

# The Washington Division of Geology and Earth Resources

## Geology in the Public Interest

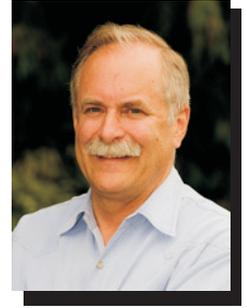


WASHINGTON STATE DEPARTMENT OF  
**Natural Resources**

Peter Goldmark - Commissioner of Public Lands

David K. Norman - State Geologist

Washington's complex geology gives rise to many geologic hazards—earthquakes, active volcanoes, landslides, tsunamis, and abandoned mines. One of the more important missions of the Division of Geology and Earth Resources is to reduce the impact of geologic hazards on the citizens of Washington. As Washington's geological survey, the Division contributes to the safety and economic well-being of Washington's citizens by educating the public, government, and industry about the consequences of foreseeable geologic events and the nature of the land around us, including the availability of important resources such as aquifers and sand and gravel. The Division has provided this information at very low cost to taxpayers, and studies have shown that providing geologic information to the public more than pays for itself over time. The Division of Geology is regarded as the primary source of geological products and services in support of decision-making by Washington's government agencies, its businesses, and the public.



Peter Goldmark  
Commissioner of Public Lands

The Division of Geology provides:

- Evaluation of geologic hazards and advice on their mitigation,
- Disaster response and damage assessment,
- Surface and subsurface geological mapping,
- Inventory and regulation of mineral, oil & gas, and geothermal resources,
- Technical support for environmental and forest protection,
- A comprehensive library collection on the geology of Washington,
- The *Washington State Interactive Geologic Information Portal*, and
- Easily accessible information on Washington geology.

### ENVIRONMENTAL GEOLOGY AND HAZARDS

Division geologists identify and assess geologic hazards using modern geotechnical and geophysical methods. Our hazard maps are critical for transportation, land-use, and emergency-management planning, as well as disaster response and building-code implementation. As our population grows, there is increasing pressure to develop in hazardous areas. Delineation of these areas has never been more important.

Our mapping program identifies geologic materials characteristics, areas of low and high water infiltration potential, and probable groundwater pathways, as well as areas subject to ground failure during earthquakes and large precipitation events. In the Puget Sound area, we work closely with the

Puget Sound Partnership, the Hood Canal Dissolved Oxygen Program, and local agencies to help implement our findings.

Additionally, we are mapping tsunami hazard zones and collateral earthquake-induced ground failures. We are partnering with the Washington Emergency Management Division to do the public outreach that fosters tsunami-resilient communities. This can contribute to good policy decisions, such as preserving the coastal habitats that serve as tsunami buffers.

In response to the Growth Management Act's mandate to use the 'best available science', our geologists meet with local governments and citizens in at-risk communities to educate them about geologic hazards and ensure that these hazards are considered in growth-management and disaster planning.

The Division is also among the first responders to disasters, helping staff the State Emergency Operations Center at Camp Murray and later documenting damage in the field.

### Landslides

Landslides are a continuing problem along our hillsides, shorelines, and roadways. Just since 1996, landslides have caused hundreds of millions of dollars in damage and at least six deaths in Washington. Average loss from landslides over the last 30 years is more than \$20 million per year.

The Division is a leader in landslide hazard identification, mitigation, and emergency response. Our geologists responded to landslide emergencies in

Seattle, Olympia, Grand Coulee, Snohomish County, and Whidbey Island. We have mapped Cowlitz County's landslide hazard areas to assist with growth-management planning that will protect future homeowners. The county's Aldercrest landslide, which destroyed 138 homes, was declared a federal disaster area. Damage to public and private property was estimated in excess of \$30 million.

Storms in 2007 and 2009 resulted in thousands of landslides and millions of dollars in damage. The Division's Quick Reports and use of the Internet on these events has set a new standard to help with emergency response. Our statewide landslide database, with over 50,000 mapped landslides, is available on our new interactive *Washington State Geologic Information Portal*.

Landslide hazard maps can help avoid loss to property and save lives by showing those areas that are unsafe for building. To this end, additional landslide mapping projects are planned for the shorelines of Puget Sound.

Division geologists are also studying large ancient landslides that may record



Debris flow at Division and Mill Street in the town of Concrete, Skagit County. Photo by Kelsay Davis-Stanton.



Debris from a parapet failure on the south side of the Washington Federal Savings building in downtown Olympia caused by the Nisqually earthquake of February 2001. Photo by Joe Dragovich.

prehistoric earthquakes to help document the recurrence intervals for major earthquakes, which could be devastating to western Washington.

### Earthquakes

Washington is the second most at-risk state for damage and monetary losses from earthquakes, with estimated annualized losses of \$228 million. Estimated loss from a M 6.7 event on the Seattle fault is \$33 billion, with 1600 fatalities and 24,000 injured.

Seattle is the seventh most at-risk city in the U.S. because of the Seattle fault, but geologic evidence suggests that most of Washington is at risk from large earthquakes. In 1700, a mega-quake occurred on the Cascadia subduction zone off the coast of Washington. The largest quake since European settlement was in a sparsely populated area east of the Cascades in 1872. Puget Lowland earthquakes in 1946, 1949, and 1965 killed 15 people and caused more than \$350 million in property damage, and the Nisqually earthquake in 2001 caused more than \$2 billion in damage.

The Division produces earthquake hazard maps for at-risk urban areas. These maps show areas where earthquake damage from soil liquefaction or amplification of earthquake waves can be expected to be high. Damage can then be mitigated by either reinforcing structures in these areas or not building there at all.

Nine detailed liquefaction maps and one ground-shaking map have been published by the Division to date. Our Olympia map was tested by the 2001 Nisqually earthquake and successfully predicted areas of greatest liquefaction.

Division geologists hold workshops to show cities and counties how to use these maps for land-use and emergency-management planning.

### Volcanoes

In the past 12,000 years, Washington's five active volcanoes have erupted more than 200 times, producing ash, lava, and massive mudflows. The 1980 eruption of Mount St. Helens killed 57 people, blanketed eastern Washington with ash, and caused more than \$1 billion in damage.

Mount Rainier is our most dangerous volcano because of the large population close to the mountain. Previous lahars (mudflows) from Mount Rainier inundated Puget Lowland valleys as far as current-day Renton, Tacoma, and the Nisqually delta. The Division has mapped and determined the age of many of these events to present a much clearer picture of their frequency and magnitude.

In the past, lahars from Glacier Peak have flowed through the Skagit Valley all the way to La Conner. Recent mapping by Division geologists in Skagit and Whatcom Counties has identified previously unrecognized, young lahars from Glacier Peak that would obliterate small towns, such as Darrington, and destroy sections of Interstate 5 should they occur today.

The Division collaborates with the U.S. Geological Survey's Cascades Volcano Observatory to produce volcano hazard maps and develop response plans for each volcano. We assist at-risk communities with their land-use, evacuation, and emergency-management plans and hold open meetings in at-risk communities to present the danger and allow citizens to ask questions and voice concerns.



Mount St. Helens from the Pumice Plain, about one mile north of the mountain, on April 16, 1983. Photo by Pat Pringle.



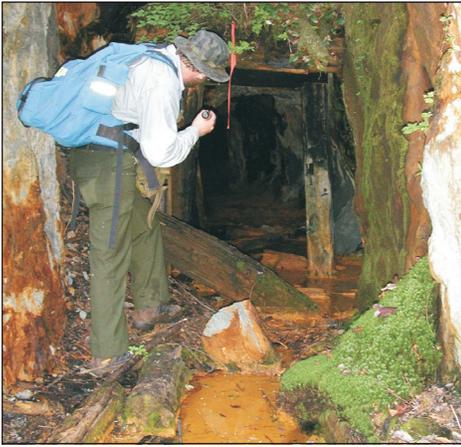
### Tsunamis

The coast of Washington is at risk from tsunamis of both local and distant origin. Our current technology gives us adequate warning for tsunamis produced by distant quakes. An earthquake on the Cascadia subduction zone, however—like the 1700 event or the Indian Ocean earthquake of 2004 that killed more than 225,000 people—could generate a tsunami that would strike our coast with great force within a few tens of minutes.

The Division is on the front line in disseminating information about tsunamis. To date, we have produced eight tsunami hazard maps showing projected areas of inundation for much of our outer coast, where more than 40,000 residents and \$1.5 billion in property are at risk, as well as for the Strait of Juan de Fuca, northern Puget Sound, and Seattle. We hold educational workshops in coastal communities and help local governments develop evacuation and emergency-management plans.

We have worked with coastal counties to prepare 14 tsunami evacuation brochures. In addition, we participated with the Applied Technology Council and Federal Emergency Management Agency to produce engineering guidance for structures to be used for vertical evacuation from tsunamis in areas where there is no nearby high ground available for evacuation.

We also participate in the National Tsunami Hazard Mitigation Program (NTHMP) to improve tsunami warnings, inundation modeling, and dissemination of tsunami research. Our librarian, under a grant from the NTHMP, prepares and publishes *TsuInfo Alert*, a



The main adit at the Lockwood Pyrite mine, showing acid mine drainage with dissolved metals. Photo by Mac McKay.

newsletter that links tsunami scientists, emergency responders, and community planners to the latest tsunami research. Our library holds the NTHMP's collection of tsunami information.

### **Coal Mine Subsidence**

Abandoned coal mines underlie at least 50,000 acres in King, Kittitas, Lewis, Pierce, Skagit, and Whatcom Counties. Some of these mines are near the surface and pose a risk to buildings from mine collapse. Information about the location and condition of coal mines is necessary to identify hazardous areas. Our extensive coal mine map collection and staff expertise are invaluable in guiding development in these areas. We work with local governments to accurately locate mines and interpret mine maps. We also respond to collapses in urban areas.

### **Abandoned Metal Mines**

There are more than 3800 abandoned metal mines in Washington. The mines were worked and abandoned before there was a requirement for reclamation and cleanup. Mine hazards include water quality degradation from high concentrations of heavy metals, and physical hazards such as vertical pits, caving shafts, and collapsing underground workings. These hazards have obvious liability problems for land owners, the public, and government. Other states have found that it only takes one accident to create a headline in every newspaper in the state.

We are currently cataloging and investigating these sites for the

Inventory of Inactive and Abandoned Mine Lands. The Division works closely with the U.S. Forest Service, BLM, and Ecology in cleanup because of our technical expertise and the extensive collection of reports and data about these mines in our library. We publish our findings on each mining district as the site investigation work is done.

### **GEOLOGIC MAPPING**

Geologic maps show the types and ages of rocks that occur at or near the Earth's surface. They show the locations of faults and folds, landslides, glacial deposits, and other regional or local features, depending on the scale of the map. Geologic maps are the most fundamental and important tool of earth scientists.

Most geologic mapping done by companies and universities is for a specific purpose and covers a small irregular area. Our job as the state survey is to produce maps that cover whole areas of the state at various scales. We compile mapping done by others and add our own mapping to complete the coverage.

Our geologic maps are used for a broad range of practical applications, including growth-management planning, transportation, dam safety, hazard and risk assessment, Puget Sound cleanup and restoration, water-resource appraisals, resource use and protection, education, recreation, and scientific research. Our work on Hood Canal is proving critical to solving the dissolved oxygen problem.

Virtually every Environmental Impact Statement (about 50 each year) begins with a geologic map. Without our maps, EIS originators would be required to generate their own information at significant cost.

Storm-water runoff mitigation in the West Plains area of Spokane was based on our geologic mapping, which discovered permeable rock into which storm water could be drained, thus preventing frequent flooding.

Our current mapping focuses on 7.5-minute quadrangles at a scale of 1:24,000. This work is partially supported by grants from the U.S. Geological Survey STATEMAP Program.

### **Subsurface Mapping**

Division geologists gather subsurface data to create maps and cross sections that can be used for ground-water resource planning and evaluation, aggregate resource evaluation, and earthquake and volcano hazards. For instance, our subsurface mapping of the Spokane aquifer was critical in planning new development to make the best use of available water. Subsurface mapping also aids in environmental cleanup.

### **Resource Mapping**

Washington has an \$800 million/year mineral industry that includes sand and gravel, crushed stone, metals, and industrial minerals, such as diatomite, clay, silica, and olivine. Industry uses our maps and publications, along with other reports from our library, to help find new resources.

The Division has done many mineral and other resource inventories. Recent emphasis has been on locating the aggregate resources needed for highway and infrastructure construction. We have produced aggregate resource maps that are useful for guiding zoning decisions and balanced resource planning at the local level. To date only about 10 percent of the state has been mapped for aggregate resources.

### **RESOURCE REGULATION**

#### **Surface Mine Reclamation**

There are about 1100 active surface mines in Washington, primarily sand and gravel operations. The Department of Natural Resources oversees surface mine reclamation. The Division monitors the operation of these mines to ensure current environmental protection and future beneficial use. Mines are often reclaimed for fish and wildlife, grazing, forestry, wetlands, and commercial and industrial uses.

The Division has produced a 'best management practices' manual for surface mining to educate miners in the art and science of reclamation, and also holds workshops and provides technical assistance to train miners on reclamation. Both of these efforts are aimed at reducing the cost to the State of cleaning up after badly managed mines.

Every other year, we document active mine site footprints using orthorectified air photos with permit boundary and disturbed acreage lines. This allows the history of each mine site to be tracked visually over time.

### Oil and Gas Regulation

The oil and gas regulatory program supervises exploration and drilling so that these activities are done in a manner that protects the environment and conserves resources, including ground-water resources.

About 600 oil and gas wells have been drilled in Washington, although there has been no large-scale commercial production. The gas storage project at Jackson Prairie in Lewis County has been the state's most beneficial oil and gas project. Jackson Prairie is the world's third-largest natural gas storage field and stores enough natural gas to provide uninterrupted supplies to our region.

### TECHNICAL SUPPORT

The expertise of the Division is often sought on various environmental issues. For example, the Division:

- ▮ Participated in a study of the effects of mining on the Yakima River. Partners in the project were Yakima County, the Yakama Tribe, and the Washington Departments of Ecology and Fish and Wildlife. The emphasis of the project was on salmon recovery and developing better mining methods.
- ▮ Has ongoing work in Puget Sound. For instance, we have assisted in environmental cleanups, including the Asarco smelter site and Elliott Bay.



The Geology Library can be a busy place. Many of the geologic reports in the collection cannot be found anywhere else. Photo by Karl Wegmann.

- ▮ Provides critical mapping and data for the Hood Canal Dissolved Oxygen Program to help restore Puget Sound.
- ▮ Assists the Emergency Management Division with planning for and responding to geologic disasters.
- ▮ Helps educate local government and citizens about beach erosion and effects of armoring coastlines.
- ▮ Assists the Department of Natural Resources in evaluating land-management practices, assessing land values for land trades or acquisitions, and identifying resources.
- ▮ Reviews State Environmental Protection Act (SEPA) and National Environmental Protection Act (NEPA) documents to ensure that geologic hazards and resources are considered.

### GEOLOGY LIBRARY

Geologic research is expensive and time-consuming. Fortunately, research reports retain their value and utility for many years, providing an economic return to society many times their original cost. To fully understand the geology of an area requires studies of its soils, surficial deposits, bedrock, stratigraphy, paleontology, mineralogy, geochemistry, geochronology, structural geology, hydrology, and geophysics (seismic, gravity, magnetic and other surveys), to name a few.

The Washington Geology Library has the state's largest collection about the geology of Washington, and more than 1000 items are added each year. Our librarian is knowledgeable and eager to help users find what they need. A full library catalog and geologic map index are available online.

The library has many unique and exhaustive collections. For example, the periodically updated U.S. Geological Survey topographic maps are invaluable for understanding river channel migration, landform changes, development patterns, and land use. We have the largest collection of Washington topographic maps held anywhere.

Master's theses and doctoral dissertations are important original sources of geologic information but are usually held only by the originating university. The library has copies of all of these works about Washington

geology—more than 2000 of them—from all universities, internationally.

As populations grow and land-use pressures increase, government and industry on all levels need quick access to geologic and geotechnical information to address growth-management issues and decide where to build roads and other public lifelines. The Growth Management Act's mandate to use the 'best available science' only increases this need. Our users often have very little time to do their studies and cannot afford to do original research. For them, time is money. They rely on existing reports, which they can find most efficiently through us. Their work would be much more difficult and expensive without ready access to our library.

### GOVERNMENT OUTREACH

Division cartographers and editors prepare the results of geologic mapping, earthquake, landslide, tsunami, and volcano research for publication in various formats, such as maps, road guides, and scientific papers.

The Division's website provides a wealth of information on the geology of Washington for a variety of audiences, including introductory information on many topics, geographic information system (GIS) data, forms, teacher resources, how-tos, and our new *Washington State Geologic Information Portal*. Interactive mapping sites are the most prominent features of the portal, designed to make geologic map data more accessible and allow the user to create, save, and print custom maps and find out more information about map features.

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