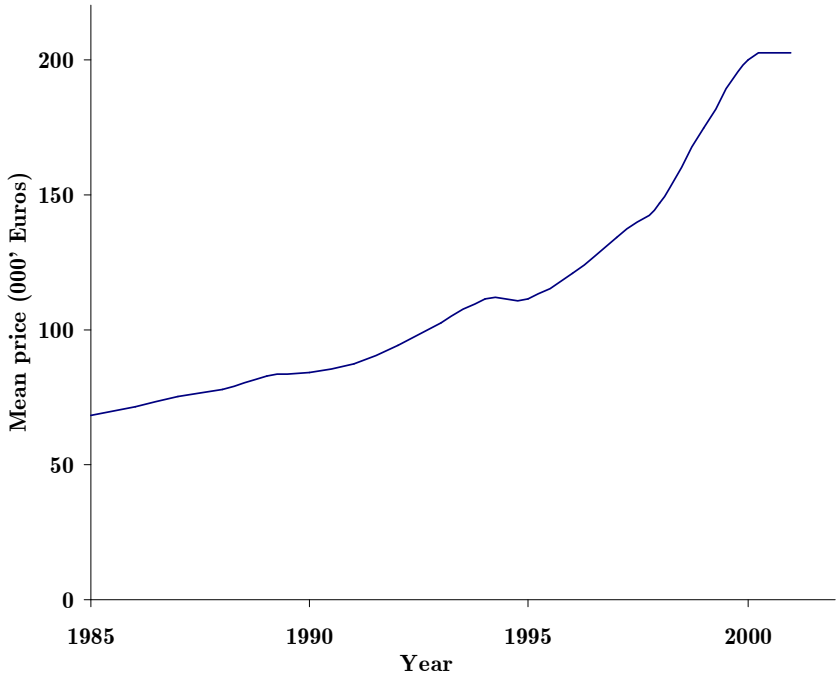

Figure 1: Mean price of houses by year

The distance to the most frequently chosen station is on average about 1 kilometre longer than the average distance to the nearest railway station. The average frequency of trains at the most frequently chosen station is more than 100 trains per day over the average frequency of trains at

the nearest railway station. This gives and indication of the trade-off travellers make between proximity of stations and the level of service they offer. Figure 1 shows the average transaction price in each year. This increase can be attributed to combined effect of inflation and real value increase.

(B) RAILWAY STATION CHARACTERISTICS

The data of particular interest in this study concerns the railway accessibility and associated noise or congestion. Railway accessibility can be explained by two features: the proximity feature and service level features. The first feature is more or less captured by the distance measure whereas various features can contribute to the service level. Examples include the number of trains leaving the station per time unit, and network connectivity as measured by the number of destinations served by the station. In addition, it may also include facilities that supplement railway transport. For example the availability of parking space, the park and ride status of the station and the availability of bicycle safes can be mentioned. The overall Dutch railway network is composed of about 360 stations. Our data allows us to use the most frequently chosen departure station for households aggregated at the 4-digit post code level.

Table 2: Descriptive statistics for the railway station characteristics

	No. stations	Minimum	Maximum	Mean	Std. Deviation
Rail service					
Frequency of trains per day		18	788	113	103
Destinations reached without a transfer		1	114	16	14
Destination reached with one transfer		8	246	87	53
Travel demand					
Total Passenger turnout per day		46	145,700	5,600	13,770
Station type					
Inter-city stations	64			0.18	
Station Facilities (dummy variables)					
Train taxi	109			0.30	
Bicycle stand	96			0.27	
Bicycle safe	264			0.74	
Bicycle rent	114			0.31	
Park and Ride	49			0.14	
Parking	326			0.91	
Taxi	163			0.45	
Car rent	1			0.00	
Luggage deposit	64			0.18	
International connection	22			0.06	

4. METHODOLOGY

The hedonic pricing methodology is found to be effective in singling out the effect of one characteristic from a number of characteristics composing a property (Rosen 1974). This paper uses this approach to determine the effect of the three categories of house features in general and railway accessibility in particular. A semi logarithmic specification is adapted. Thus, the dependent variable in our analysis is the natural logarithm of the transaction price of residential houses. A wide range of independent variables that are expected to explain the house prices are included. These include the physical characteristics of the houses, environmental amenities and the accessibility variables that correspond to the houses under study. Due to the fact that the data set covers a relatively long period, and house prices have increased continuously during the last decade temporal effects are also expected to play a role in explaining the variation in the sales price of houses. Thus, we include sales year dummies to capture the temporal effects. These account for the inflation, real value changes and other temporal effects across the time period. To account for the spatial effect regional dummies are included at the municipality level. The main focus of the analysis here is the effect of railway station proximity and service quality of the stations. We also include the effect of proximity to highway entry/exit points to account for competition by the car.

MODEL SPECIFICATION

Even though the data include a longer period, we could not organise our data in a panel structure because there were not many repeated sales over the time. Therefore, our data is organised in a cross-sectional pattern. The semi logarithmic hedonic specification is widely used in the property value literature. Its use is motivated by the fact it gives robust estimates and it enables convenient coefficient interpretation. The general structure of the model we adopt here is:

$$Ln(P_i) = B_0 + B_1^{'} X_{i1} + B_2^{'} X_{i2} + ... + B_n^{'} X_{in} + \varepsilon_i \qquad (1)$$

P_i is the price house i, $X_{i1} \ldots X_{in}$ are vectors of explanatory variables for the price of house i. The dependent variable is given in the natural logarithmic form; thus the values of the coefficients represent percentage change. The specifications used in the estimations are given by equations 2 and 3. Distances from the houses to railway station and line and highway entry /exit

points are distinguished according to several distance categories. The first model includes the distance and frequency effect (station quality) separately. The second model includes the interaction between distance and frequency. In both specifications proximity to railway station and railway line are treated in piecewise fashion. Frequency of trains at the reference station is given in continuous form. The models have the following form:

$$\begin{aligned}\ln(\text{tranPrice}_i) = \alpha &+ \beta'_{HC} \times HouseChr_i + \beta'_{dc} \times Distcategrail_i + \beta_{freq} \times \ln(FreqT_i) \\ &+ \beta'_{hw} \times Distcateghway_i + \beta'_{railline} \times Drailline_i + \beta'_{Neighb} \times Neighb_i \\ &+ \beta'_{Region} \times Dregional_i + \beta'_{time} \times Dtime_i + \varepsilon_i\end{aligned} \tag{2}$$

$$\begin{aligned}\ln(\text{tranPrice}_i) = \alpha &+ \beta'_{HC} \times HouseChr_i + \beta'_{DC \otimes Freq} \times Distcategrail_i \otimes \ln(FreqT_i) \\ &+ \beta'_{hw} \times Distcateghway_i + \beta'_{railline} \times Drailline_i + \beta'_{Neighb} \times Neighb_i \\ &+ \beta'_{Region} \times Dregional_i + \beta'_{time} \times Dtime_i + \varepsilon_i\end{aligned} \tag{3}$$

Where tranPrice_i represents the transaction price of house i; $HouseChr_i$ is a vector of house characteristics for house i, which includes variables for type of house, surface area, total number of rooms, number of bathrooms, presence of garage and garden for the house, presence of gas heater and fire place, monument, age of the building; $Distcategrail_i$ is a vector of dummy variables representing the distance category at which house i is located from a station. To see the smoothness of the effect we use a 500 meters range categories except in the two inner circle categories of the station, which are 250 meters each. Thus we have 31 categories of distances up to 15,000 meter. Areas beyond this limit are taken as a reference group in the estimation. $FreqT_i$ is the frequency of trains at the station to which the distance is computed and is given in trains per day. In our analysis we make two station considerations: the nearest vs the most frequently chosen station in the post-code area. $\otimes$ is the Kronecker product to indicate the cross production of distance classes and frequency of trains at the reference station. $Distcateghway_i$ is a vector of dummies representing the distance category at which a highway entry/exit point is located from the house. In the same fashion as the railway distance categories, we also have 31 distance categories for these variables. $Drailline_i$ is a vector of two dummy variables representing at which distance category the house is locating from the railway line. This is expected to account for the noise effect of trains. The railway noise is expected to have localized effect and thus we

compare the effect of noise on two nearby distance against rest. $Neighb_i$ is a vector of neighborhood characteristics including income, ratio of foreigners and rate of land use types. It is given at the four-digit post code level. $Dregional_i$ is a vector of dummy variables representing to which municipality the house belongs. $Dtime_i$ is a vector of time dummy variables representing the year when the transaction took place. ε_i is the error term.

The accessibility related variables included are the distances to the railway stations, the frequency of trains at the stations and highway entry/ exit points. The structural features considered are the type of the houses, surface area of the houses, total number of rooms, number of bathrooms, presence of garage, garden, gas heater and fire place, monumental status of the houses, and age of the houses. Variables included under the environmental features are average household income, ratio of foreigners, and rate land use types at the post code level and regional municipality dummy variables. The distance to the railway line is another variable that can be considered under the environmental variables. Year dummies are also used to account for the temporal effect. All in all the total number of explanatory variables in the hedonic pricing models is 344. Of these 34 relate to house characteristics, 28 to neighbourhood features, 16 to time series dummies and 203 to municipality dummies. The remaining 63 variables represent railway and highway accessibility. In the presentation of estimations below we focus on the impact of the accessibility variables. The municipality dummies can be considered to represent the many municipality specific factors that may affect house values. Thus, the effects we find for the railway station proximity have been corrected for municipality specific impacts.

Generally, the price of houses is expected to rise as one comes close to the railway station and/or highway entry/exit points. At the same time, the influence of a station to the house prices is expected to increase with the increase in the service level provided by the station as given by frequency of trains and the number of destinations directly served by the station. However, the latter two variables are highly correlated, thus we prefer to include one of the two in our estimation. We find the frequency variable more telling since it addresses scheduling and waiting time aspects, an important dimension of generalized costs. In addition, frequency is related to reliability since delays are less disturbing in the case of high frequency.

5. ESTIMATION RESULTS AND DISCUSSIONS

Table 3 gives four estimation results based on equations 2 and 3. To save space we only report the coefficients of the factors that relate to railway aspects. The complete estimation results are available upon request from the authors. The first two estimations correspond to the simple linear effect of piecewise distances and frequency of trains effect treated separately as given by Equation 2. The last two estimations are based on the model given by Equation 3. The cross distance-frequency estimation gives the effect of frequency of trains on house prices for each of the distance classes. The semi-log nature of the model makes the interpretation of the coefficients easier. Each coefficient for the distance categories in the first two estimations shows the percentage effect on house prices of distance to the station compared to houses located beyond 15 kilometres. Thus, we observe a difference as big as 32% in house prices for houses within 500m of the nearest station and houses beyond 15 kilometres from the stations. This difference gets smaller in the case of the most frequently chosen station effect (about 27%), where we encounter the peak house price to be between 250 and 500 metres. The trend of the effect sizes for this specification is given in Figure 2. This figure shows irregularity in the distance category of 7.5 to 8 kilometers. This is due to the small number of observations in this category. Such irregularities are inevitable when small distance classes are used. The difference between the distance effect of the nearest and most frequently chosen station is remarkable. The advantage of being close to the station is not so large in the case of the most frequently chosen station compared with the nearest station. The reason is that the most frequently chosen station apparently has extra qualities that make it more attractive than the nearest station. Hence, one may expect that distance to the station matters less in the price effect on real estate. The mirror image is that the quality of the station, as reflected among others by the frequency, has a larger effect. This explains why the frequency elasticity in Table 3 is so high for the most frequently chosen station compared with the nearest station (0.09 versus 0.03). A doubling of frequency of trains at the most frequently chosen station has 9% house price increase in the post code area compared to 3% for the case of the nearest railway station (see the first 2 columns of Table 3). Finally, we find clear negative effects of railway noise on house values: houses located in the zone within 250 meters from a railway line are about 5% less expensive than houses located 500 meters or more. For the zone between 250-500 meters intermediate values are found.

However, the measure of frequency of trains' effect discussed above is crude since it is not distance dependent. The point is that for dwellings close to a station a frequency increase is probably of more importance than for dwellings far away. The last two columns of Table 3 provide the estimation of the cross distance-frequency effect. Doubling the frequency of trains in the nearest station results in as much as 3.5% price increase for houses located up to 2 kilometres compared to the effect on dwellings located beyond 15 kilometres. Doubling the frequency of the most frequently chosen station on the other hand results in about 3.0% price increase for the same distance section. The pattern in the elasticities of frequency for the different distance categories is depicted graphically in Figure 3. These estimations demonstrate that the value of property may depend on the proximity to more than one railway station. We will not investigate this issue in more detail here, but this is an indication that railway station accessibility is a more complex concept than one might think: it involves competition between railway stations.

Furthermore, the percentage effect of different levels of frequency is given in Table 4 below. The table shows -not surprisingly- that the effect of railway proximity is largest in the case of a station with a high level of service. Note that such a differentiated effect is not present in the specification given by Equation 2. However, the frequency impact is smaller than one might expect. The price curves are clearly steeper around stations with higher frequencies. Further, we find that even for stations with a small number of trains a substantial effect of railway presence is found. Note that this estimation is based on a specification where corrections were carried out for a large number of other variables. In particular, a dummy has been added for each municipality so that it has been assured that the results found do not capture the effects of other variables such as population density or other municipality specific factors.

Table 3: Estimation of Railway station effects on house values: piecewise distance effect *(N.B. Only railway related parameters are presented)*

Variable	Nearest Station		Most frequently chosen station		Cross distance-frequency of trains effect			
					Nearest Station		Most frequently chosen Station	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
(Constant)	8.966***	0.009	8.775***	0.009	9.189***	0.008	9.232***	0.008
raildist250	0.323***	0.006	0.271***	0.004	0.050***	0.001	0.043***	0.001
raildist250_500	0.321***	0.005	0.274***	0.003	0.050***	0.001	0.044***	0.001
raildist500_1000	0.315***	0.005	0.260***	0.003	0.049***	0.001	0.043***	0.001
raildist1000_1500	0.308***	0.005	0.246***	0.003	0.048***	0.001	0.042***	0.001
raildist1500_2000	0.316***	0.005	0.245***	0.003	0.049***	0.001	0.043***	0.001
raildist2000_2500	0.296***	0.005	0.232***	0.003	0.045***	0.001	0.041***	0.001
raildist2500_3000	0.287***	0.005	0.203***	0.003	0.042***	0.001	0.036***	0.001
raildist3000_3500	0.277***	0.005	0.203***	0.003	0.041***	0.001	0.038***	0.001
raildist3500_4000	0.299***	0.005	0.201***	0.003	0.046***	0.001	0.038***	0.001
raildist4000_4500	0.284***	0.005	0.181***	0.003	0.042***	0.001	0.035***	0.001
raildist4500_5000	0.252***	0.005	0.160***	0.003	0.037***	0.001	0.033***	0.001
raildist5000_5500	0.238***	0.005	0.153***	0.003	0.033***	0.001	0.033***	0.001
raildist5500_6000	0.234***	0.005	0.133***	0.004	0.033***	0.001	0.030***	0.001
raildist6000_6500	0.226***	0.006	0.106***	0.004	0.031***	0.001	0.027***	0.001
raildist6500_7000	0.229***	0.006	0.105***	0.004	0.032***	0.001	0.028***	0.001
raildist7000_7500	0.204***	0.006	0.093***	0.004	0.027***	0.001	0.026***	0.001
raildist7500_8000	0.235***	0.006	0.006***	0.004	0.034***	0.001	0.009***	0.001
raildist8000_8500	0.215***	0.006	0.065***	0.004	0.029***	0.001	0.021***	0.001
raildist8500_9000	0.266***	0.006	0.098***	0.004	0.040***	0.001	0.028***	0.001
raildist9000_9500	0.213***	0.007	0.106***	0.004	0.029***	0.001	0.030***	0.001
raildist9500_10000	0.177***	0.007	0.100***	0.004	0.023***	0.001	0.028***	0.001
raildist10000_10500	0.158***	0.007	0.047***	0.005	0.019***	0.001	0.018***	0.001
raildist10500_11000	0.069***	0.007	0.040***	0.005	0.002	0.001	0.017***	0.001
raildist11000_11500	0.037***	0.008	0.038***	0.005	-0.005***	0.002	0.016***	0.001
raildist11500_12000	0.036***	0.008	0.053***	0.005	-0.006***	0.002	0.022***	0.001
raildist12000_12500	0.036***	0.009	0.070***	0.005	-0.005***	0.002	0.026***	0.001
raildist12500_13000	0.022***	0.009	0.070***	0.005	-0.011***	0.002	0.024***	0.001
raildist13000_13500	0.007	0.009	0.047***	0.005	-0.013***	0.002	0.020***	0.001
raildist13500_14000	0.028***	0.008	0.034***	0.005	-0.007***	0.002	0.016***	0.001
raildist14000_14500	0.031***	0.008	0.062***	0.005	-0.003	0.002	0.021***	0.001
raildist14500_15000	0.029***	0.009	0.035***	0.005	-0.002	0.002	0.015***	0.001
Log (frequency)	0.033***	0.001	0.096***	0.001				
railline250	-0.051***	0.001	-0.055***	0.001	-0.050	0.001	-0.047***	0.001
railline250_500	-0.038***	0.001	-0.042***	0.001	-0.037	0.001	-0.036***	0.001
R square	0.829		0.831		0.829		0.830	
N	542,884		543,873		542,884		543,873	

Linear regression model coefficients with standard errors of the estimates in parentheses
*** stands for a significance level of less than 1%
** stands for a significance level of less than 5%
* stands for a significance level of less than 10%

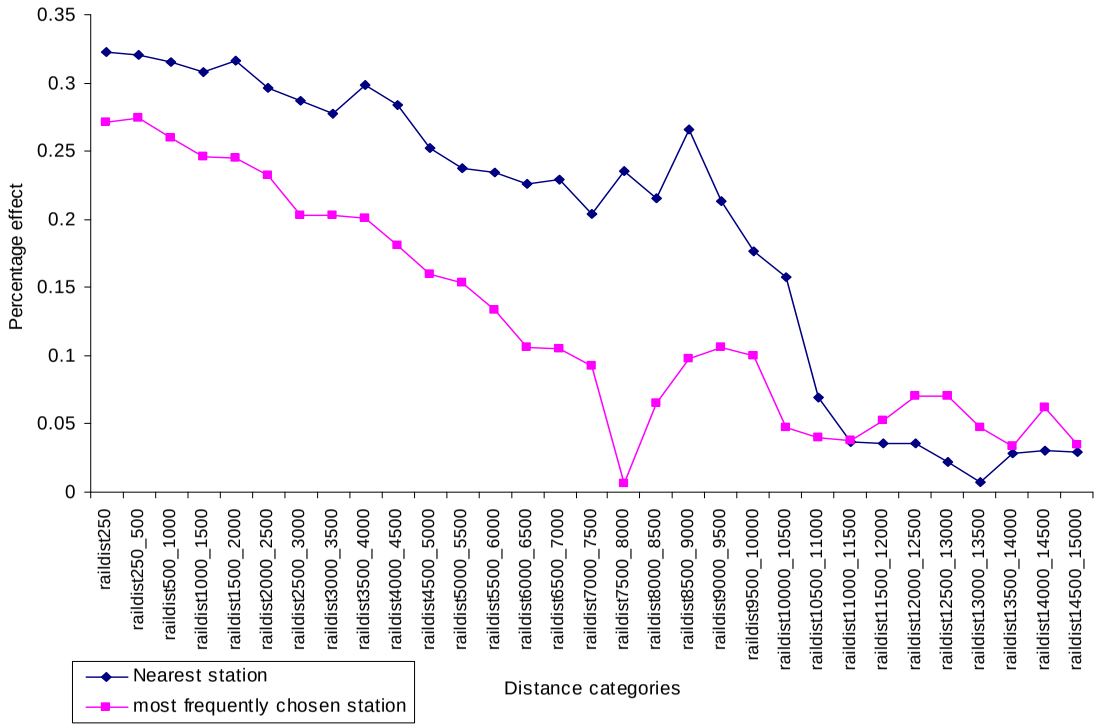

Figure 2: Effect of railway station distance on house prices

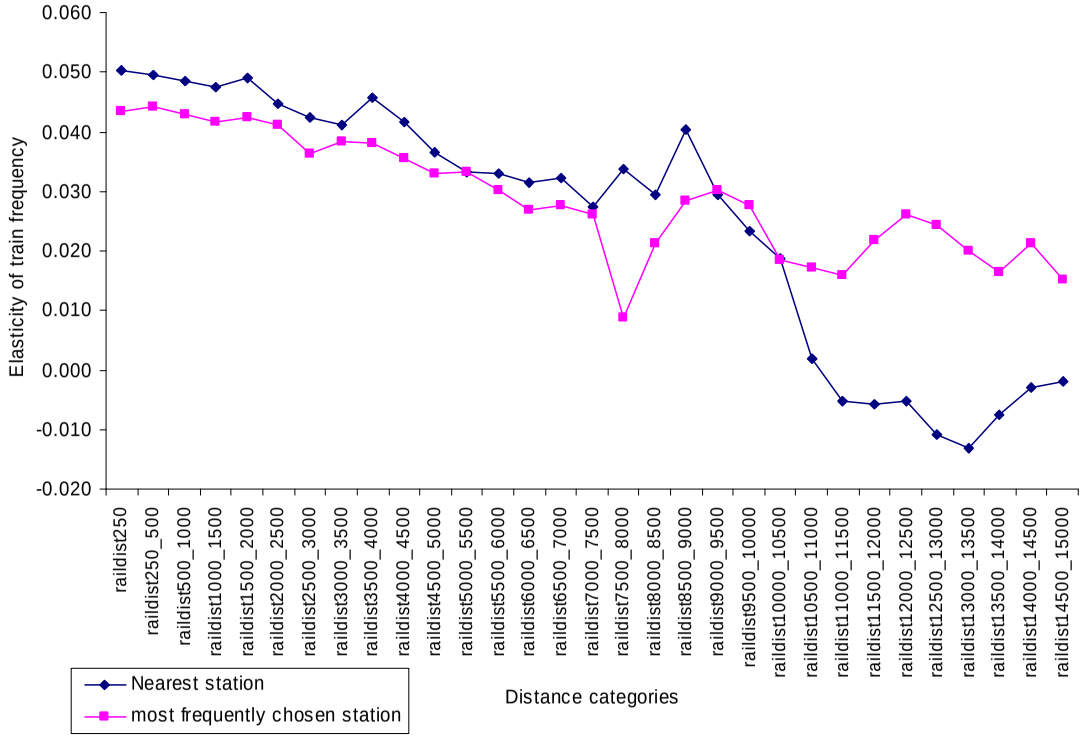

Figure 3: Cross-effect of railway station distance and frequency of trains on house prices

Table 4: The relative price difference of dwellings at sample distances compared with dwellings located beyond 15 kilometres. (Based on cross distance –frequency specification)

Distance	0-250 m		5000-5500 m		10000-10500 m	
Frequency (trains/day)	Nearest station	Mostly chosen station	Nearest station	Mostly chosen station	Nearest station	Mostly chosen station
50	19.6%	16.8%	12.9%	12.9%	7.4%	7.0%
100	23.0%	19.8%	15.2%	15.2%	8.7%	8.3%
200	26.5%	22.8%	17.5%	17.5%	10.1%	9.5%
400	30.0%	25.8%	19.8%	19.8%	11.4%	10.8%
800	33.4%	28.7%	22.1%	22.1%	12.7%	12.0%

When one wants to achieve an increase in real estate values along a railway line, there are several strategies. One strategy would be to increase the frequency of service on existing stations, and Table 4 shows the rather modest effects. Another strategy would be to create an extra station. If two stations are located at distances of say 10 kilometres and a new station is built in between the two, the distance to the nearest station decreases up to a maximum of 5 km. As indicated by Table 4, the latter strategy would lead to an increase in house value of at most 6.7% (19.6%-12.9%) of the dwellings located in the immediate vicinity of the station. With the present model it is not possible to investigate the consequences of adverse effects on travel times due to the extra stop. Note that, when we compare the effects of creating an extra station or a frequency increase, the first mainly affects property values in one location, whereas the latter would be beneficial for all stations where the train would stop.

6. SUMMARY AND CONCLUSION

This paper analyses the effect of railway station accessibility on the house prices. A cross sectional hedonic price model is estimated based on Dutch residential house transaction in the years from 1985 to 2001. The model accounts for physical, environmental, temporal and accessibility features of the residential houses. For each of these features a wide range of

variables is included. The main focus of this paper is, however, to analyse the effect of accessibility provided by railway transport on property values. Most studies in this area only consider the proximity of properties to railway stations. However, this approach is limited because accessibility of railway stations is more than proximity to railway stations. In other words, railway stations are not chosen as departure points for reasons of proximity alone. Thus, we need a better approach to address railway accessibility in the analysis. Railway accessibility is a function of the distance and the service levels at the relevant departure railway stations. The choice for a departure railway station is also affected by the levels of rail service, network connectivity, service coverage and facilities. Thus, it is possible for the residential property value to react to an important railway station located farther away than a less important one located nearby. In this respect most previous studies had shortcomings in that they neglect the choice process for a departure station in their property value effect analysis by sticking to the nearest railway station. This paper adds to the literature in this area in two respects. First, we make a distinction between the nearest railway station to the property and the most frequently chosen station in the post code area to which the property under consideration belongs. Second, a broader approach for addressing accessibility is applied by taking into account the frequency of services. The effects of proximity and service levels on property values are analysed. In addition we pay attention to the distance to railway lines to reflect potential noise and other disturbance effects.

Correcting for a wide range of other determinants of house prices we find that dwellings very close to a station are on average about 25% more expensive than dwellings at a distance of 15 kilometres or more. This percentage ranges between 19% for low frequency stations and 33% for high frequency stations (see Table 4). A doubling of frequency leads to an increase of house values of about 2.5%, ranging from 3.5 for houses close to the station to 1.3% for houses far away. Finally we find a negative effect of distance to railways, probably due to noise effects: within the zone up to 250 meters around a railway line prices are about 5% lower compared with locations further away than 500 meters. As a result of the two distance effects, the price gradient starts to increase as one moves away from a station, followed by a gradual decrease after a distance of about 250 meters.

Our estimations reveal that the distinction between nearest railway station and most frequently chosen railway station is important. In many cases the traveller does not choose the closest station. This is an indication that railway station accessibility is a more complex concept than one might think, as it involves competition between railway stations, a subject we intend to address in a forthcoming paper.

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Attachment M
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SURVEY

Undesirable facilities and property values: a summary of empirical studies

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Abstract

Undesirable land uses are expected to impose health or amenity risks on surrounding communities. These risks are expected to be translated economically into negative effects on adjacent property values. These negative effects may be present even when such uses possess offsetting advantages of proximity, such as employment opportunities. The purpose of this study is to summarize empirical studies completed to date that test whether undesirable land uses have observable negative effects on adjacent property values. This information may be useful in assessing minimum valuations of terminating undesirable land uses, such as clean-up of hazardous sites, or compensation necessary to ameliorate the economic impacts of new undesirable uses. © 1998 Elsevier Science B.V.

1. Introduction

People have concerns about environmental risks or nuisances and express a willingness to pay to avoid them (Fischer et al., 1991). These concerns range from worries about health risk to public images of the community, and are rationally related to more than quantitative risk factors (Wandersman and Hallman, 1993). Under conditions of adequate information, the real or perceived location-specific adverse hazard or amenity effects of certain types of land use are, in principle, incorporated in location-related markets as people would be willing to pay to reside or work where risks or nuisances are lower. The most obvious impacted market is adjacent property markets, while a less obviously impacted market may include local labor markets. This study provides a summary of empirical tests of whether the location of undesirable land uses, such as waste sites, hazardous manufacturing facilities, or electric utility plants, have adverse effects on residential property values in surrounding communities or neighborhoods. This is an important issue for several reasons.

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First, health and amenity risks associated with environmental hazards, whether real or perceived, may become translated into economic risks as well. A broad range of studies has shown relations between adverse general environmental conditions, such as air pollution, and economic effects on wages and property values, raising wages and lowering property values where conditions are poor (Freeman, 1979). Studies have shown that negative attitudes toward facilities which pose nuisance, health or environmental risks are strong and geographically extensive (Council on Environmental Quality, 1980; Lindell and Earle, 1983). These attitudes are frequently translated into reduced likelihoods of economic activities, such as vacationing, taking a job, or locating a business, in regions with such facilities (Slovic et al., 1991).

Second, the issue of siting hazardous or nuisance activities has raised public concern for localized risks to the point where siting such activities, while perhaps necessary in an industrial world, is becoming very difficult. Lober and Green (1994) have found that public opposition to undesirable land uses, such as waste disposal facilities, diminishes with distance from a site in a predictable manner. Some researchers have proposed that it is the mismatch between costs and benefits of such uses that motivates this opposition (Lober and Green, 1995). This aversion has spawned a range of policy responses to siting that are directed toward reducing community perceived costs of siting. For example, opposition to undesirable facilities may be moderated by community compensation grants (Kunreuther et al., 1990). Massachusetts requires private companies to negotiate with host communities in establishing adequate compensation for the location of hazardous waste facilities (Massachusetts General Laws, Chapter 21D, §12). The magnitude of adequate compensation may depend partially on real or perceived adverse property value impacts of siting.

A third reason is related to the emerging concern for environmental justice and the related use of civil rights law to protect citizens from environmental risks. Discrimination, per se, independent of proof of adverse effects of potentially hazardous facilities or nuisance activities, is the focus of this argument (Environment Week, October 14, 1993). However, there must be some presumption that the discrimination has an adverse consequence, otherwise why would there be a concern. A finding of adverse economic impacts of undersirable land uses could provide a substantive basis for concerns of environmental justice. For example, siting a hazardous waste facility in a low income, minority community may adversely impact both the health and economic well-being of that community, providing a basis for concerns that such communities bear both health and economic risks from siting procedures.

A final reason is that property value impact measures serve as indicators of the costs to communities of accepting undesirable land uses, and as measures of potential benefits from remediating the risks associated with those uses. As a cost measure, property value impact studies may be useful in estimating acceptable compensation for undesirable land uses. While a community's acceptable price can be established through bargaining with the individual community, this price will almost certainly depend on community circumstances such as income levels and discrimination in housing and labor markets. Concerns for environmental equity may seek to avoid taking advantage of hardship communities, who could bear disproportionate risks for little compensation. Conversely, communities may strategically set high prices for accepting undesirable land uses as a bargaining strategy. Property value effects from other communities can be useful as a basis for setting bounds for compensation in such cases. As a benefit measure, these studies are useful in estimating benefits of policies such as hazardous site cleanups (Adler et al., 1982).

This review of property value studies first outlines the theoretical foundations for the statistical analysis of disamenity effects on property values in Section 2. Section 3 outlines the details of the reviewed studies. Section 4 presents a broad summary of these studies along with a discussion of the results for a range of facilities and incidents.

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2. Theory

The fact that neighborhood and community amenities affect the relative desirability of residential locations is well known (Bartik and Smith, 1987). It is also well known that certain types of facilities are considered disamenities which people would rather avoid in making residential location decisions. Research on communities near hazardous waste landfills, for example, has found serious concerns for health as well as property values and community image. Residents near such facilities had greater fears of cancer than more distant residents. These perceived risks were supported by sensible beliefs and outrage factors stemming from unfamiliarity, uncontrollability, and inescapability (Wandersman and Hallman, 1993). A study of residents in an industrial area of Rijnmond, Holland, with a high number of chemical plants and refineries, found that 60% of persons living within 4 km of a facility felt extraordinarily defensive or vigilant (Stallen and Tomas, 1988).

The willingness to accept risky land uses, such as a nuclear waste disposal facility, may depend more on subjective risk factors than on objective factors such as likelihoods of events (Kunreuther et al., 1990). In general, perceived risks may differ substantially from statistical risks, albeit in logical ways. A considerable literature has developed showing that perceived risks are a function of statistical risks as well as subjective risk factors, such as dread, involuntariness, controllability, severity of consequences, etc. (Slovic, 1979). However, regardless of whether the source of the perception is quantitative or subjective, the impact on property markets can be the same. Property markets are not behaving irrationally when subjective risk factors enter as price determinants.

These studies are useful in substantiating the nature and intensity of reactions to local adverse land uses. However, they fall short in providing quantifiable estimates of harm sufficient for measuring economic damages. The economic methods for quantifying this harm have consisted of both revealed preference and hypothetical survey techniques. The former method consists primarily of property or wage market studies; the latter is typically a variant of contingent valuation (CV) methodology. Each of these methods is discussed below.

The revealed preference method seeks to observe what individuals apparently really pay or require in compensation associated with adjacent adverse land uses. The typical method is to use information on related markets, usually property and labor markets, to determine compensating differentials associated with the land use. In cases where the land use is so localized as to have little impact on general economic conditions of a community, adjacent property values are expected to capitalize adjacent land use impacts. The theoretical argument is that property provides a flow of services which becomes monetized and capitalized in property markets, and that flow is diminished by adverse adjacent land uses. In practice, however, there can be considerable difficulty in identifying the property market impact of a disamenity.

The market values of properties and their structures depend upon an array of factors associated with characteristics of those properties and structures, ranging from physical features, such as lot size and age of structure, to relational features associated with the proximity of those sites to relevant economic activities such as job and population centers, beaches, lakes, etc. Economic theory suggests that each feature will have its own implicit price (Palmquist, 1984). For example, each mile that the property is closer to an undesirable amenity the lower the market value of the site; hence, each mile of proximity has a negative price and each mile further distant has a positive price.

Many factors impact property markets, and adjacent land use is only one of them. Hedonic pricing methods (Rosen, 1974) are helpful in this regard, since they attempt to identify the price effects associated with each of the many dimensions impacting property values. This technique has commonly been applied to urban housing markets (Follain and Jimenez, 1985). The implicit values of a wide range of environmental amenities and disamenities have been estimated using this technique (Harrison and Rubinfeld, 1978; Freeman, 1979). Control group methods attempt to explicitly control for variations in value determin-

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ing factors by selecting comparison properties that are comparable in every respect except for the adjacent adverse land use. This is the typical appraisal technique.

Hedonic methods are limited in several respects. First, property markets may not be in equilibrium. Price differentials associated with disamenities may be more or less than what they would be when all relocations have taken place (Freeman, 1993). This is particularly problematic when attempting to estimate the impacts of a new disamenity or removal of an old one. Second, there is an inherent problem in statistically identifying from property-distance value gradients the willingness to pay to avoid a disamenity (Freeman, 1993). For example, selectivity plays a strong role in residential location decisions. When persons most willing to accept the disamenity, or who have limited housing options because of income or discrimination, locate adjacent to a disamenity, property value differentials will overestimate the disamenity effect for the general population. Third, to the extent that the adverse activity may be locally job enhancing, adjacent housing values could be elevated and apparently perverse because of positive wage effects associated with the land use. Although there could still be a negative amenity component, it may be offset by a positive wage effect. A hedonic study that does not allow for labor market effects would underestimate the adverse amenity effect.

The CV method essentially establishes a hypothetical choice situation (Mitchell and Carson, 1989). There are a wide variety of choice formats. The most straightforward variant would be to ask individuals a question such as: 'what would you pay to avoid living (or accept in compensation to live) next to a Superfund site?' A more complex variant, conjoint analysis, would present individuals with a set of options, with each option characterized by several dimensions, and ask the individuals to choose or rank the options.

In principle, CV is a very direct method of obtaining valuation information when the real situation is muddled by lack of information or confounding variables. It is useful in this context because it has the potential of singling out the particular amenity or disamenity to be valued. In practice, there are many pitfalls associated with the proper specification of CV scenarios and interview techniques. Perhaps the most severe problem in this context of valuing environmental disamenities is the incentive to misrepresent values, or strategic bias. This may be especially true if the respondent thinks that actual compensation or policy may depend upon their response (Freeman, 1993). For example, there would be a serious potential bias problem if the respondent believes that compensation under litigation for hazardous site related damages will depend on CV responses; or if the respondent believes that the policy to locate a nuclear power plant would depend upon responses. When an individual does not see or believe a connection between responses and policies, such circumstances do not arise and strategic bias may not be a severe problem with CV techniques. In this case, consumer choice theory suggests that CV valuations will be less than or equal to hedonic based valuations. Brookshire et al. (1982) show this is the case in a study of air pollution in the Los Angeles, CA, basin.

3. Studies of undesirable facilities and property values

The empirical studies of effects of undesirable facilities and activities on surrounding property values have been limited to the analysis of residential properties. Micro scale studies estimate the distance gradient effects of undesirable land uses, while the macro scale studies estimate community-wide property market effects after controlling for broad housing value determinants. Both cross-sectional and time-series methods are used. The cross-sectional method would consider property values for different properties during essentially the same time period. For example, it may compare housing prices in neighborhoods or communities having undesirable facilities with those in areas where such facilities are absent; or it may compare contemporary housing prices at various distances from an undesirable land use. The time-series method would investigate values over time, possibly using repeat sales and including periods before and after undesirable facilities or activities were revealed.

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There are reasons to expect that observed property market impacts of undesirable land uses may differ according to local conditions, such as the strength of economies and housing markets, tastes and preferences of impacted communities, and the real or perceived risk or adversity compared with the benefits of locating nearby. For example, an industrial facility may pose health and amenity risks, but offer employment, resulting in increased property values observed near the facility. People have degrees of aversions to different types of facilities. For example, a study of Boston residents (Smith and Desvousges, 1986) found that only 23, 33, and 48% of the surveyed population would willingly live within 5 miles of a nuclear power plant, hazardous waste landfill, or coal-fired electric generating plant, respectively. These are all facilities from which benefits of the services provided, electricity and waste disposal, can be obtained without being adjacent to them. However, employment opportunities may create demands for adjacency to the power plants, but not the waste facility. If tolerance to risk is a function of both perceived risk and benefits (Slovic et al., 1980), we might expect that negative property value effects from proximity to the waste facility would be more severe than for the power plants. The point is that we would not necessarily expect the property value effects to be similar across types of facilities and land uses.

Table 1 presents a brief summary of relevant studies. Ten of the twenty-five studies summarized pertain to hazardous waste (HW) or National Priority List (NPL) sites. NPL sites are hazardous waste sites that pose such high risks that they are listed under the Superfund program. They receive a higher level of scrutiny and public visibility than non-listed sites. One study pertains to a closed municipal landfill site and six to open solid waste landfills and incinerators. One study considered the effects of a coal-fired electric utility, while two studies estimated the effects of existing nuclear facilities. One study estimated the impacts of chemical facilities while another considered a broad range of undesirable facilities. Two studies considered the effects of disastrous events: a PCB spill and a nuclear disaster. The hazardous waste site studies include both NPL sites and closed or active non-NPL sites. There are four potential estimable effects for NPL sites: distance effects prior to NPL nomination announcements; announcement effects; effects after NPL announcements; and effects after cleanup. Housing value effects are converted to 1993 dollars when possible.

The Michaels and Smith (1990) hedonic study showed that property values increased with distance from HW sites in suburban Boston, both before and after the announcement that those sites would be NPL sites. However, only the effect after the announcement was statistically significant, implying that values would increase 1.3% to 1.9% per mile, depending upon the quality of the housing market. This implies average annual housing cost increases for each additional mile from a site of $124 per year for the full sample; or a capitalized average of $1168 per mile. This capitalized value can be indexed up to 1993 dollars, and is equal to $3310 per mile. The major effects were only in the 'Premier' and 'Average' quality housing markets.

A similar pre- and post-NPL announcement pattern was found by Kohlhase (1991) in a hedonic study of Houston. Pre-announcement housing prices increased between $880 and $1180 per mile from future NPL sites; but increased by $2364 per mile after announcements with one site showing a $3310 per mile distance effect. It is important to note that there were no distance effects observed after the cleanup of sites.

A hedonic study of smaller communities in the suburbs of Toledo, OH, found that each additional mile from an active hazardous waste landfill increased property values between 16 and 25%, or between $9000 and $14 000 for the study area (Smolen et al., 1991). This effect is greater than those estimated for the larger urban areas of Boston and Houston. This larger effect for a smaller community is consistent with Greenberg and Hughes (1992) conclusions that Superfund sites had greater negative impacts on property values in rural communities than in more urbanized communities. The Smolen et al. (1991) study also investigated the effects of the announcement, and subsequent cancellation of a proposed low level radioactive waste site. The announcement

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Table 1
Summary of studies of hazardous facilities/incidents and residential property values

Study	Years	Event/Facility	Region	Effect	Special comments
H	62–70	Solid waste landfills	Fort Wayne, IN	Each additional mile from site increases values approximately $3200 [$14,016 per mile]	+effect of degrees away from downwind direction
B	70	Coal-fired electric utility	Winnetka, IL	Each additional mile from site increases values $3256 [$14,261 per mile]	+effect limited to three miles
S and R	70–75	Solid waste landfills	Los Angeles, CA	No price effect for two sites; negative distance effect for one site	The site with the negative distance effect was to close and become a golf course course within several years of the study
RPC	70–80	Sanitary landfills	Houston, Baltimore, Minneapolis, Atlanta	No adverse effects on property values using projected values or comparison communities for three of four sites; positive effect at one site	Study funded by Browning Ferris in regions BFI anticipated developing site
A	74	NPL HW site	Pleasant Plains, NJ	After contamination discovered, each additional mile from site increased values $2700 ($9468 per mile)	+effect limited to 2.25 miles
K	76–85	Announce NPL HW site	Houston, TX	Each additional mile from site increases values $880–1180 [$1250–1676 per mile] prior to announcement, and $2364 [$3357 per mile] after announcement	Non-linear distance effect is highest at site ($5000) and decreases with distance. No effect after cleanup
M and S	77–81	NPL HW site	Suburban Boston	Insignificant effect prior to announcement but after announcement additional mile from site increases values $124 per year; capitalized to $1168 [$3310 per mile]	Major effects in 'Premier' and 'Average' markets
N	79	Three Mile Island event	TMI, PA	No TMI event effect on sales prices	No analysis of time on market
C and N	79	Various undesirable facilities	U.S. counties	Higher property values when density of refineries in count decreased but lower wages. Net annualized effect is $468–1764; capitalized to $4412–16,629 [$9974–37,585 per home]	No HW site effect, but data pre-superfund
KK	80	HW sites	New Jersey	More HW sites in a municipality reduces median home values: one additional site reduces median values 2–2.5%; or $1255–1600 [$2410–3072 per home]	Correlation: number sites, % non-white, property tax rates (controlled in hedonic model)

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Table 1 (continued)

Study	Years	Event/Facility	Region	Effect	Special comments
G	77–81	Sanitary landfills	Pennsylvania	Positive effect of distance to landfill on property values in only one of two study years; no effect in other two years (based on anay-sis of only one site	Large landfill (>500 t/day) had lower rates residential new construction and sales than small landfill
G and D	75–80	Nuclear power plant	Pennsylvania and East Coast	Additional mile from PA plant increased property values by $163 [$313 per mile]; but no effect for East Coast plants	PA plant could have been located in depressed housing market
G and H(a)	75–88	NPL HW sites	New Jersey	Number of Superfund communities with property prices increases was less than for control communities	Superfund site effect most marked in rural communities; and in 'Hot' markets
M	69–88	PCB incident	New Bedford, MA	Loss in value in zones proximate to impacted areas ranges from 3% to 8%; or $7000–10,000 [$8190–11,700 per home]	Negative effect increased after 1981, at least doubling by 1985
M and S and H	83–85	HW landfill	Los Angeles, CA	Health risk beliefs adversely affected values and closing landfill reduced risk beliefs. Expected $5000 [$7100 per home] gain in value after closing	Distance from site reduced perceived health risk
Z and A	82–87	Solid waste landfill and solid waste incinerator	Landfill-Tacoma, WA; Incinerator-Salem, OR	No effects of distance from landfill or incinerator (during any siting phase)	Maximum distance from sites in sample not clear; possibly broader effects than testable in sample
S and D	84	HW landfill	Boston, MA suburbs	Respondents willing to pay $330–495 per year more for housing one additional mile from site; capitalized to $2472–3199 [$3708–4799 per mile]	na
D	84–85	Chemical facilities	Charleston, WV	Each additional mile from nearest facility increased price by $157 [$222 per mile]; houses beyond 3 miles of any facility worth $1330–5978 [$1885–8472 per home] more	Announcement of Bhopal reduced prices 2.5%
S and C and S	85	Hypothetical HW landfill	Rural central IL	Property tax reductions necessary to induce respondents to live closer to hypothetical site: a 75% tax reduction increased willingness to live within 5 miles from 10% of sample to 20%	Sample was a small rural community

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Table 1 (continued)

Study	Years	Event/Facility	Region	Effect	Special comments
S	85–86	Inactive Municipal landfill	Kitchner, Ontario	Positive effect of distance from landfill site up to 500′: values $4264–7018 [$5714–9404 per home] lower within 140′ of site than at 500′ or beyond	Sample was small city; housing development occurred after site closed
N and G and G	79–89	Solid waste landfill	Ramsey, MN	Each additional mile from facility increased price by $4900 [$6948 per mile]	+effect limited to 2–2.5 miles
S and M	86–90	HW landfill and low level radioactive disposal site announcement	Toledo, OH	Positive effect of distance from HW site up to 2.6 miles: an additional mile increased values $9000–14,000 [$9990–15,540 per mile (16%–25% of sales price). Announced radioactive disposal facility created $4000 [$4440 per mile] gradient (up 5.75 miles); but cancellation eliminated gradient	Landfill neighborhood is blue-collar
G and H(b)	92	Superfund hazardous waste sites	New Jersey	Survey of assessors found 28% believing sites adversely impacted values within 1/4 mile of site; 21% believed adversely impacted number of sales; 16% believed existing land uses harmed; and 23% believed new land uses deterred	Only 26% response rate. Few believed impacts extended beyond 1/4 mile
K and M(a)	74–92	Solid waste-to-energy incinerator, from rumor to operations	North Andover, MA	No effect prior to construction; during construction, additional mile increased values $2283 [$2671 per mile]; during on-line phase, $8100 [$9497 per mile]; and during operations, $6607 [$7746 per mile]	+effect limited to 3.5 miles
K and M	74–92	Solid waste-to-energy incinerator, from rumor to operations	North Andover, MA	Appreciation rates 2% to 3.5% lower for samples community during construction to operations phases than prior phases; repeat sales showed positive effect of distance from site only for operations phase	na

$1993 in parentheses.
The 'Shelter' component of the CPI was used for adjustment. Annual values capitalized at 10% over thirty years.
Key to Study Abbreviations:A: Adler et al. (1982); B: Blomquist (1974); C and N: Clark and Nieves (1991); D: Dunn (1986); G: Gamble et al. (1982); G and D: Gamble and Downing (1982); G and H(a): Greenberg and Hughes (1992); G and H(b): Greenberg and Hughes (1993); H: Havlicek et al. (1971); K: Kohlhase (1991); KK: Ketkar (1992); K and M(a): Kiel and McClain (1995a); K and M(b): Kiel and McClain (1995b); M: Mendelsohn et al. (1992); M and S: Michaels and Smith (1990), Per mile estimate = MWTP/Mean distance change; M and S and H: McClelland et al. (1990); N: Nelson (1981); N and G and G: Nelson et al. (1992); RPC: Research Planning Consultants (1983); S: Skaburskis (1989); S and D: Smith and Desvousges (1986); S and C and S: Swartzman et al. (1985); S and M: Smolen et al. (1991); S and R: Schmalensee et al. (1975); Z and A: Zeiss and Atwater (1989).

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immediately created a positive and significant distance gradient of roughly $4000 per mile per house; but the gradient became insignificant after the proposed site was cancelled.

McClelland et al. (1990) combine psychological and economic analyses for estimating the impacts of hazardous waste sites on property values. This study found that health risk beliefs did affect property values, and adverse risk beliefs declined with distance from hazardous waste sites. After estimating the property value response to reduced risk beliefs, they were able to conclude that closing hazardous waste landfills would increase average property values by $5000.

These studies are quite consistent in the direction and magnitudes of observed effects of hazardous waste facilities. The higher negative impact in smaller communities simply points to the fact that property value impacts will vary with community characteristics. This suggests, for example, that compensation for economic damages or the economic values of site cleanups may differ with circumstances.

Kiel and McClain (1995a,b) hedonic studies considered price and distance effects of a municipal solid waste-to-energy incinerator in Massachusetts. They estimated effects for different stages of the siting process, from rumor to operation stages. Although there were no observable effects prior to construction, adverse effects were evident during construction, and during initial on-line and operations phases. An additional mile from the site raised residential property values by $2671, $9497 and $7746 per mile for each of these three phases, respectively. Furthermore, housing appreciation rates were 2–3.5% lower during these phases in the impacted community compared to non-impacted communities. The above studies suggest that the timing of observations across various phases of site use are important in estimating the magnitude of adverse impacts. A hedonic study by Havlicek et al. (1971) found that each additional mile from a municipal solid waste landfill increased property values by $3200 in a medium-sized midwestern town. The relative magnitudes of the impacts of these two types of municipal solid waste disposal facilities make some sense, in that landfills may have more nuisance than health effects, and incinerators have a perception of creating pervasive potential health risks (Kiel and McClain, 1995b). It may not be meaningful to make too much of these relative magnitudes, however, since the Havlicek study is dated and risk perceptions and environmental concerns may have increased considerably over time.

A hedonic study of Charleston, WV, chemical facilities showed that distance from such facilities significantly increased residential property prices, even after controlling for other amenity factors such as pollution (Dunn, 1986). A one-mile increase in distance from the nearest facility increased prices by $157, or 0.24%, a rather small amount. However, other estimates showed that houses within 3 miles of any chemical facility, the 'danger zone,' sold for nearly $3000, or 4%, less than homes outside these danger zones. The Bhopal, India, incident appeared to have had a significant adverse impact on all sales prices in the study area. It would not be surprising to find property value impacts of chemical facilities to be less than impacts for hazardous waste disposal facilities, since chemical plants may offer a positive benefit of employment opportunities. However, these employment effects may be regional and not localized enough around a plant to offset its potentially negative risk or nuisance effects.

Adverse adjacent property value impacts may be limited geographically. The Toledo, OH, study (Smolen et al., 1991) found a significant depressed housing value effect up to only 2.6 miles from an active hazardous waste landfill site with this effect tapering off to zero beyond 5.75 miles. A study of an inactive municipal landfill in a small city in Ontario found that distance from the site significantly increased housing values (Skaburskis, 1989). The adverse effect of the site impacted properties up to 500′ from the site. Property values were between $4264 and $7018 lower near the site. An interesting feature of this study is that all properties were developed after the site was closed. These measured adverse effects would likely be less than if the site were active or if the site was developed after the housing development. A study by Nelson et al. (1992) found that an additional mile from a landfill site in Minnesota

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had a positive $8393 effect on sales prices and this effect was limited to between 2 and 2.5 miles. The apparent fact of adverse property value effects from undesirable land uses does not necessarily translate into professional valuation assessments. An opinion survey of assessors found only 28% of respondents believed that Superfund sites adversely impacted property values within 1/4 mile of a site (Greenberg and Hughes, 1993).

Several hedonic studies considered the property value effects of electric utility facilities. Blomquist (1974) found that each additional mile from a coal-fired plant increased property values by $3256. Gamble and Downing (1982) found no significant distance effect for nuclear power plants along the East Coast. However, there was a positive, but very small, distance effect with distance from the Three Mile Island nuclear facility prior to the incident at that facility (Nelson, 1981). This was attributed to the fact that the area around that facility was an economically depressed area even prior to the construction of the nuclear facility. However, this observation does not consider whether the facility further depressed the housing market.

Results of other hedonic studies contrast with the above micro type studies. Zeiss and Atwater (1989) found no effect of a hazardous waste landfill and a hazardous waste incinerator on residential sales prices in two communities they studied. However, they suggested that sellers holding out for higher prices could explain this, and that market effects may be observable in time on the market. Gamble et al. (1982) found no evidence of negative effects of sanitary landfill sites on the rates of residential construction. However, the study did find that larger landfill sites were associated with lower rates of residential construction and sales than smaller sites. In one of the three study years, property values did increase with distance from the site; but there was no relation for two of the study years. Only one site was considered for the property value analysis. Another study (Research Planning Consultants, 1983) found no adverse property value effects of sanitary landfills in three of the four study sites; and a positive property value effect for one site. This study was funded by Browning Ferris Industries and sites were selected on the basis of BFI's interest in developing landfills in those regions, so the integrity of this study is suspect. A study of solid waste landfills in Los Angeles, CA (Schmalensee et al., 1975) found no distance price effect for two of the three studied landfills, and a perverse negative distance effect for one site. However, the latter site was scheduled to close and be converted to a golf course, suggesting a positive amenity effect. This latter case is interesting since it suggests that undesirable land uses can become desirable.

Hedonic studies are useful in estimating localized impacts, but would be less helpful where impacts are more community-wide, i.e. where all regional housing markets are jointly impacted. Macro type studies have investigated the community-wide impacts of adverse activities. A study of municipalities in New Jersey, both urban and rural, found that increasing the number of hazardous waste sites requiring cleanup reduced average home values in a municipality (Ketkar, 1992); each additional site reduced average values by 2–2.5%, or between $1255 and $1600 per property (1980 dollars). Although there was a high positive correlation between the number of sites, percent non-white and property tax rates, these factors were controlled in the hedonic study. This study suggests a rather large geographic area of impact.

Housing and labor markets are related at a regional level. One study addressed the possibility that some types of facilities may enhance employment opportunities while still creating disamenities in regional housing markets (Clark and Nieves, 1991). It found that there was a positive wage effect of refineries at the county level, but a negative property value effect. The net effect of increasing the density of refineries in a county was negative, ranging from $468 to $1764 per household per year. There was no observable effect of hazardous waste sites; however, the study period was pre-Superfund. Slovic et al. (1991) allude to adverse potential regional economic impacts of land uses having negative images in their study of nuclear waste repository in Nevada. They show that preferences for vacation, retirement and new business locations depend on perceived images of

PC 1 8-3875

cities and states, and that these images are adversely affected by the image of a nuclear waste storage facility or nuclear test site. Unfortunately, they do not go further to estimate the magnitude of economic impact.

Contingent valuation (CV) studies have been much less prevalent than the hedonic or control group studies. A study by Smith and Desvousges (1986) found that survey respondents would be willing to pay between $2472 and $3199 more for residential properties located a mile further from a hazardous waste landfill. A study of a rural community in central Illinois (Swartzman et al., 1985) found that a 75% reduction in property taxes would be necessary to increase from 10 to 20% the share of survey respondents willing to live within 5 miles of a hypothetical hazardous waste landfill. Only 10% of the population would willingly live within 5 miles of a hypothetical hazardous waste landfill; 60% wished to live at least 50 miles from such a facility. Mitchell (1980) administered a national survey in which he found that only 10% of the population would willingly live within one mile of a nuclear power plant or hazardous waste disposal site.

The above studies focussed on potentially undesirable land uses. Several studies have sought to estimate property value impacts of potentially hazardous events or degradation in adjacent water quality. A panel study of PCB pollution in the harbor of New Bedford, MA, found a negative effect of the discovery of pollution on surrounding property values within 2 miles of the site (Mendelsohn et al., 1992). After statistically controlling for sales price determining characteristics, losses in property values ranged from 3 to 8% of value, or up to $10 000 per property (1989 dollars), with the larger impact on more proximate properties. This negative impact increased considerably with time after discovery. The adverse effect could have been a combination of loss in amenity value, as well as concern for financing cleanup. This result is consistent with Epp and Al-Ani (1979), who found lower values for properties adjacent to polluted Pennsylvania streams than those adjacent to clean streams. In contrast, Page and Rabinowitz (1993) found no assessed value effect of incidents of groundwater contamination on residences in impacted communities, although there were pronounced negative effects on the commercial and industrial properties directly contaminated. The authors suggest there is no residential property effect since householders do not envision themselves as being liable for any damages. However, another explanation may include the possibility that assessed values may not accurately reflect prices. The incident at the Three Mile Island nuclear facility, did not depress housing market prices as expected (Nelson, 1981). However, the author noted that any potential effects of this accident could have been offset by government assurance programs. He also suggested that housing markets may be slow to react and effects would not be noticable within the short nine month post-TMI study period. Also, costly facility cleanup resulted in a considerable influx of new residents and an enhancement of the local labor market.

4. Summary of quantified adverse impact estimates

Table 2 provides a highly condensed summary of these studies, grouped by type of facility or incident. All impacts have been converted to 1993 dollars. Impacts of undesirable facilities are measurable as a gradient effect, such as increased property values per mile from a facility, as well as a zonal effect, such as reduced property values for homes with proximate facilities. The greatest number of studies are for hazardous waste facilities. There is considerable agreement in the gradient effects across three of the post-announcement studies, with the effect being on the order of $3500 per mile, and ranging roughly from $3000 to $15 000 per mile. A proposed, but later cancelled, low level radioactive waste disposal facility had a comparable gradient effect prior to cancellation. Pre-announcement effects of hazardous wastes sites were considerably smaller than post-announcement effects. Sanitary landfills and coal-fired utilities had comparable, and very large, gradients; roughly $14 000 per mile. These gradients are larger than those for hazardous waste facilities. One should not make too much of this

PC 1 8-3876

Table 2
Summary of gradient and zonal effects by type of facility or impact in $1993

Type of facility or incident	Gradient effect	Zonal effect
Sanitary landfill	$14 016/mile (H)	
	$6948/mile (N and G and G)	
		$5714
		–9404/home (S)
Solid waste incinerator		
During construction	$2671/mile	
On-line phase	$9497/mile	
Operations phase	$7746/mile (K and Ma)	
Hazardous waste site-pre announcement	$1250–1676/mile (K)	
Hazardous waste site-post announcement	$3357/mile (K)	
	$3310/mile (M and S)	
		$2410
		–3072/home (KK)
	$3708–4799/mile (S and D)	
		$7100/home (M and S and H)
	$9468/mile (A)	
	$9990	
	–15 540/mile (S and M)	
Chemical refinery	$222/mile (D)	$1885
		–8472/home (D)
		$9974
		–37 585/home (C and N)
Coal-fired utility	$14 261/mile (B)	
Nuclear utility	$313/mile (G and D)	
Proposed radioactive waste disposal site	$4440/mile (S and M)	
PCB contamination		$8190
		–11 700/home (M)

Study sources are noted in parentheses and refer to Table 1.

difference, since the number of studies is limited. Chemical refineries and nuclear power plants had roughly comparable gradients, $200–300 per mile. The zonal effects of the existence of refineries and sanitary landfills, and the effects of PCB contamination were quite comparable and substantial.

One would expect the property value gradient away from undesirable land uses to be the result of two competing forces: amenities and employment opportunities. The gradients from the studies presented above do not suggest any obvious pattern consistent with this competing forces hypothesis. Lower perceived risk facilities that offer job opportunities should result in the smallest land use impact; yet that does not appear to be the case. Coal fired utilities have a higher gradient than nuclear power plants when Smith and Desvousges (1986) have found that fewer people would like to live near the nuclear plants. It is equally odd that sanitary landfills have a higher gradient than hazardous waste facilities. Perhaps the number of studies is so small that these differences in gradients are not meaningful.

5. Conclusions

The studies summarized clearly show that some types of undesirable facilities or incidents reduce property values in their vicinity. Property value effects reflect the costs of such facilities and incidents. These adverse effects diminished with distance from some facilities or events, resulting in increased property values as distances from these sites increased. Housing markets are sensitive to the real or perceived risks associated with those adverse risks. Hazardous facility studies have been dominated by consideration of hazardous waste sites, including National Priority List (NPL) sites. Some studies show that there were adverse property value effects at these sites even before their listing. These adverse effects were only magnified after listing, but appeared to become more moderate after clean-up was commenced or completed. This suggests a rational response of housing markets to real risks. Increases in property values after clean-up can be used to estimate the localized benefits of site improvement.

PC 1 8-3877

There was considerable agreement across studies on the effects of hazardous waste facilities. There was evidence that more moderate risk facilities, such as municipal landfills or refineries, also created adverse property value effects in some instances, although these results are more mixed than for hazardous waste sites. One study jointly tested the wage and property value effects of hazardous industrial facilities, finding some employment enhancement at the county level but a negative property value effect. There was also evidence that the adverse property value effects of undesirable facilities could be more severe in the 'thin' housing markets of rural areas than in urban areas. One study (Greenberg and Hughes, 1992) suggested this may be due to the natural diversity of a city. The effects of the existence of sanitary landfills, chemical refineries, and PCB contaminated sites all had comparable effects on housing values.

A typical argument for the location of hazardous facilities is economic development, either from employment at the facilities or at facilities which use the hazardous sites. This report does not address this more complicated issue. It should be noted that even if there is a positive employment and income effect (Smith et al., 1986), some localized neighborhoods in the proximity of these facility may experience asset losses from reduced property values. Employment effects, if they arise at all, are likely to be geographically broad. However, those studies cited above which explicitly consider distances from sites are quite clear in finding that adverse property value effects are relatively localized. Therefore, 'who gains and who loses' from these facilities is a very important question.

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PC 1 8-3878

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PC 1 8-3879

Attachment F
Exhibit 4007-000014-CWF
Columbia Waterfront LLC

BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: *Application No. 2013-01* *TESORO SAVAGE, LLC* *VANCOUVER ENERGY DISTRIBUTION TERMINAL*	CASE NO. 15-001 WRITTEN EXPERT TESTIMONY OF BRIAN SCHAEFFER

I, Brian Schaeffer, declare that I am qualified to provide expert testimony in the adjudicatory hearing regarding the application by Tesoro Savage, LLC for the Vancouver Energy Distribution Terminal as set forth below:

I have been the Assistant Chief for the Spokane Fire Department since 2005. Prior to coming to Spokane, I was the Deputy Chief of the City of Yakima, Washington Fire Department from 2003 to 2005 and for Yakima County, WA Fire District 12 from 2001-2002. I served in previous assignments as a Fire Chief in Missouri and Flight Paramedic for an Air Medical Program. I have earned a Bachelor's Degree in Fire Science from Sterling College in Kansas City, Missouri and a Master's Degree in Public Administration from the University of Missouri. I am currently in the dissertation phase of a doctorate degree through Creighton University.

I serve on numerous local and state public safety and health-related committees including a previous Governor appointment to the Emergency Management Council and the State's Homeland Security Committee. From the Hazardous Materials standpoint, I have served in progressive positions as a Hazardous Materials Technician, Specialist and Incident Commander during my fire service employment in the Kansas City, Missouri City Metro Area. In the City of Yakima Fire Department, I led an amalgamation with the Tri-County Hazardous Materials Team which is still in existence today. In my current position, I oversee Operations, Communications, Integrated Health and Training in the Spokane Fire Department.

The 360,000 barrels of crude oil capable of being received at the oil terminal at the Port of Vancouver proposed by Tesoro Savage Petroleum Terminal LLC will delivered to the proposed Facility by railroad within "unit trains" composed of up to 120 sole-purpose crude oil cars. According to the data contained in the Draft Environmental Impact Statement, the most likely source of crude oil sources would be northern mid-continent crude oil produced in Bakken Oil Fields in North Dakota and Montana, and in Canada. The oil will be transported by existing railroad tracks belonging to Burlington Northern Santa Fe (BNSF). An average of four unit trains per day would travel along the BNSF railroad through the heart of the City of Spokane, including through the downtown core resulting in a total of 1,460 round trips per year of 120 unit oil trains traveling through the City of Spokane as a result of the oil terminal being permitted in the Port of Vancouver. The permitting of the oil terminal will create higher oil train traffic density resulting in the following impacts to the City's fire and emergency response capabilities.

1. Notification.

The Emergency Notification System in use by the City of Spokane, commonly known as Alert Spokane is a fundamental system that supports area identification and single messaging (this system is limited to 7,000 calls an hour). Additional Alert and Warning System functions such as the Emergency Alert System (EAS) must be performed separately. The City of Spokane lacks a Comprehensive Alert and Warning System. Specifically, the existing system cannot notify key facilities (schools, hospitals, assisted living facilities, etc.), of an oil train derailment utilize message sharing and layering, develop plume modeling, or the ability to utilize multiple platforms (e.g. phone, text, internet) for messaging. Lastly, the existing system does not integrate with the Public Alert and Warning System (IPAWS)

2. Evacuation.

The BNSF mainline transects downtown Spokane just north of I-90 and south of the Spokane River. Thousands of citizens work and live within a one mile evacuation radius from the BNSF mainline. Under the current Evacuation Plan, the City of Spokane Police Department would be responsible to provide for the coordinated evacuation of the population from a hazard area, and coordinate their safe return when the threat has passed. The plan addresses evacuation emergency activities for the authorization, direction, routing and relocating of individuals from their homes, schools, and places of business on a very limited basis. This plan was developed to address small-scale incidents; primarily, Wild Land Urban Interface Fires. Nothing in this plan addresses an evaluation of the magnitude necessary to protect those in harm's way within an urbanized city center such as the City of Spokane.

3. Sheltering.

Once the public is notified to evacuate to an assembly area, they must be provided with shelter. The City of Spokane and the greater region lack sufficient sheltering capability for an evacuation resulting from a train derailment and subsequent fire within an urbanized center.

4. Firefighting Capability

Because of the size and complexity of an oil crude rail tank car related fire incident, the existing capability of the Spokane Community will likely be inadequate and ineffective. Tactical issues such as a lack of AFFF Foam, access and availability of large hose streams and firefighter staffing all contribute to the increasing risk to the Spokane Community.

5. Hazardous Materials Team Capability

The Spokane Fire Department staffs a Type II Hazardous Materials Response Team with a daily roster of 13 personnel every 24 hours. The team is the only municipal hazardous materials team in the Spokane Region and is often forced to rely on off-duty personnel to fulfill staffing requirements. There are no municipal hazardous materials teams available to the City of Spokane through contract or mutual aid in Washington State. If a derailment were to occur, the crisis would immediately overwhelm the existing team and put responder and citizen lives in danger.

These five issues are not an exhaustive list of Fire Department concerns, nonetheless they do serve as illustration that the City of Spokane Fire Department does not have the capability to respond to this predictable and preventable risk.

DECLARATION

I, Brian P. Schaeffer, declare under penalty of perjury under the laws of the State of Washington that I make this declaration of personal knowledge, could and would competently testify to its content and that the foregoing is true and correct.

Signed at: Spokane, Washington on this 9th day of May, 2016.

BRIAN P. SCHAEFFER

FOOTAGE OF THE MOSIER DERAILMENT WAS PROVIDED BY FRIENDS OF THE COLUMBIA GORGE AND IS AVAILABLE UPON REQUEST

Mosier Oil Train Derailment

06/03/16

PC 1 8-3885

Personnel Background:

I have been employed in the railroad industry for the most of 38 years. My experience encompasses working at a Class 1 railroad as a Mechanical Apprentice, Freight Carmen, Car Foremen, Foremen General and Safety Training Coordinator for Oregon, Washington and Idaho. I also was employed by a worldwide railcar leasing and railcar building company as a General Manager of Mechanical. Most of my comments will be from a mechanical car standpoint.

I am in no way associated with the city of Mosier. I am simply a concerned citizen of Mosier.

It is a well known fact that the chance of a secondary derailment at a previous derailment site drastically increases. This is the reason for the slow orders issued at the accident site. Secondary reasoning would be for the safety of personnel working adjacent to the derailment site.

Given the aforementioned fact, what is the FRA's stance on continuing train traffic while leaking partial to full compromised oil tankers are within harms way of the moving rolling stock?

The three main causes of derailments are train handling, infrastructure and mechanical not necessarily in that order.

What are the leading causes of derailments?

The shift in recent years has been to eliminate mechanical inspection personnel from Class 1 railroads and become more reliant on contractors to perform inspections as well as analyzing wayside detection device data.

In the FRA's estimation, and if any studies have been performed, has overall train safety been on par between locations exclusively serviced by running repair agents (contractors) as compared to locations served by actual trained railroad workers? Is there any data indication an increase in derailments in contrast between these two entities? Case in point is referenced on the following slide.

I am not sure of the outcome, but one of the Class 1 railroads most highly utilized contractors who performs these mechanical inspections was or is under intense scrutiny by the justice department.

By **CONSTANTINE VON HOFFMAN** / **MONEYWATCH** / *November 22, 2013, 1:16 PM*

Report: Caterpillar unit probed over possible parts dumping

Comment / Share / Tweet / Stumble / Email

(MoneyWatch) A subsidiary of heavy equipment manufacturer Caterpillar (CAT) is being investigated by federal officials over charges it dumped train parts into the Pacific Ocean in an effort to bill railroad companies for unneeded repairs, according to published reports.

The Wall Street Journal, citing unnamed sources, reports a grand jury investigation is being conducted by the U.S. Attorney for the Central District of California. The grand jury is said to be examining whether Caterpillar subsidiary Progress Rail dumped parts into the ocean near the Port of Long Beach, Calif., to conceal the fact that Progress was charging owners of rail equipment for replacing parts that were still in good shape.

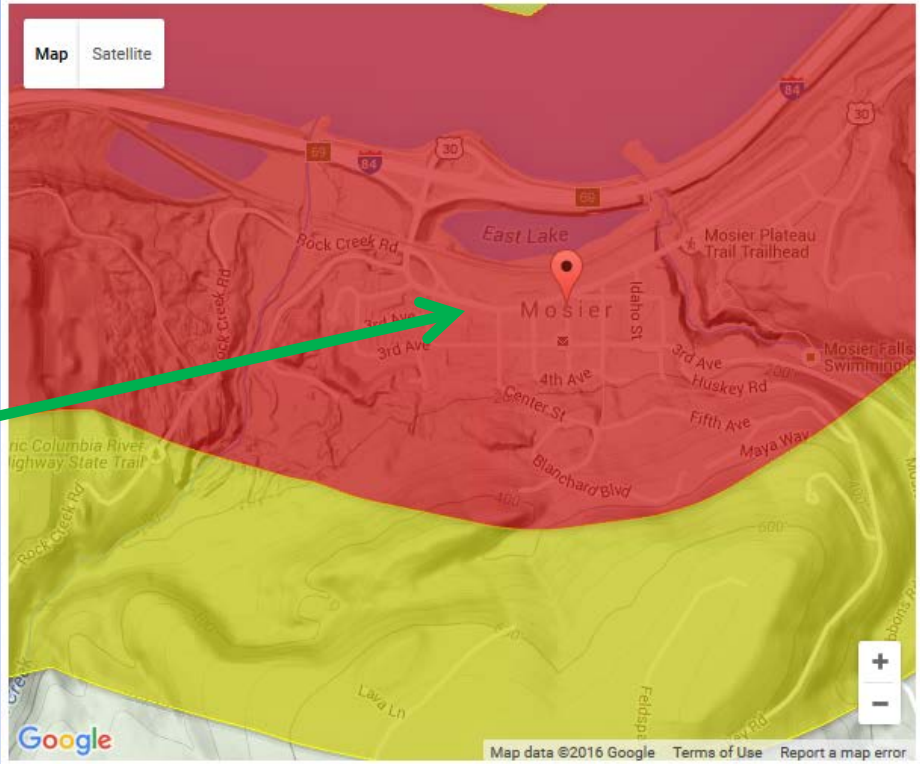
This picture displays the Oil Train Blast Zone as defined and courtesy of Stand.com

Location of the school in Mosier. The school grounds are within 312 ft. of the railroad tracks.

Oil Train Blast Zone

How close are you to oil trains and a derailment disaster? Use the blast zone map below to find out and take action.

mosier, oregon | Find



☑ Show Blast Zone

0.5 Mile US DOT Evacuation Zone for Oil Train Derailments

1.0 Mile US DOT Potential Impact Zone in Case of Oil Train Fire

Are there oil trains in your town, not on this map? Send us an email to let us know.

STAND
FORMERLY FORESTETHICS

PC 1 8-3888

Given the proximity of our school to the train tracks, would the school have time to bring students inside, seal exits and close dampers from outside air in the event of a catastrophic oil train derailment?

How many oil trains pass Mosier on the average day?

What would be the proposed increase in oil trains be if export terminals are increased?

What is the normal operating speeds of trains containing hazardous material passing through Mosier?

Will this train velocity increase given the UP's plan to add double tracks through Mosier?

Are these oil trains defined as extended haul trains which would drastically increase the miles between inspections?

Who typically inspects these trains? Is it actual railroad personal or contractors?

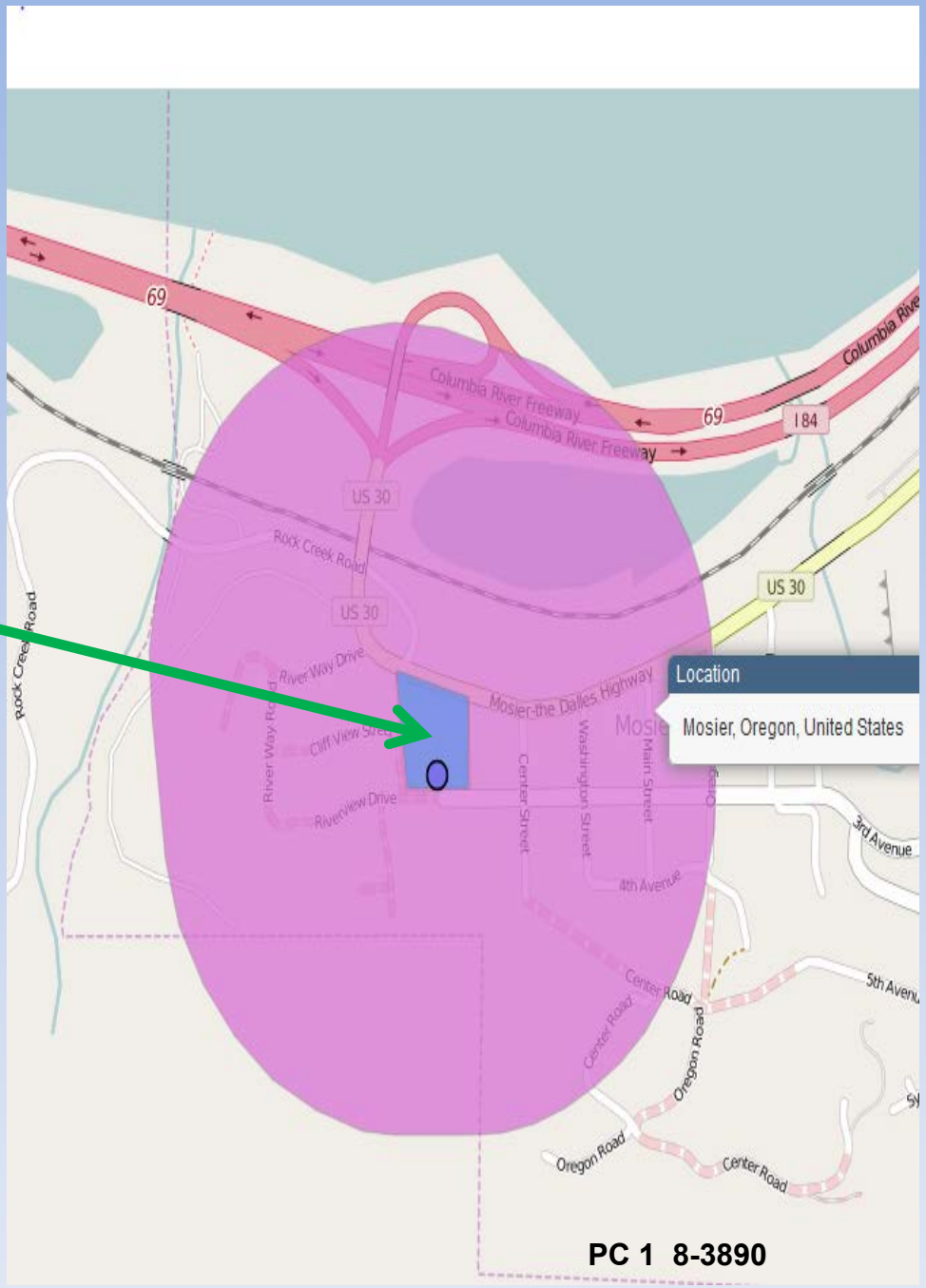
All freight car billing is distributed to car managers/owners through Railinc. Does the industry scrutinize data for repairs with an emphasis on high mileage cars not seeing the industry norm for safety related components such as wheel consumption?

In contrast, this picture represents the school footprint buffer zone (1000 feet) for marijuana dispensary's.

Dispensaries must set up shop outside the 1000 foot purple parameter.

Location of the elementary school in Mosier.

Notwithstanding your personal stance on this topic, I find it untenable to imagine that we would be more concerned about a marijuana dispensary then oil trains operating roughly 300 ft from a public school



PC 1 8-3890

Thank you…

Calvin Mattson
460 Maya Way
Mosier, Or
97040