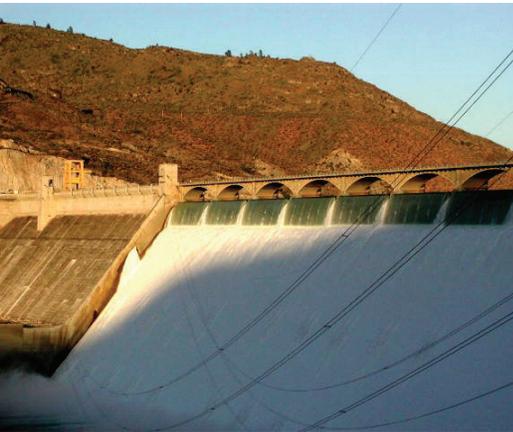


10. Infrastructure and the Built Environment





10. Infrastructure and the Built Environment

Maintaining safe and reliable infrastructure is critical for Washington’s economy, environment, and way of life. This chapter addresses climate impacts and strategies to prepare our transportation, energy, communities, and communications infrastructure for a changing climate. Coastal and water infrastructure are addressed more fully in Chapter 6, **Ocean and Coastlines**, and Chapter 7, **Water Resources**.

Washington’s infrastructure is vulnerable to a changing climate. Infrastructure systems are designed and maintained based on our past and current experiences. For example, bridges are built to allow logs and other debris to pass under during anticipated high flows. Climate change is moving us beyond the range where past experience is a good guide for what we might experience in the future. Climate change could both create new challenges and exacerbate our current challenges in managing infrastructure systems for coastal erosion, flooding, unstable slopes, higher temperatures, and extreme events.

Climate impacts could:

- Increase maintenance and repair costs.
- Affect public safety.
- Interrupt critical evacuation routes and energy supplies.
- Cause travel delays and disruptions.
- Disrupt economic activity.
- Degrade our quality of life.

10. Infrastructure and the Built Environment

The impacts of climate change will vary across the state depending on geography, topography, and the capacity of different communities to adapt. Recognizing the risks associated with climate change is an important first step toward better planning of new infrastructure investments and mitigating potential damage to existing infrastructure.

Because infrastructure is designed to last for decades, it is important to consider climate change in planning and design. The high costs and length of time it takes to alter infrastructure means that, for responsible asset management, we must begin to take into account future climate conditions now. The work we do to prepare for and adapt to our changing climate will protect taxpayer investments and our vital infrastructure systems for conditions both today and in the future.

The following sections describe the scientific understanding of the impacts of climate change on Washington's infrastructure and built environment and outline key strategies to support state and local efforts to protect them and lower risks to our communities.





Impacts of Climate Change on Infrastructure and the Built Environment

Climate change is expected to increase the risk of flooding and damage to infrastructure and communities, resulting in travel delays and disruptions to transportation, energy, communities, and communications systems.

- Sea level rise and storm surge will increase the risk of flooding, erosion, and damage to coastal infrastructure.
- More extreme precipitation will increase the risk of flooding, landslides, and erosion, which may damage or disrupt infrastructure systems and overwhelm drainage structures.
- Warmer temperatures and heat waves could strain energy and transportation systems—though they also offer benefits such as reduced snow and ice removal costs.
- Prolonged low summer flows could affect river navigation.
- Lower summer streamflow will reduce summer hydropower production at a time when warmer temperatures will increase electricity demand for cooling.
- Larger and more intense forest fires could damage buildings, roads, and other infrastructure.

Our infrastructure is an interconnected network, which will require an integrated approach to addressing climate change impacts. Utility lines are often strung along bridges or within the road right-of-way. Parts of our energy distribution systems, like fuel delivery for vehicles and for heating rely on road networks.

Many climate impacts are common to all types of infrastructure. For example, rain or sea-level inundation could flood underground equipment and instruments associated with power stations, telecommunication and cable boxes, and traffic signals for all modes of transportation. Increased flooding and landslides would affect operations and maintenance of many types of infrastructure.

1 Transportation systems

Climate change impacts pose significant challenges to our transportation system. Sea-level rise and storm surge will increase the risk of major impacts to vulnerable transportation infrastructure along coastlines. Airports, rail lines, roads, and other structures in low-lying coastal areas will be at a higher risk of temporary or permanent flooding and erosion.¹⁵⁴ Closures and travel delays could increase, especially in densely populated areas near the coasts. Evacuation routes along the coast could be washed out. Washington's seaports and the connected distribution networks will face higher risks of flooding. Together, these impacts could significantly affect communities and economic activity along the coasts.

Extreme weather events are becoming more frequent and intense, and they pose major challenges for transportation. Heavy downpours have increased by 25 percent in magnitude in the Puget Sound region over the past 50 years, and they are projected to continue to increase.¹⁵⁵ When combined with changes in streamflow, population growth, and development pressures, this change could increase the risk of flooding, weather-related accidents, delays, and traffic disruptions.¹⁵⁶ In 2007, flooding closed a 20-mile section of Interstate-5 in the Chehalis Basin for four days, resulting in \$47 million in lost economic output to the state. The 2007 storm caused approximately \$23 million in damages to interstate and state highways in Washington as well as \$39 million in damages to city and county roads.¹⁵⁷ More severe flooding will increase the risk of damage to bridges and could overwhelm drainage structures, such as culverts.¹⁵⁸ The risks to public safety will increase, along with the risk of major economic impacts from closures and delays.

More heavy downpours and more precipitation falling as rain instead of snow could increase the risk of landslides and slope failures, leading to more frequent road closures and higher maintenance costs.¹⁵⁹ In 2010, nearly 130 Amtrak Cascades passenger trains were delayed or canceled because of mudslides and hillside washouts. In 2011, the number of



¹⁵⁴ U.S. Global Change Research Program (2009).

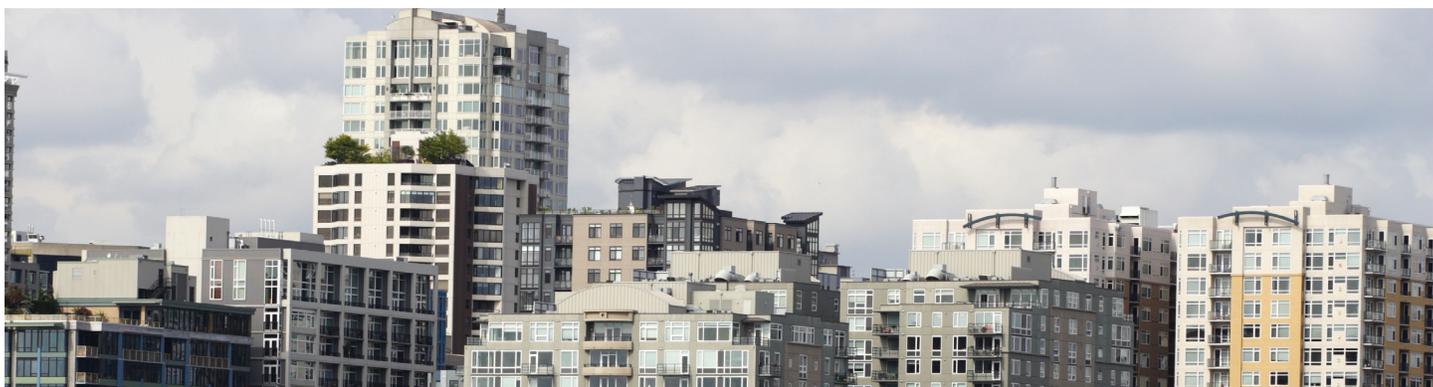
¹⁵⁵ Rosenberg *et al.* (2009)

¹⁵⁶ U.S. Global Change Research Program (2009).

¹⁵⁷ Washington State Department of Transportation (2008a).

¹⁵⁸ Washington State Department of Transportation (2008a).

¹⁵⁹ Washington State Department of Transportation (2008a).



delays and cancellations had doubled by October.¹⁶⁰ Along the 466-mile route for Amtrak Cascades, more than 60 areas have been identified as at risk for mudslides. The closures also affect Sound Transit's Sounder, the Amtrak Coast Starlight long-distance train, and BNSF (Burlington Northern Santa Fe Corporation) Railway freight trains. These types of events will potentially become more common.

An increase in extreme heat can negatively affect pavements, rails, striping, and other materials. Infrastructure impacts include:

- Heat-related buckling of pavements and rails.
- Traffic-related rutting of pavements.
- Thermal expansion of bridge joints.

Rising temperatures could benefit our transportation system by reducing road closures and costs for snow and ice removal. The temperature changes for our region are unlikely to cause catastrophic failures; rather, the change in conditions can be addressed through selection of materials that can withstand the new temperature norms.

Larger and more severe wildfires will increase risks to traffic operations and safety by obscuring visibility for drivers. Large fires can sometimes create enough smoke to require closure of roadways, limiting mobility and creating economic impacts.¹⁶¹ Fires and insect damage can also have a secondary impact of reducing vegetation coverage, leading to increased erosion and landslides that can erode or cover roadways during or following heavy rains and snowmelt.¹⁶²

Climate risks to our transportation infrastructure will vary by location. Effectively preparing for climate change requires an improved understanding of the areas and assets at high risk. The Washington State Department of Transportation (WSDOT) recently completed work to pilot a risk assessment model developed by the Federal Highway Administration. As part of the pilot, WSDOT completed a qualitative assessment and initial screening of state-owned transportation infrastructure vulnerable to climate impacts. The results of the assessment will be used to help prepare for future conditions and incorporate climate information into decision-making. (See box on page 162 for more information.)

¹⁶⁰ See wsdotblog.blogspot.com/2011/10/wsdot-takes-mudslides-head-on-to.html

¹⁶¹ Hamlet *et al.* (2011).

¹⁶² Hamlet *et al.* (2010).

2 Energy systems, supply, and use

Climate change is expected to alter the supply and demand for energy in Washington State (see Table 2). Shifts in the amount and timing of streamflow are expected to lead to substantial changes in seasonal hydroelectric power generation, which supplies two-thirds of the state's electricity needs. Winter hydropower production is projected to increase, and summer hydropower production is projected to decline.

Extreme heat wave events are likely to increase in frequency, generating an increase in the peak demand for electricity for air conditioning and industrial cooling in the summer. The increase in summer demand will coincide with a decline in summer hydropower availability.

Warmer temperatures will decrease demand for heating in the winter, which is primarily from natural gas. Because of expected growth in population, however, the overall demand for winter heating is still projected to increase.



Year	2020s	2040s	2080s
Summer hydropower generation	Decrease 9-11%	Decrease 13-16%	Decrease 18-21%
Winter hydropower generation	Increase 0.5-4%	Increase 4-4.2%	Increase 7-10%
Annual hydropower generation	Decrease 1-4%	Decrease 2.5-4%	Decrease 3-3.5%
Winter demand for energy for heating*	Decrease 11-12%	Decrease 15-19%	Decrease 24-32%
Summer demand for energy for cooling*	Increase 92-118%	Increase 174-289%	Increase 371-749%

Table 2. Projected changes in hydropower generation and energy demand compared to 1917-2006 (not including population growth).

*Figures are for a fixed year 2000 population. Population growth is projected to increase winter demand for energy for heating and summer demand for energy for cooling.

Source: Hamlet et al. (2010).



Climate change is also likely to affect the potential to generate electricity from other renewable energy sources besides hydropower—such as wind, solar, and biomass (plant-based sources)—although these effects are not well understood.¹⁶³

Sea level rise, storm surge, and extreme weather events could increase the risk of flooding and damage to energy production and delivery systems, such as power plants, transmission lines, pipelines, and oil refineries. More storm activity could increase the cost of power and infrastructure maintenance and lead to more, longer blackouts and disruptions of services. Extreme heat could affect transmission efficiency. Declines in summer streamflows could also threaten supplies of cooling water for thermal power plants.

3 Communities and development

Climate impacts will also affect local communities and the infrastructure they depend on. Commercial and residential buildings near floodplains or along the coast could face higher risks from flood damage. Heavier downpours could strain the capacity of stormwater systems, creating backups and flooding and increasing the risks of combined sewer overflows that pollute rivers, lakes, and Puget Sound. Climate risks will vary by location and will affect decisions about land use and development patterns.

4 Communications infrastructure

Along the coasts, inundation from sea level rise and flooding may affect access chambers, vaults, and other underground communications facilities. Increased storm activity may raise the cost of telecommunications supply and infrastructure maintenance, due to increased frequency and length of network outages and disruption of communication services.

¹⁶³ U.S. Global Change Research Program (2009).

Recommended Adaptation Strategies and Actions—Infrastructure and the Built Environment

Moving forward to protect our infrastructure minimizes risk and helps ensure that infrastructure, services, and operations remain effective in both current and future climate conditions. The five adaptation strategies and actions presented below emphasize building on existing work to identify risks and vulnerabilities and taking proactive measures to prepare for risks.

Adaptation approaches vary based on the risk and importance of the infrastructure, and efforts may include:

- Protecting infrastructure by strengthening dikes and levees and by using other hard or soft structural approaches.
- Strengthening infrastructure to better withstand climate impacts (such as flooding or extreme heat) through improved materials, design, and construction techniques.
- Raising or elevating infrastructure to protect it from flooding.
- Relocating, decommissioning or abandoning selected infrastructure where the costs of protection and maintenance outweighs the benefit.
- Care must be taken to avoid approaches that have negative impacts on fish and wildlife or cause unintended consequences.





To protect infrastructure, we must also integrate consideration of climate change impacts and adaptation into existing planning, operations, and investment decisions at the state and local levels. These include plans related to:

- The Growth Management Act.
- The Shoreline Management Act.
- Emergency preparedness and response.
- Transportation.
- Energy.

Because land use drives the location of substantial public investment, care should be used in planning where future development occurs. Availability of data, mapping, resources, and the policy guidance would allow each local government to determine the appropriate set of decisions for its situation and likely impacts.

Adaptation responses require coordination among multiple jurisdictions and private entities that own and operate infrastructure, respond to emergencies, and engage in long-range planning related to land use, transportation, energy, and emergency preparedness.

Strategy G-1. Protect vulnerable infrastructure and ensure it is safe, functional, and resilient to climate impacts.

Actions:

1. Develop a common framework and methodology for transportation infrastructure risk assessment at a regional scale and for all transportation modes and operations.
2. Encourage local, regional, tribal, and federal governments and private entities to prepare detailed inventories and climate vulnerability assessments to identify critical and vulnerable infrastructure within their jurisdictions.
3. Work with ports to determine short- and long-term strategies to protect port infrastructure and transportation linkages to ensure movement of commerce and international trade.
4. Encourage owners and operators of critical energy infrastructure to evaluate vulnerability to the impacts of climate change, including risks of damage and the potential for disruptions and outages from flooding, sea level rise, extreme heat, erosion, and extreme weather events.
5. Adopt regulatory and incentive programs to encourage state, tribal, and local transit organizations; public works departments; utilities; and other partners to demonstrate awareness and, where possible, consistency with efforts to address vulnerable systems.
6. Work with the insurance industry to identify and implement mechanisms to reduce risks to property owners from climate-related hazards and to educate consumers on ways to reduce exposure to risk.

Washington's Transportation Infrastructure

The Washington State Department of Transportation is one of five entities that the Federal Highway Administration funded to “test drive” its draft vulnerability and risk assessment conceptual model for transportation infrastructure.

WSDOT conducted the statewide assessment on state-owned and managed infrastructure, using data from the University of Washington's Climate Impacts Group. Through workshops and the FHWA model, WSDOT found vulnerable infrastructure across the state. Most of our newer bridges are resistant to climate changes—some can withstand a sea level rise of up to 4 feet or more.

In some areas, however, road approaches to bridges appear more vulnerable than previously thought. From the data and maps that came out of the workshops, WSDOT can see where climate changes are likely to intensify the threats already facing our transportation facilities.

www.wsdot.wa.gov/SustainableTransportation/adapting.htm

Strategy G-2. Guide future development away from areas at risk.

Actions:

1. Gather and provide the best available scientific information on climate impacts and areas at high risk from flooding, seawater inundation, landslides, extreme heat, and wildfires. Provide information for a range of climate scenarios, for all regions in the state and on a basin-by-basin basis, using consistent data from the UW Climate Impacts Group and other reputable sources. Make the information available and readily accessible to citizens, businesses, local governments, tribes, and others to assist in making informed decisions to prepare for and adapt to climate impacts.
2. Develop guidance as well as regulatory and incentive programs to encourage state and local governments to limit new development in high-risk areas and to incorporate projected climate change impacts and adaptation actions into long-term planning, policies, and investment decisions. These policies and plans include regional or countywide planning policies, comprehensive plans, shoreline master plans, development regulations, and urban growth area expansions.
3. Determine how to consider potential climate impacts and adaptation options for non-project and project actions, as part of the State Environmental Policy Act.
4. Encourage the federal government to accelerate modernized flood mapping and implement fundamental reforms to the National Flood Insurance Program to incorporate risks from climate change.
5. Limit new development in floodplains and coastal areas vulnerable to sea level rise and return some coastal and floodplain areas to natural conditions.
6. Encourage local jurisdictions to identify and implement ordinances and other approaches to reduce wildfire risks.



Strategy G-3. Reduce or avoid climate risks by considering climate in the planning, funding, design, and construction of infrastructure projects and by promoting improved design and construction standards in areas vulnerable to climate risks.

Actions:

1. Develop a framework to guide the state's planning and investments to:
 - *Protect, repair, elevate, or decommission vulnerable infrastructure.*
 - *Protect safety and key evacuation routes.*
 - *Protect critical transportation facilities and corridors for the movement of people and freight, both within Washington and to nearby states and Canada.*
 - *Address potential financial, social, and environmental impacts.*
2. The framework should identify a process to decide when the state will not invest in at-risk projects with a long lifespan.
3. Require incorporation of climate impacts and response strategies in the state's long-range transportation plans; mode-specific plans for highways, rail, aviation, and ferries; and regional transportation plans.
4. Develop transportation design and engineering guidance to minimize climate change risks. The design guidance should be used when siting and designing new transportation infrastructure and project-related infrastructure, such as stormwater treatment and flow control, wetlands protection and mitigation, and fish passages. The guidance should provide information on techniques and materials resistant to increased heat and other climate impacts.
5. Require consideration of climate risks and response strategies in the site selection, design, and construction of state-funded infrastructure projects.
6. Advance the adoption and enforcement of progressive building codes and design standards to reduce vulnerability of structures to climate-related hazards.

7. Provide incentives to incorporate climate risks and response strategies in the design of commercial and residential buildings. Promote strategies and technologies, including those that:
 - *Reduce energy and water use.*
 - *Accelerate deployment of smart-grid technologies—using electronic control, metering, and monitoring to reduce energy use (see box on page 167).*
 - *Maximize rain and snow seepage into the ground, which reduces runoff and replenishes groundwater, using green infrastructure and low-impact development approaches.*
 - *Collect rainwater onsite.*
 - *Maximize open spaces to reduce urban heat effects.*
8. Identify and provide financial incentives to property owners to reduce exposure to risk, such as low-cost loans or financial incentives to rebuild—or relocate—according to improved construction standards, increased setbacks, or elevation of the structure.

Green infrastructure encompasses the preservation and restoration of natural landscape features, such as forests, wetlands, floodplains, and natural drainage features. At the site scale, it involves low-impact development (LID) and sustainable building features, such as rain gardens, green roofs, permeable pavement, rainwater harvesting, urban forestry, and preservation of green open spaces such as parks and wetlands.

Benefits of green infrastructure include:

- Better management of stormwater runoff.
- Lower incidence of combined sewer overflows (CSOs).
- Water capture and conservation.
- Flood prevention.
- Storm surge protection.
- Defense against sea level rise.
- Accommodation of natural hazards.
- Reduced ambient temperatures and urban heat island effects.

For more information:

www.ccap.org/green_infrastructure.html

Strategy G-4. Enhance the preparedness of transportation, energy, and emergency service providers to respond to more frequent and intense weather-related emergencies.

Actions:

1. Incorporate information about climate impacts into state and local emergency planning efforts, including the Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan, and the Hazard Identification and Vulnerability Analysis.
2. Bolster contingency plans for key critical transportation, energy supply and distribution networks, telecommunications, and water infrastructure at risk.

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3. Identify and protect critical evacuation routes. Coordinate emergency evacuation planning among adjacent cities and counties.
4. Improve systems to provide engineers, public works, and maintenance staff with early warning of problems, engage onsite protections in advance of an emergency, and provide early warning to the public. Revise existing systems—or develop better systems, such as using sensors and smart technologies—for monitoring:
 - *Bridge abutments.*
 - *Land slopes.*
 - *Stormwater runoff and drainage systems.*
 - *Real-time flood levels and storm surge.*
 - *Other climate impacts on infrastructure.*
5. Adjust routine operations, maintenance and inspection, and capital budget expenses to prepare for more frequent and intense storms, floods, landslides, wildfires, and extreme heat events.
6. Seek more reliable funding mechanisms to ensure that local governments can safeguard vulnerable populations, especially during heat waves. Provide incentives to prepare for energy supply interruptions and develop backup systems in schools, clinics, and emergency shelters.
7. Foster interaction with communication service providers to improve reliability of emergency services during extreme weather events, encourage communication companies to identify alternative means of communication during emergencies, and seek incentives for new technology to diversify and decouple communications from electric grids or otherwise improve their resilience.



Strategy G-5. Build capacity of the energy sector to respond to climate-related disruptions and meet potential increases in energy demand and changes in supply.

Actions:

1. Continue to consider climate-related changes in energy supply and demand, system reliability, and in the State Energy Strategy and the Northwest Power Plan. Encourage utilities to consider potential climate impacts in integrated resource plans.
2. Require consideration of climate risks in relicensing existing and siting new energy projects.
3. Aggressively increase energy efficiency and conservation efforts.
4. Encourage additional research into the impacts of climate change on alternative energy sources. Identify how future climate impacts could affect the state's renewable energy goals, and work with utilities to ensure that renewable energy and energy conservation goals are met.
5. Encourage the development of small energy sources on site (e.g., solar panels) to increase reliability by having redundant systems and to reduce risks associated with the long-distance transmission of energy.
6. Construct stronger, more resilient transmission and distribution systems to improve system reliability and to create additional capacity and redundancy.
7. Adjust reservoir management to account for climate impacts—either too little water or too much water—in considering multiple objectives for energy production, agriculture irrigation, flood management, fish flows, and other needs.

What is Smart Grid?

Smart Grid is an advanced telecommunications and electric grid with sensors and smart devices linking all aspects of the current grid—from generator to consumer—and delivering enhanced operational capabilities that:

- Provide users with the information and tools necessary to respond to electricity grid conditions, including price and reliability, through the use of electric devices and new services.
- Ensure efficient use of the electric grid, optimizing current assets while integrating emerging technologies such as renewable energy and storage devices.
- Enhance reliability by protecting the grid from cyber attacks, increasing power quality, and promoting early detection and self-correction of grid disruptions.

For more information:

www.pnwsmartgrid.org/