



I -1: Technical Appendix

This technical appendix describes the methodology adopted in risk analysis.

Washington State Natural Hazard Risk Assessment Approach

This risk assessment adopts a holistic view of risk. Traditional risk assessments and tools often address one hazard at a time, and consequently target regions most vulnerable to the one particular hazard; areas subject to multiple hazards, however, are not considered.

The Washington State Risk Index used here adopts a multi-hazard view of risk, combining the natural hazards with socio-economic factors, to create a holistic understanding of the risk faced by communities. This analytical approach is similar to the ongoing initiative by Federal Emergency Management Agency (FEMA) at the national level to create a National Risk Index. The National Risk Index (NRI) incorporates data on social vulnerability, built environment, community resilience, and natural hazards to create a baseline of natural hazards risk for U.S. at the county and census tract level.

The Washington State Risk Index (WaSRI) adopts an analytical approach similar to the National Risk Index with modifications in variable selection and statistical methods to better reflect local priorities and concerns. The risk index is based on spatial overlays of the hazard zone with area, population distribution, vulnerable population distribution, built environment, critical infrastructure facilities, State facilities (owned and leased), and first responder facilities (fire stations, law enforcement buildings, and EMS). The proportional exposure along each of these dimensions were combined to create hazard risk indices for each county. The county indices were aggregated to create the Washington State Hazard Risk Index for each of the ten natural hazards listed earlier.

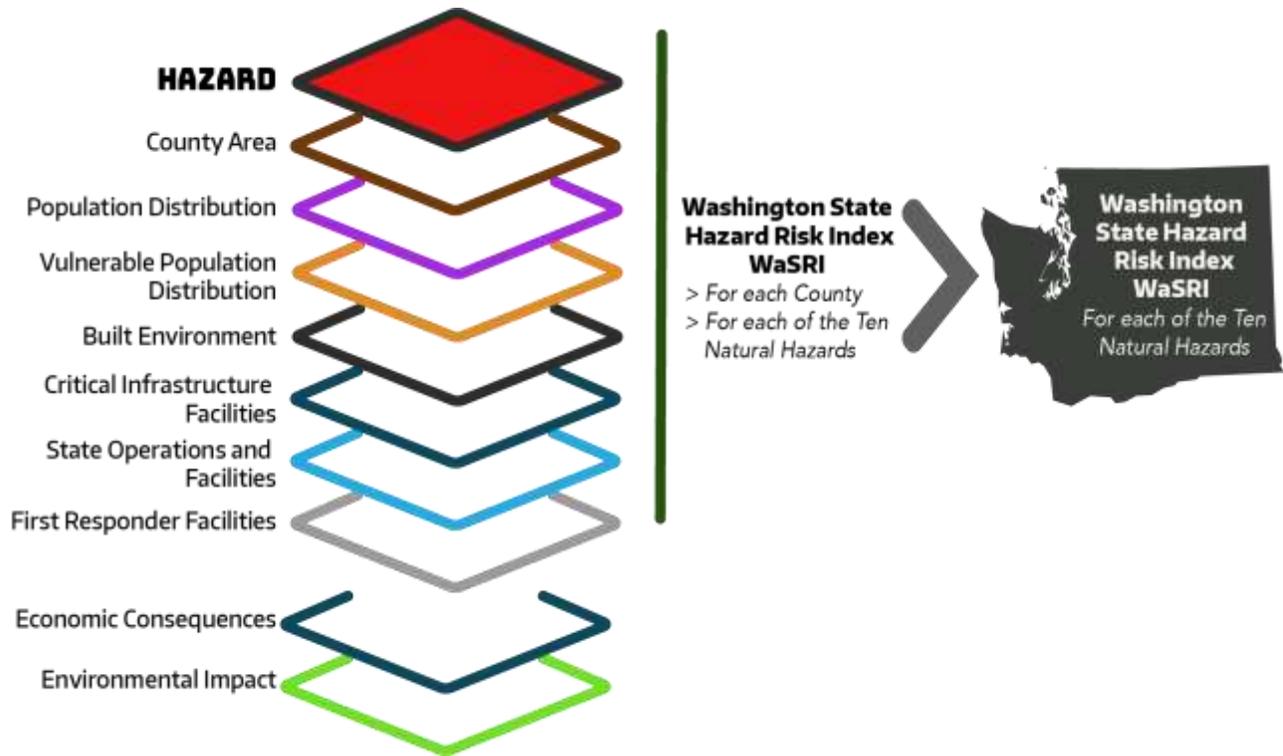


FIGURE TA 1: RISK INDEX CREATION METHODOLOGY

Assessment of economic consequences and environmental impacts were also conducted but were not included in the construction of the index due to methodological limitations as explained in each of the respective hazard sections.

The key exposure assessments for each natural hazard include

1. Area Impacted
2. Population
3. Vulnerable Population
4. Built Environment
5. Critical Infrastructure
6. State Operations and Exposure Facilities
7. First Responder Facilities
8. Economic Consequences
9. Environmental Impacts

Area Impacted

County area exposed to natural hazard risk is estimated by overlaying the hazard area map with the county map to estimate the percentage area exposed to the natural hazard in each county. County map was projected in ESRI ARCMAP[®] software utilizing the Lambert Conformal Conic projection

coordination system - NAD1983 HARN State Plane Washington South FIPS 4602 Feet. The hazard layers were also re-projected into the same geographic projection system to ensure accurate area estimation.

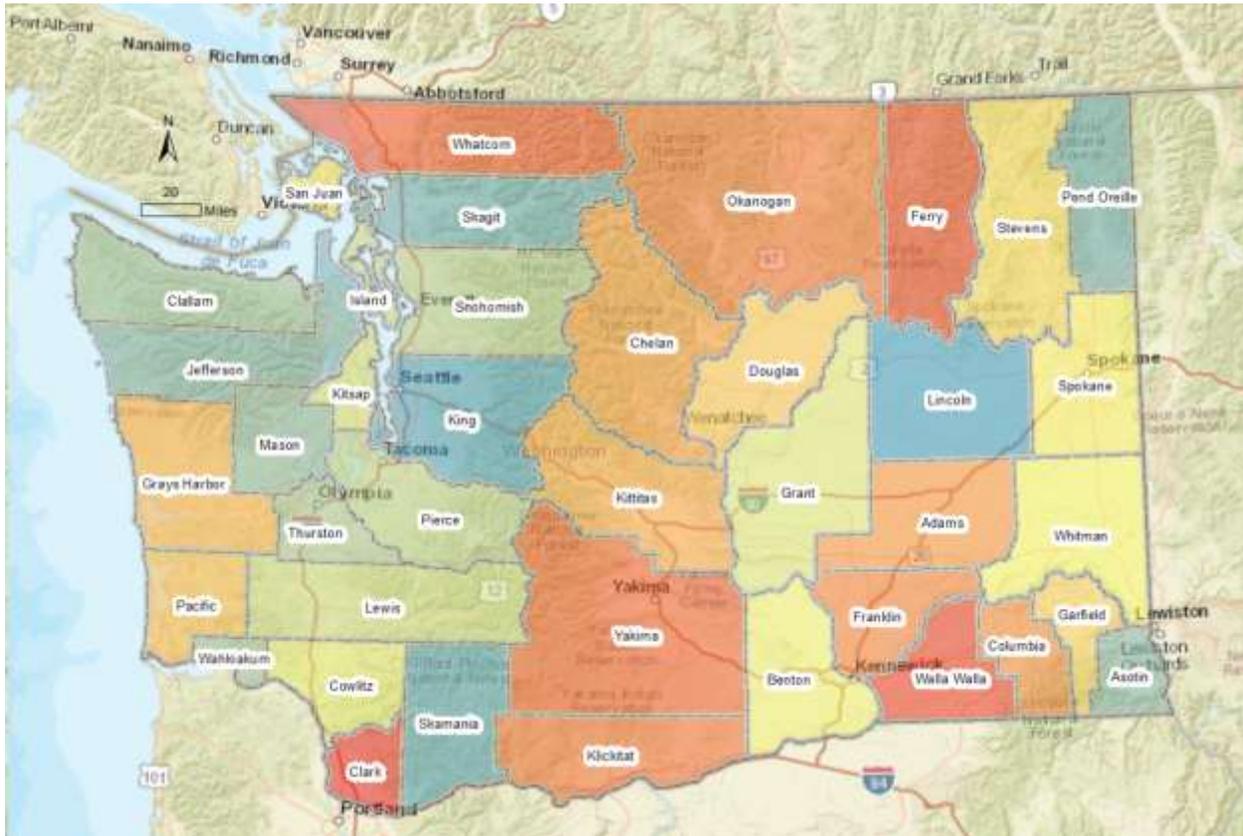


FIGURE TA 2: WASHINGTON COUNTIES

Population

Population exposure to earthquake hazard is estimated by overlaying the hazard layer (medium or higher rank) over the 2011 developed areas derived from the land cover database. The 2017 estimated population for all census tracts was allocated to respective urban areas and the overlap with hazard exposure is estimated using spatial analysis in Geographic Information System (GIS).

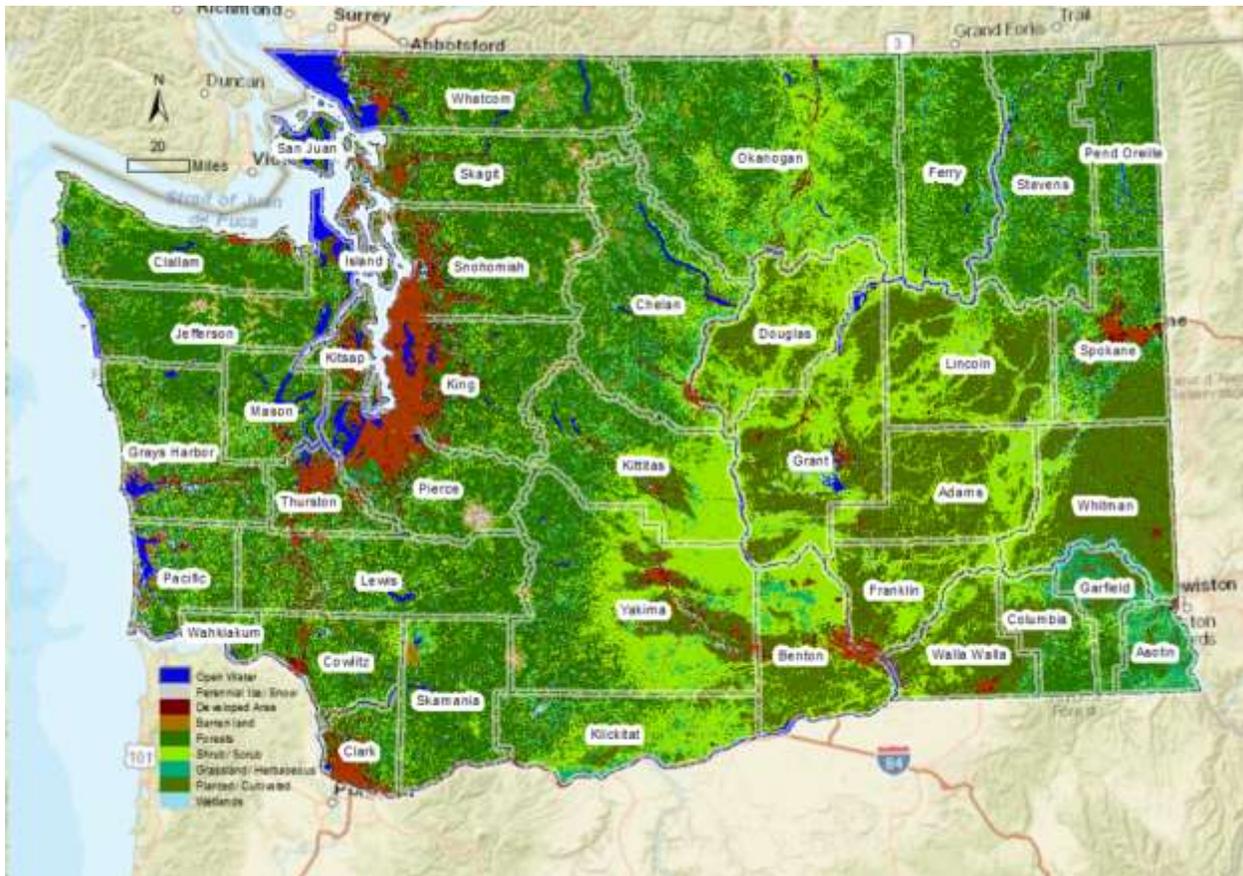


FIGURE TA 3: NATIONAL LAND COVER DATABASE 2011 (SOURCE: WWW.MRLC.GOV)

Vulnerable Population

Social vulnerability examines the differential impact of hazards on society based on existing socio-demographic conditions and community characteristics. A number of social vulnerability Indices have been used by researchers as tools for assessing differences across communities that influence their capacity to prepare for, respond to, and recover from hazards. As part of this risk analysis, a modified version of social vulnerability index based on the methodology developed by ATSDR's Geospatial Research, Analysis & Services Program (GRASP) was utilized. This risk analysis utilizes the following 15 variables from 5-year ACS estimates (2012-2016):

1. Percentage of persons below poverty
2. Percentage of civilians unemployed
3. Per-capita income
4. Percentage of persons (25+) with no HS
5. Percentage of persons aged 65 and older
6. Percentage of persons aged 17 and younger
7. Percentage of civilian non-institutionalized population with a disability



8. Percentage of minority race (non-whites)
9. Percentage of persons (age 5+) who speak English “less than well”
10. Percentage of housing in structures with 10 or more units
11. Percentage of mobile homes
12. Percentage of occupied housing units with more people than rooms
13. Percentage of households with no vehicle
14. Percentage of persons in institutionalized group quarters
15. Percentage of persons with health insurance

These were combined into an Index of Social Vulnerability with equal weights, that is each variable was given equal importance and not statistically weighted. While the quality of the estimates for individual variables may vary (differences in the margins of error for sampling, for example), the 5-year ACS data was used because it is the only census product providing the detailed data required in understanding social vulnerability. The ACS samples 20% of the population every year, so the 5-year estimates represent the best available data on socioeconomic attributes. The margins of error increase as scale decreases (error larger at block group than tract, for example). This precludes the downscaling of the index below a census tract level because in some instances, the margins of error are greater than the values reported for the individual variable. The resulting estimates are categorized into 5 classes (1-low to 5-high) based on z-score transformation (standard deviations from the mean). The overall county index for social vulnerability is the arithmetic mean of the social vulnerability estimates for each tract.

Built Environment

The built environment exposure to natural hazards is calculated using the general building stock data (2014) provided by FEMA that contains the building values for all structures in the census tracts. General building stock values used in this analysis are the total structure value of all buildings (except agricultural) in each census tract in 2014 dollars. Building values for all occupancy types were summed for each census tract using only structure values (not content values) and assigned to the developed areas within each tract. These maps were then overlaid on the hazard layer to estimate the general building stock value within hazard exposure areas. Individual tract level estimates were aggregated to create the county level estimates.



Critical Infrastructure Exposure

Location of 12 critical infrastructure facilities was mapped for the whole state. The following facilities were identified from the Homeland Security Foundation Level Database (HIFLD) for critical infrastructure analysis:

1. Airports (23)
2. Communication (16097)
3. Dams (268)
4. Education Facilities (5331)
5. Electric Substations (1392)
6. Hospitals (147)
7. Power Plants (146)
8. Public Transit Stations (60)
9. Railroad Bridges (1619)
10. Railway Stations (317)
11. Urgent Care Facilities (113)
12. Weather Radar Stations (2)

This data was overlaid with the hazard exposure layer to identify facilities located in natural hazard areas. This analysis is limited to point data and not critical infrastructure represented by a line such as roads and rail corridors. These networks will also be impacted by natural hazard events but due to data limitation they have not been included in this analysis.

State Operations and Facilities Exposure

The list of state owned (9415) and leased facilities (1039) was obtained from 2017 Facilities Inventory System Report produced by Office of Financial Management. These facilities were geo-located based on the addresses provided in the facilities inventory report and then overlaid with hazard layer.

First Responder Facilities Exposure

Locations of fire stations, law enforcement buildings, and emergency medical stations in the State were identified from the Homeland Security Foundation Level Database (HIFLD). Using ESRI ArcMap geocoding services 1,268 fire stations, 332 law enforcement agencies, and 1,162 EMS stations (including those co-located with fire stations) were located on the State map.

Economic Consequences

The economic activity data was derived from National Association of Counties. This dataset



provides the county level estimates of Gross Domestic Product (GDP) for 2016.¹ The Washington State Hazard Risk Index for each hazard was compared with the county GDP to assess the possible economic impacts.

County GDP 2016 Data	
County	GDP 2016 (in Mill.)
Adams	\$746.07
Asotin	\$618.43
Benton	\$10,627.85
Chelan	\$4,363.01
Clallam	\$2,573.06
Clark	\$18,682.64
Columbia	\$144.20
Cowlitz	\$4,474.88
Douglas	\$1,037.39
Ferry	\$198.13
Franklin	\$3,356.16
Garfield	\$97.44
Grant	\$3,803.65
Grays Harbor	\$2,237.44
Island	\$2,796.80
Jefferson	\$867.23
King	\$230,344.61
Kitsap	\$12,082.18
Kittitas	\$1,566.21
Klickitat	\$1,004.05
Lewis	\$2,573.06
Lincoln	\$347.25
Mason	\$1,566.21
Okanogan	\$1,678.08
Pacific	\$637.45
Pend Oreille	\$354.63
Pierce	\$41,280.80
San Juan	\$602.88
Skagit	\$5,705.48
Skamania	\$218.04
Snohomish	\$39,378.97
Spokane	\$24,723.73
Stevens	\$1,111.56
Thurston	\$12,865.29
Wahkiakum	\$93.41
Walla Walla	\$2,908.67
Whatcom	\$10,068.49
Whitman	\$2,237.44
Yakima	\$10,404.10

¹ <http://explorer.naco.org>



Risk to Environment

To assess the risk to environmental resources, the spatial land cover mapped data was overlaid with the hazard layer. Forests, scrubland, wetland, and cropland areas were identified as environmentally critical areas. The overlap between these areas of ecological importance and hazard areas was analyzed through spatial analysis in GIS software.