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June 13, 2016

Millennium Bulk Terminals – Longview SEPA EIS
c/o ICF International
710 Second Avenue, Suite 550
Seattle, Washington 98104

U.S. Army Corps of Engineers
Washington Department of Ecology
Cowlitz County Commission

Subject: Comments on the Draft Environmental Impact Statement for Millennium Bulk Terminals, Longview LLC Coal Export Terminal

Thank you for the opportunity to comment on the draft environmental impact statement (DEIS) for the proposed Millennium Bulk Terminal in Longview, Washington. As the state health department, we are interested in the impact this project will have on the health and well-being of people in Washington State. We recognize that noise, traffic, air pollution, greenhouse gas emissions contributing to climate change, and the risks of spills or derailments could negatively impact public health. We also recognize the project could impact social determinants of health such as employment, education, and transportation. With this project we are particularly concerned about the greenhouse gas emissions under the Department of Ecology's model and the associated public health impacts of climate change in Washington State. We would also like to thank you for the cumulative impacts section: it adds value to the discussion of fossil fuel transportation in the state beyond the local implications of the Millennium Bulk Terminal. We have recommendations for reducing potential negative public health impacts of the Millennium Terminal. They are summarized here and explained in more detail below. Please contact us if you have any questions or if you would like to collaborate on solutions.

<u>Summary of Recommendations:</u>

- Estimate the public health impacts of climate change from greenhouse gas (GHG) emissions and design appropriate mitigations.
- Coordinate with emergency responders for medical (ambulance and fire), environmental (flood, earthquake, etc.), and rail related emergencies, and design mitigations that correct for the increased risk of Kelso–Longview residents.

- Develop mitigations to reduce the total Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), and Particulate Matter ($PM_{2.5}$) emissions. Kelso–Longview residents already have worse than average asthma health outcomes and this project will be the largest contributor of criteria pollutants in the county.
- Install air quality monitors for NO_2 and SO_2 near the project site prior to construction and operation. Base final EIS air quality projections on real, rather than modeled, data.
- Post anti-idling signage at the most severely affected intersections, such as the project access at 38th Avenue and Weyerhaeuser access at Washington Way.
- Electrify the port to reduce emissions from ships idling or "hoteling" at the port.
- Change the vehicle safety metric to crashes involving fatalities and serious injuries. This better aligns with Washington State's traffic safety goals. We further recommend that the project make investments in the intersections identified as having risks of greater than 0.04 accidents per year that are sufficient to support Washington State's Target Zero goal.

Greenhouse Gas Emissions Leading to Climate Change

The Washington State Department of Ecology (ECY) used a broad scope when calculating total greenhouse gas emissions from the project. From a public health perspective, we believe this is the appropriate scope because of the global nature of climate change. To put the greenhouse gas emissions from this project in context, over a 20 year period ECY estimated that GHG emissions would be 35 million tons of CO_2.

ECY is also working at the direction of Governor Inslee on a Clean Air Rule that would reduce Washington State's GHG emissions by approximately 120 million tons over 20 years by regulating the emissions of approximately 30 companies. Based upon ECY's *most likely* estimate, the Millennium Bulk Terminal project would erase a quarter of those GHG gains. If market conditions were favorable for coal, the project could completely neutralize the GHG reductions for the Clean Air Rule.

The DEIS discusses some of the impacts of climate change on Washington State such as rainfall, flooding, snowpack, and wildfires, but it does not discuss the impact those changes will have on health. The Washington State Department of Health (DOH) has identified ongoing and projected public health impacts of climate change for the residents of Washington State. The report is available in Appendix A. Some climate change impacts that will detract from the public's health are increased ozone and $PM_{2.5}$ concentrations, risk of vibrio from shellfish, and increased vector-borne and zoonotic diseases.

Recommendation: Estimate the public health impacts of climate change from GHG emissions and design appropriate mitigations. Mitigation measures should use the Washington Clean Air Rule as a guide for assuring real, permanent, and measurable offsets.

Emergency Response

At the request of our emergency response team at DOH, the Washington Tracking Network created a Social Vulnerability to Hazards Index to identify populations at increased risk during emergencies due to the built environment and social and demographic characteristics.[1] Six census tracts in the Longview–

[1] Washington Tracking Network, Washington Department of Health. Web. "Information by Location: Social Vulnerability to Hazards". Retrieved June 6, 2016, from
(see next page for continuation of footnote)

Kelso city center rank in the highest risk category for social vulnerability to hazards (10/10). These high risk census tracts are in close proximity to rail routes within the city centers.

Recommendation:

Coordinate with emergency responders for medical (ambulance and fire), environmental (flood, earthquake, etc.), and rail related emergencies, and design mitigations that correct for the increased risk of this population.

Air Pollution

Surveillance data suggests that populations near the project site are at greater risk for respiratory illness than the state population as a whole. In 2010-2015, asthma hospitalizations in Washington were 6.22 per 100,000 people. In the two zip codes nearest the project site (98623 and 98626), asthma hospitalization rates were 11.73 and 9.00, respectively. These rates are statistically significantly higher than the state average. Some census tracts near the project site also have higher than average cardiovascular disease and cancer deaths rates, both conditions that can be related to air quality. In addition, access to care is limited in these populations: insurance rates in the Longview-Kelso area are lower than the state average.

The proposed Millennium Bulk Terminal project will not exceed National Ambient Air Quality Standards (NAAQS). It will bring the area significantly closer to the NAAQS levels for 1-hour NO_2, SO_2, and $PM_{2.5}$. NO_2, SO_2, and $PM_{2.5}$ are criteria pollutants regulated under the federal Clean Air Act because of their impacts on human health and regional air quality impacts. The air quality assessment in the DEIS indicates that these three pollutants are the most likely to cause exceedances in the project site due to background levels plus contributions from activities at the site (Tables 5.67–5.6-8). Modeled 1-hour concentrations of NO_2 predict levels at 83 percent of the existing standard, SO_2 levels at 73 percent of the existing standard, and $PM_{2.5}$ 24-hour levels are predicted to be 85 percent of the existing standard. **This represents a 2.7 fold increase in NO_2, a nearly 10 fold increase in SO_2, and a 1.5 fold increase in $PM_{2.5}$.** These pollutants are lung irritants and can exacerbate asthma and other respiratory diseases and contribute to heart disease resulting in more hospital admissions. Air quality projections do not predict exceedances of air quality standards for these pollutants. However, these predictions were based almost exclusively on modeled data (with the exception of $PM_{2.5}$) where actual air quality monitoring of criteria pollutants would be preferable.

Recommendations:

- Accommodate worse than the state average respiratory health in the Kelso–Longview area, and to mitigate the prospect of being the greatest contributor of criteria air pollutants in the county, the applicant should develop mitigations to reduce the total NO_2, SO_2, and $PM_{2.5}$ emissions.
- Install air quality monitors for criteria pollutants other than $PM_{2.5}$ near the project site before construction and operation to collect real ambient air quality data. Base final EIS air quality projections on measured instead of modeled data.

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http://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/WashingtonTrackingNetworkWTN/InformationbyLocation.

- Post anti-idling signage at the most severely affected intersections such as the project access at 38th Avenue and Weyerhaeuser access at Washington Way.
- Electrify the port to reduce emissions from ships idling or "hoteling" at the port.

Vehicle Transportation

The vehicle transportation section uses level of service, queuing, and vehicle safety as performance measures. Washington State's Traffic Safety Commission and Department of Transportation have collaborated on Target Zero, a plan that aims to reduce fatalities and serious injuries from crashes to zero by 2030. According to data obtained from the Washington State Department of Transportation and the Washington Traffic Safety Commission, all census tracts between downtown Vancouver and the Millennium site have fatality and serious injury rates in the top 30 percent of Washington State census tracts.

Recommendation:

Change the vehicle safety metric to crashes involving fatalities and serious injuries. This better aligns with Washington State's traffic safety goals. We further recommend that the project make investments in the intersections identified as having risks of greater than 0.04 accidents per year that are sufficient to support Washington State's Target Zero goal.

If you have any questions, please contact Rad Cunningham at (360) 236-3359 or rad.cunningham@doh.wa.gov.

Sincerely,

Clark Halvorson
Assistant Secretary

Attachment

Appendix A: Health Impacts of Climate Change in Washington State

Authors: Hilary Browning, Research Investigator; Denise LaFlamme, Epidemiologist; Jerry Borchert, Marine Biotoxin Lead; Joan Hardy, Toxicologist; Clara Hard, Shellfish Illness Coordinator; Elizabeth Dykstra, Entomologist; and Ginny Stern, Hydrogeologist

Summary of Findings, Research, or Data

Heat Waves

Background and public health impact

- There will be a direct public health impact from increasing air temperatures due to climate change. Elevated air temperature is a risk factor for a number of heat-related illnesses including heat cramps, heat exhaustion, and heat stroke.
- Warm nighttime temperatures are more strongly associated with adverse health outcomes than are warm daytime temperatures (Gershunov et al. 2009; Kalkstein and Davis 1989). It has been proposed that elevated overnight lows hamper physiological recovery from daytime heat.

Observations

- Both maximum and minimum air temperatures are predicted to increase in response to climate change. Already, from 1951 to 2010, there was an average increase of 0.6°C (1.08°F) in global maximum daily temperatures. Global minimum daily temperatures increased even more–by 0.8°C (1.44°F), on average (Donat and Alexander 2012).
- In the Pacific Northwest, the frequency of nighttime heat waves has increased over time (Bumbaco et al. 2013).
- A study by the Climate Impacts Group (CIG) found from 1980–2006 in Washington State, the risk of death from non-traumatic[2] and circulatory[3] causes was statistically significantly ($P < 0.05$) elevated for all ages on most days of a heat event (Jackson et al. 2010).

Projections

- The CIG projects that by 2085 there will be between 107 and 988 additional excess heat-related deaths per year in Seattle, and between 17 and 76 excess deaths in Eastern Washington (Spokane, Tri-Cities, and Yakima) (Jackson et al. 2010).

Vulnerability

- Residents of the Pacific Northwest are particularly vulnerable to heat waves because of the rarity of this type of weather. Kalkstein and Davis (1989) determined that the "threshold" temperature for adverse health impacts for the Pacific Coast was only 30°C (86°F), compared to 43°C (109.4°F) for Phoenix and Las Vegas.

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[2] ICD-9: 001-799; ICD-10: A00-R99

[3] ICD-9: 390-459; ICD-10:I00-I99, G45, G46

- General risk factors for heat-related mortality and morbidity include urban living, low socioeconomic standing, young or old age, and not practicing preventative behaviors. These risk factors are reviewed in depth in McGeehin and Mirabelli (2001).

Air Pollution

Background and public health impact

- Climate change is expected to worsen air quality in the United States mainly due to increases in ozone and particulate matter air pollution in some areas (Luber et al. 2014).
- Ozone is the main contributor to smog and is produced from the interaction of sunlight with nitrous oxides (NOx) and volatile organic compounds (VOCs). Ozone air pollution mainly occurs in urban areas during warm summer months.
- Ozone has been associated with chest pain, aggravating bronchitis, emphysema and asthma, reduced lung function, inflammation of airways, and increased susceptibility to respiratory infections.
- Smoke contributes to particulate matter air pollution, especially fine particulate air pollution (less than 2.5 microns in diameter ($PM_{2.5}$)).
- $PM_{2.5}$ air pollution has been linked with a variety of health problems including decreased lung function, increased respiratory symptoms including asthma symptoms, nonfatal heart attacks, irregular heartbeat, and premature death in people with heart or lung disease.

Observations

- $PM_{2.5}$ air concentrations (as 24 hour averages) were ≥ 135.4 ug/m3 for 14 days in Wenatchee during the 2012 wildfires which are defined as hazardous to health under the Washington Air Quality Index (WAQI). The WAQI provides health-based warning levels associated with different levels of $PM_{2.5}$ air concentrations (G. Palcisko, personal communication, October 14, 2015).
- A surveillance study by DOH, the Chelan-Douglas Health District and Kittitas County Public Health found a two-fold increase in the number of children's clinic and emergency department outpatient visits for asthma and respiratory and chest symptoms during 2012 wildfires in north central Washington compared to two weeks before the fires. A 60 percent increase in outpatient visits was also observed for chronic obstructive pulmonary diseases, excluding asthma, for all age groups for the same time period (DOH et al. 2015).
- All areas of Washington are currently in compliance with the U.S. EPA's ozone standards and Washington State has relatively low levels of ozone compared to other parts of the country.

Projections

- Ground level ozone concentrations are expected to increase in parts of the U.S. due to increases in summer temperatures, mainly in the Northeast, South, Midwest and Southwest (Patz et al. 2014; Garcia-Menendez et al. 2015).
- However, one study estimated that elevated local ozone concentrations could increase the number of cardiopulmonary deaths in King and Spokane counties by 63 and 37 people per year, respectively (Jackson et al. 2010).
- $PM_{2.5}$ air pollution is expected to increase with climate change due to increases in forest fires (see **Wildfires**).

- Climate change is also expected to lengthen the pollen producing season and increase pollen production (Rogers et al. 2006; Ziska and Caulfield 2000) which may result in prolonged and increased allergy and asthma symptoms (reviewed *in* Gamble et al. 2008).

Vulnerability

- Children, older adults and people with asthma and other lung and heart conditions are especially sensitive to impacts from $PM_{2.5}$ and ozone air pollution. Washington residents may be especially sensitive to these air pollutants due to higher rates of asthma in the state compared to the U.S. average (DOH 2014).

Wildfires

Background and public health impact

- Wildfires produce smoke that can be distributed over a large geographic area, potentially affecting many people. Smoke from wildfires contains fine particulates and gases including carbon monoxide (Lipsett et al. 2012). Fine particulates, also referred to as particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), can be carried deep into the lung when breathed.
- Exposure to wildfire smoke has been most strongly associated with respiratory health outcomes including respiratory symptoms, asthmatic symptoms, emergency room visits and hospital admissions for respiratory conditions (Liu et al. 2015). Wildfire smoke has also been associated with cardiovascular effects including hospital admissions for cardiovascular symptoms.

Observations

- From the mid-1980s onward, the incidence of large wildfires (>400 hectares) in western forests increased, as has the length of the wildfire season and the amount of area burned. Specifically, Westerling et al. (2006) compared 1970–1986 to 1986–2003 and found that average wildfire season length increased by 78 days and the acreage burned increased more than six and half times.
- These changes are accompanied by a shift toward unusually warm springs, longer summer dry seasons, and drier vegetation, all of which are due in part to reduced winter precipitation, early melting of spring snowpack (Westerling et al. 2006), and drought influences (Westerling et al. 2003).
- In 2015, 2.5 percent of Washington lands were burned by wildfires, compared to 1 percent, 0.4 percent and 0.8 percent in 2014, 2013, and 2012, respectively (DOH 2015).

Projections

- Due to increased summer temperature and decreased summer precipitation, the area burned by fire in the Pacific Northwest is expected to double by the 2040s and quadruple by the 2080s, relative to the 1916–2006 average (Littell et al. 2010).

Vulnerability

- Some studies have reported higher risks of cardiorespiratory health outcomes among older adults, children, and lower socioeconomic status populations associated with wildfire smoke exposures (Liu et al., 2015).

Sea Level Rise and Tidal Flooding

Background and public health impact

- Globally, sea level is rising in response to thermal expansion of water and melting of land-based ice (IPCC 2013).
- Local sea level is influenced by global sea level, and by two additional forces: (1) local changes in wind pushing water towards or away from the coast, and (2) tectonic forces that locally raise or lower the land itself (Mote et al. 2008). Washington State is affected by this final driver because the subduction of the Juan de Fuca plate under the North American plate is uplifting coastal land at a rate of 1-3 mm per year (Verdonck 2006).
- In spite of the mitigating effect of tectonic forces, some parts of Washington will still be affected by local sea level rise (Mote et al. 2008; see *Projections*).
- Local sea level rise would likely impact public health by contributing to coastal erosion and tidal flooding, in addition to relatively minor impacts on coastal drinking water supplies (Huppert et al. 2009).

Observations

- Worldwide sea level rose an average of 3 mm (⅛ inch) per year from 1993 to 2012 (IPCC 2013).
- A review of the literature did not reveal any evidence of recent, past sea level rise in Washington.

Projections

- Global sea level is projected to rise an additional 4.4–11.2 mm per year through the end of the 21st century (IPCC 2013).
- According to the Intergovernmental Panel on Climate Change (IPCC), it is very likely that global mean sea level rise will contribute to upward trends in extremely high coastal water levels that can lead to tidal flooding (IPCC 2012).
- Due to the additive effects of tectonic forces and global sea level rise, some parts of Washington will experience local sea level rise in the next 100 years whereas others may not.
- The Climate Impacts Group estimates the Olympic Coast will experience minimal sea level rise due to tectonic uplift, and the central and southern coast will experience between 1 and 18 inches by 2050. However, Puget Sound will experience between 3 and 22 inches of sea level rise by 2050, and 6 to 50 inches by 2100 (Mote et al. 2008).
- Note, however, the Mote et al. (2008) stresses that: (1) these calculations have not formally quantified the probabilities, (2) sea level rise cannot be estimated accurately at specific locations, and (3) these numbers are for advisory purposes and are not actual predictions.

Vulnerability

- Sea level rise is expected to increase flooding and erosion of beaches along Washington's coast. Homes and infrastructure near the coast will be threatened by changes in shorelines as a result of erosion. Several communities in southwest Washington and on Bainbridge Island have been identified as particularly susceptible to damage from beach erosion (Huppert et al., 2009).
- Many recognized tribal communities in Washington State have reservations near the coasts where sea level is expected to rise, and are at risk of being displaced from their land. Given that tribal cultural values are place-based, relocation due to environmental degradation is not an acceptable option (Grah and Beaulieu 2013). Sea level rise could also severely limit collection of important traditional food sources like shellfish (Lynn et al. 2013).

Heavy Precipitation and River Flooding

Background and public health impact

- Many studies have investigated the modelled impact of climate change upon weather extremes, including precipitation. There is strong agreement that the enhanced capacity of warm air to hold water vapor will increase the intensity of short-term precipitation (reviewed *in* Meehl et al. 2005).
- The potential public health impacts of heavy precipitation include river flooding and diminished water quality.
- Flooding damages housing and critical infrastructure like landfills and sewer systems. Flooding can contaminate drinking water supplies with bacteria, chemicals or saltwater and contributes to contamination of housing with chemicals or mold (these impacts reviewed *in* Alderman et al. 2012). However, there is still limited data about the health effects of floods in relation to morbidity (Ahern et al. 2005).

Observations

- Total yearly precipitation did not change for the 30°–50° latitude (including the United States) during the 20th century (Zhang et al. 2007).
- Many studies have demonstrated at least a modest increase in heavy precipitation events in Washington over the last 60–100 years (reviewed *in* Mass et al. 2011).

Projections

- Annual mean precipitation in the Pacific Northwest is projected to remain steady throughout the 21st century (Mote and Salathé 2010).
- However, it is expected that precipitation in the Pacific Northwest will become more seasonally variable and erratic in the future.
- Most models forecast a decline in summertime precipitation and an increase in winter precipitation in the Pacific Northwest (Mote and Salathé 2010). Regional climate models also predict an increase in the number of extreme high precipitation days in the next fifty years, particularly around the Puget Sound and Olympic coast (Salathé et al. 2010).
- The impact of climate change on river flood risk in Washington varies by basin. In snow-dominant watersheds, flood risk is likely to decrease due to reductions in snowpack (Hamlet and

Lettenmaier 2007). Mixed snow-rain watersheds flood risk depends upon a complex set of conditions and could either decrease or increase, but may experience heightened winter flooding (Mantua et al. 2010). Rain-dominant watersheds will likely experience little change (Hamlet and Lettenmaier 2007).

Vulnerability

- The largest increases in river flood frequency are predicted for catchments in Puget Sound, the west slopes of the Cascades in southwest Washington, and in the lower elevations on the east side of the Cascades. Modeling predicts increasing flood magnitudes in western Washington and decreasing or unchanged flooding magnitudes in eastern Washington (Mantua et al. 2010).

Drought and Snowpack

Background and public health impact

- Drought is a hydrologic condition where local water supply (for any use) is notably less than the historical average. In Washington State a drought emergency may be officially declared when the water supply for a geographical area is below seventy-five percent of normal, and the water shortage is likely to create undue hardships for various water uses and users (RCW 43.83B.400).
- Impacts to public health from drought include reduced availability of drinking water, failure of infrastructure due to low flows, and changes to water quality. Drought is also a contributing factor to increased wildfire activity (Westerling et al. 2003; Hessl et al. 2004).
- Drought can be caused by a variety of factors aside from net reduction in precipitation (rain/snow). Changes in the timing or type of precipitation can cause drought if it creates a condition where not enough water is available when it is needed. For instance, Washington State depends heavily upon melting snow (snowpack) to sustain water supplies during the drier summer months. Low accumulation snowpack over the winter can lead to drought in the summer.
- The capacity for snowpack to form is closely linked to air temperatures. Mountainous regions with winter air temperatures < -6°C (21.2°F) favor precipitation falling as snow, whereas regions averaging > 5°C (41°F) in midwinter tend to be dominated by rain (Hamlet and Lettenmaier 2007).

Observations

- Since 2000, Washington has declared three statewide drought emergencies (in 2001, 2005, and 2015). In 2006 the State declared a localized drought emergency in two watersheds on the Olympic Peninsula.
- Statewide drought emergencies are not common. However, in 6 of the last 15 years the water supply drought advisory committee has been convened to evaluate snowpack and water supply conditions because formation of the normal winter snowpack was late or low.
- Furthermore, from 1950 to 2000 snowpack in the Cascades was observed to decline by approximately 29 percent. This decline is largely attributable to rising air temperature (Mote 2003; Mote et al. 2005).

Projections

- Total snowpack is projected to decline an additional 38–46 percent by the 2040s, compared to the mean of the 1917–2006 water years. Low elevation snowpack is expected to be even more impacted: declines there will range between 49 percent and 58 percent by the 2040s, and will almost disappear by the 2080s (Elsner et al. 2010).
- Historically, the majority of basins that receive at least part of their precipitation as snow were centered along the Cascade Mountains and northern Washington. It is anticipated that by the 2080s none of these watersheds will be dominated by snow, and that the mixed snow/rain watersheds of the central/southern Cascades and northeastern Washington will have completely lost their snowpack (Mantua et al. 2010).
- These changes in the way water is stored could lead to increased incidence of drought in the future if resource managers fail to adjust their management strategies.

Vulnerability

- Agricultural interests are vulnerable to drought. The farmers most vulnerable to the impacts of drought are dryland farmers in the south central and east regions, berry farmers in the southwest/Olympic Peninsula region, and farmers with junior water rights in the south central region (Fontaine and Steinemann 2009).
- As with sea level rise (see **Sea Level Rise and Tidal Flooding**), some tribal communities are at risk of losing access to traditionally important food sources (i.e., salmon, lamprey) due to loss of snowpack and resulting streamflow (Dittmer 2013; Grah and Beaulieu 2013).

Vector-Borne and Zoonotic Diseases

Background and public health impact

- Several vector-borne and zoonotic diseases (VBZD) are present in Washington and human cases occur each year, although at lower numbers than are seen in much of the United States. The following are three high profile diseases that exist in Washington.
- **West Nile virus** (WNV) is a virus transmitted by mosquitos that first appeared in the United States in 1999 (Soverow et al. 2009). The virus first appeared in Washington in 2002, and in 2009 the state had the highest number of human infections (36 cases from in-state exposure) to date. In 2015 there were 22 human cases, and 14 percent of mosquito pools that were tested were found positive for the virus.
- Approximately 80 percent of people infected with WNV are asymptomatic, while around 20 percent develop WNV fever (fever, headache, rash) and less than 1 percent develops WNV neuroinvasive disease (meningitis, encephalitis, paralysis).
- **Sin Nombre virus** is a highly pathogenic Hantavirus that infects North American deer mice (*Peromyscus maniculatus*) and can cause Hantavirus Pulmonary Syndrome (HPS) in humans (Mills et al. 2010a). Each year there are 1 to 5 cases reported, with most exposures occurring in eastern Washington. About 30 percent of cases are fatal.
- **Lyme disease** is caused by a bacterium (*Borrelia burgdorferi*) which is transmitted in Washington by the western black-legged tick, *Ixodes pacificus* (Stanek et al. 2012). Each year there are 1–3 cases of Lyme disease from in-state tick exposure. Most of these cases come from exposure on

the west side of the Cascade Mountains, which reflects the primary distribution of the Ixodes tick vectors.

- Along with flu-like symptoms and the classic bull's-eye rash, joint, nervous, and heart complications can also occur. Tick surveillance and testing since 2010 has shown that approximately 2 percent of black-legged ticks in Washington are infected with *B. burgdorferi*.

Observations

- VBZDs are influenced by climate through climate's direct effects on the pathogen, vector, and host and their interactions with one another. Environmental factors, such as temperature, relative humidity, and precipitation, also directly influence vector-borne and zoonotic disease cycles (Tabachnick 2010).
- Western black-legged ticks are found primarily in western Washington with adult population activity most prevalent from February through early summer.
- West Nile virus has become endemic in south central Washington. The virus has been detected in 0.3 percent to 25 percent of tested mosquito samples every year since 2008.
- Surveillance by DOH in the early 1990s demonstrated that Hantavirus was present in deer mouse populations across Washington.

Projections

- There is much that remains unknown about how climate change will impact VBZDs in Washington. However, any changes in VBZDs as a result of influence by climate change will likely be due to one (or a combination) of four primary mechanisms (Mills et al. 2010b):
    - Range shifts in host or vector distribution that brings these organisms into contact with new human populations (Moritz et al. 2008).
    - Changes in the population density of the host or vector that would change frequency of contact with humans.
    - Changes in the prevalence of infection in the host or vector population that would change the frequency of human contact with an infected host or vector.
    - Changes in pathogen load in hosts or vectors that would affect the likelihood that human contact would result in pathogen transmission. Pathogen loading could be brought about by changes in rates of pathogen reproduction, replication, or development.

Vulnerability

- All populations are at risk of vector-borne and zoonotic diseases, in one form or another.
- Those who work or recreate outside in parks or other undeveloped areas are at a greater risk for tick-borne diseases.
- Those who spend time outside in the late afternoon and evening during mosquito season are at the greatest risk for exposure to West Nile virus, particularly in south central Washington.

Harmful Algal Blooms

Background and public health impact

- Harmful algal blooms (HABs) are blooms of naturally occurring marine or freshwater algae that can produce potent toxins with harmful physiological effects (including illness or death) in wildlife and humans. People can be exposed to these toxins either through inhalation, ingestion of contaminated shellfish or fish or through direct skin contact, depending on the situation and species of algae. People can be exposed to freshwater biotoxins through drinking water and incidental ingestion of water during recreational activities.
- Bloom formation is favored by conditions of adequate light availability, warm water, stratification, and high nutrient levels. Marine HABs typically bloom in Washington during the summer or in shoulder seasons when water temperatures are warmer than usual. Freshwater HABs can occur throughout the year but are highest in late summer and fall in state lakes.

Observations

- Researchers have noted an apparent increase in the global frequency, duration and geographic scope of harmful algal blooms in the last several decades of the 20th century (Hallegraeff 1993; Van Dolah 2000; Glibert et al. 2005).
- This increase has been attributed to various causes, including anthropogenic nutrient enrichment, ballast water discharge, and climate change (reviewed *in* Moore et al. 2011).
- The linkages between these factors and algal abundance, distribution, and bloom characteristics are complicated, and uncertainty currently hampers our ability to determine the exact cause of observed changes. Therefore, we present the following observations as suggestive of changes in the ecosystem without necessarily limiting the causal explanation to climate change exclusively:
    - Trainer et al. (2003) noted that since the 1980s the dinoflagellate responsible for paralytic shellfish poisoning (PST; *Alexandrium catenella*) has slowly expanded its range from northern Puget Sound to the south. PSTs are now regularly found in all basins except Hood Canal (Moore et al. 2011).
    - Preliminary data analysis indicates that marine HAB closures in Puget Sound now occur earlier in the year than what was typical in the past (J. Borchert, personal communication, October 20, 2015).
    - Limited information on Puget Sound lowland lakes suggest that years with higher temperatures result in higher concentrations of microcystins and a greater number of lakes with toxins above state recreational guidance values (Hardy et al. 2015).
    - Warm water temperatures in lakes that drain into Puget Sound have been associated with the discharge of freshwater toxic blooms that bioaccumulate in marine shellfish (Preece et al. 2015a, Preece et al. 2015b).

Projections

- Based on analysis of past events, Moore et al. (2009) identified a suite of weather and environmental conditions that precede the development of toxic events due to *A. catenella* in Puget Sound. These conditions are warm air and water temperatures, weak winds, low stream flow, and small tidal height variability.

- Applying this model to future estimates of climate variability indicates that the environmental conditions that favor toxic *A. catenella* blooms may increase by nearly two weeks per year by the end of the 21st century. Furthermore, blooms are predicted to begin earlier in the year and persist for longer (Moore et al. 2011).
- Extreme rainfall events (Anderson et al. 2012) and ocean acidification combined with nutrient limitation or temperature changes (Fu et al. 2012) also are hypothesized to have future impacts upon bloom development and toxicity levels, respectively.

Vulnerability

- People who eat raw or cooked shellfish are most at risk for exposure to marine harmful algal blooms.
- People and animals that drink water from lakes with toxic blooms or ingest water during recreational activities are most at risk from freshwater HABs.

Vibrio

Background and public health impact

- *Vibrio parahaemolyticus* is a bacterium indigenous to marine and estuarine waters around the world. *Vibrio parahaemolyticus* is a common causative agent of food-borne gastroenteritis (food poisoning) and can present a serious health burden, especially to regions with high levels of raw or undercooked seafood consumption.
- *Vibrio vulnificus* is a related bacterium that typically causes more severe systemic illnesses, including necrotizing wound infections and septicemia. *Vibrio vulnificus* does not tolerate low temperatures or high salinity well (Kelly 1982) and has not been common in Washington.
- Temperature is the primary environmental predictor of vibrio abundance and distribution, and these organisms multiply rapidly when exposed to either warm water or warm ambient air temperatures (Johnson et al. 2012).
- In Washington, vibrio control is of special concern to the oyster industry. *Vibrio parahaemolyticus* can increase by four to eight times in oysters during intertidal exposure (Nordstrom et al. 2004) and by 50 to almost 800 times within 24 hours of oyster harvest, if exposed to a ≥ 26°C (82.4°F) environment (Gooch et al. 2002).

Observations

- Anomalies in sea surface temperature, such as those associated with the El-Niño Southern Oscillation (ENSO), have occurred concurrent with vibrio outbreaks in Chile (González-Escalona et al. 2005), Peru (Martinez-Urtaza et al. 2008), Alaska (McLaughlin et al. 2005), and the Pacific Northwest (CDC 1998).
- Martinez-Urtaza et al. (2010) reviewed these cases and concluded that sea surface temperature intrusion can temporarily extend the geographic range and elevate the abundance of *both V. parahaemolyticus* and *V. vulnificus*.
- There is no definitive evidence of either an increase or decrease over time in vibrio abundance or illnesses due to vibrio (vibriosis) in Washington State.

- *Vibrio vulnificus* is currently present at very low, but detectable levels in Washington (Johnson et al. 2012). While this bacterium has not yet caused any confirmed illnesses or deaths in Washington, *V. vulnificus* is considered a potential emerging threat.

Projections

- Elevated air and sea surface temperatures are both anticipated outcomes of climate change (IPCC 2013). Therefore, the observation that vibrios respond positively to warm ENSO conditions is suggestive of future vibrio range expansions and an increase in total abundance.
- However, a review of the literature found no formal projections of vibrio range or abundance, or future illnesses based upon climate change.

Vulnerability

- Residents of the Pacific Northwest are vulnerable to *Vibrio parahaemolyticus*-associated gastroenteritis because of the prevalence of raw oyster consumption in this region. The Pacific Northwest is currently at lower risk of exposure to *V. vulnificus* than other parts of the United States (e.g., the Gulf Coast states) because this bacterium prefers water > 20°C (68°F) (Kelly 1982).
- Immunocompromised individuals, especially those with impaired liver function, appear to be at the greatest risk of severe infection leading to septicemia by either *V. parahaemolyticus* or *V. vulnificus* (Hlady and Klontz 1996).

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