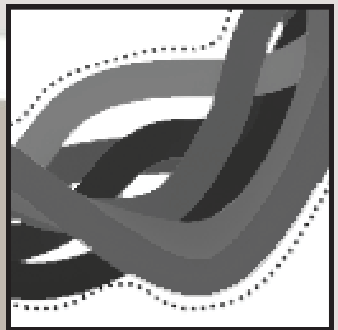


Living with the River

A Guide to Understanding Western Washington Rivers and Protecting Yourself from Floods

WASHINGTON STATE DEPARTMENT OF ECOLOGY

JUNE, 2007
PUBLICATION 07-06-016

LIVING WITH THE RIVER

A GUIDE TO UNDERSTANDING WESTERN WASHINGTON RIVERS AND PROTECTING YOURSELF FROM FLOODS

WASHINGTON STATE DEPARTMENT OF ECOLOGY
JUNE, 2007
PUBLICATION 07-06-016

Sponsored by:

SHORELINES & ENVIRONMENTAL ASSISTANCE PROGRAM
Washington Department of Ecology
Olympia

U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

Acknowledgments

The preparation of this booklet was made possible through funding and staff time from the Washington State Department of Ecology, Shorelines and Environmental Assistance Program and the Federal Emergency Management Agency.

The authors would like to acknowledge three people whose shared concept and technical review helped bring this publication to life: Dan Sokol (Washington State Department of Ecology, State Floodplain Manager), Patricia Olson (Washington State Department of Ecology, Hydrogeologist) and Lois Lopez (Federal Emergency Management Program Lead).

If you need this publication in an alternate format, please call Ecology's Shorelands and Environmental Assistance Program at 360-407-7000. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Important Notice

The contents of this publication are for general information and applications only and should not be construed as a substitute for site specific design and installation recommendations from professionals who are expert in geomorphology, hydrology or civil engineering practices. Accordingly, Washington Department of Ecology and the preparers of this booklet make no representation or warranty of any kind, whether expressed or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, material, or technique presented in this publication and assume no liability.

Booklet Author: Nancy Deschu
Graphic Design: Anne Walker

The recommended bibliographic citation for this publication is: Deschu, Nancy and Anne Walker. 2007. Living With the River: A Guide to Understanding Western Washington Rivers and Protecting Yourself from Floods. Shorelines and Environmental Assistance Program, Washington Department of Ecology, Olympia. Publication 07- 06-016

Contents

Introduction

Rivers carve through Western Washington from their headwaters in the Cascade and Olympic mountain ranges to Puget Sound, the Columbia River and the Pacific Ocean. Along the way these rivers are constantly shifting as they pick up rock, sediment and wood and then deposit it elsewhere. This is the inherent nature of a river, to balance its load of rock and sediment with its steepness and the volume of water it carries. This river balancing act is a fascinating process but that process is often hidden from our view in a world filled with buildings and roads.

In Western Washington we all live in a watershed. Maybe we do not live directly on a river, but we live in unique watersheds where the water in the area flows into rivers, lakes, groundwater and the sea. Those of us who live or work along a river may be more aware of seasonal pulses - the change in shape of the river over years and the dangers inherent when the river floods. But most of us don't think much about the workings of a river until a flood is upon us or has passed, leaving its wreckage behind.

Washington is one of the states most prone to flooding. Between 1956 and 2006, there were 32 floods in Washington that were declared Federal disasters by the President. Because of the extreme flood hazard in Washington, this booklet, "Living With the River", has been prepared for the public. The purpose of this booklet is to:

- Describe the behavior of rivers in Western Washington
- Describe land cover and land use in watersheds in Western Washington
- Assist you in conducting a flood hazard survey where you live or work
- Provide guidance on how to reduce your greatest flood hazards

It is our hope that this booklet will help you better protect your life and property from flooding in Western Washington.

A glossary of technical terms used in "Living With the River" can be found at the end of this booklet.

The Basics of River Behavior

NANCY DESCHU

A headwaters tributary to Nisqually River, Mount Rainier National Park.

"It has been said that streams are the gutters down which flow the ruins of the continents."

Leopold, Wolman and Miller, 1995.

Rivers are not isolated bands of water running through the landscape. They are complex systems that sit within a watershed. A watershed is the region that drains water from the surface of the land and from beneath the ground into a river system. There are vast and intricate connections between the river and its watershed.

What factors define a watershed?

Watersheds vary in size, underlying geology, steepness, elevation, rainfall, snowfall, soil type, vegetation type and aspect (the direction the watershed slope faces). All of these watershed factors contribute to the behavior of a river.

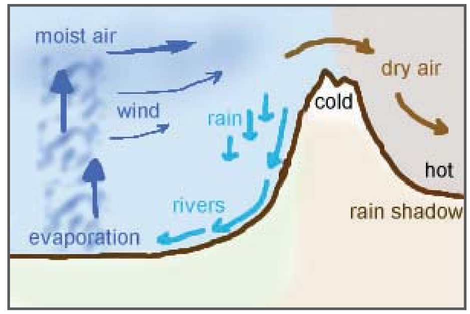
Watershed Size: The highest streams in a watershed are commonly referred to as 1st order streams. When a 1st order stream meets another stream, that is a 2nd order stream and now carries the combined water of both watersheds. This process of increasing order goes on until the river reaches the sea. By that time the watershed can be very large and carry a great volume of water. In Washington, for example, the Snohomish River is a 5th order river that encompasses 1,856 square miles.

Geology: There are 3 geologic factors that greatly influence a river: the type of rock the river must cut through as it moves downstream; the type of rock and sediment available to a river to transport downstream; and the degree to which water can percolate into the ground (permeability). For example, granite rock is impermeable whereas gravel, because of the many spaces around each stone, is a very permeable geological unit.

Steepness and Aspect: The steepness (or gradient) of a watershed affects the path and the shape a river takes as it flows downstream, always adjusting to the changing gradient of the landscape. The aspect of a watershed determines the angle at which sunlight hits the watershed. Aspect influences things like the intensity of sunlight, humidity near the ground, the development of soil, and the type of vegetation.

Elevation and Precipitation: The aspect of a watershed combined with its elevation affect whether precipitation falls as rain or snow. At colder, higher elevations precipitation usually falls as snow. Aspect and elevation also influence whether snow accumulates or melts and runs off quickly. In general, more precipitation falls on the windward side of a mountain range than the leeward side. In the Cascade Range, the west side of the mountains receive substantially more precipitation than the east side.

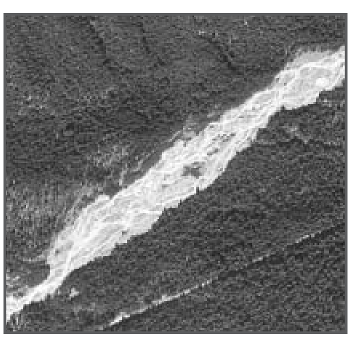
Glaciers: Glaciers form where snow continues to accumulate, compact, and eventually turn into glacial ice. As a glacier moves downslope it erodes the terrain, picking up rocks and grinding bedrock into fine sediment called glacial silt. Water from melting ice and water within the glacier carry the rocks and glacial flour and then release it into streams, rivers or the ocean. This load of rock and glacial silt makes glacial-fed rivers behave much differently than non-glacial rivers in the same region. Non-glacial rivers carry less sediment, run clear most of the year and have less sediment available to carry and deposit.



The effect of wind direction and mountains on precipitation.

Land Cover Type: If you look at a map of your entire watershed, from headwaters to the sea, you may find glaciers, scree slopes, alpine meadows, conifer forests,

Snohomish River near its mouth on North Puget Sound.



Aerial view of a braided channel.

hardwood forests, lowland meadows, coastal mudflats, forest clear-cuts, farmlands and urban development. All of these types of land cover and land uses affect how a watershed functions and how floods behave. For example, up to 50% of a year's precipitation in a forested area may be intercepted by and evaporate from the forest vegetation. Similarly, the forest floor with its spongy layer can absorb and hold rainfall. In contrast, parking lots and highways (known as impermeable surfaces) prevent water from naturally soaking into the ground.

What determines a river's behavior?

A river is always changing. As a river flows down its watershed it cuts through and dissolves the landscape. Along its course the river constantly picks up, carries and deposits rocks and sediments. These processes cause the shape and path of the channel to be in a constant state of change.

A floodplain is the relatively flat land that borders a river channel and is occasionally inundated. Floodplains are formed when the river deposits rock and sediment along its channel during high flow. So most of the year the river flows in its channel and the adjacent floodplain is dry. There might be thick vegetation on a floodplain, sometimes even large trees. Even so, the floodplain is there for the river to escape to, to release its powerful water when its flow is high. A river and its floodplain are forever inter-dependent.

If a river carries a heavy load of sediment and rock, as do glacial rivers for a good part of the year, the width of the floodplain can be very large. As a river moves down from the mountains to a wider and wider valley, the water slows down and drops its sediment and rock. On this shifting sediment floodplain, a river may cut and follow new channels as is the case in the lowlands west of the Cascade Range. A river is referred to as "braided" when there

Braided Channel

are many shifting channels in one broad floodplain.

In areas where there is unforgiving bedrock, the river may be forced to flow fast and deep in a narrow canyon. At these constricted points along a river, a traditional floodplain may not exist – instead the river's water rises in its canyon because it cannot spread out horizontally.

The degree to which a river meanders along its course is called its sinuosity. Sinuosity can become so great that the river makes extreme loops (oxbows). Eventually these loops may be cut off from the river, forming oxbow lakes in the broad floodplain.

When a swift flooding stream leaves a mountain canyon and opens into a wider area, the water will suddenly slow down and drop its heavy load of rock and sediment. A formation called an alluvial fan develops at the base of these types of canyons. (See "What Happens When a River Floods?")

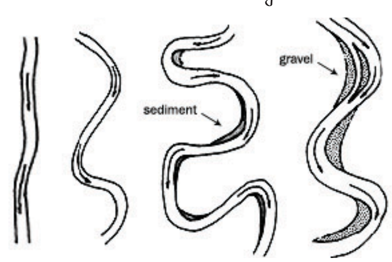
Nisqually River near its mouth on South Puget Sound.

Two Simple Hydrology Lessons

How much water does the river channel carry?

There are four interacting variables that are useful to learn if you want to understand the basics of river behavior: channel width, channel depth, water velocity (or speed) and volume of flow. Once you understand the relationship of these four components, you can observe a river with a new perspective. It's actually quite simple. At any point on a river:

The evolution of a meandering channel.



Channel Width (feet) x Channel Depth (feet) x Water Velocity (feet per second) = River Flow (cubic feet per second)


PHOTO COURTESY OF USGS

A hydrologist measures stream flow.

Measuring a river's width, depth and velocity is not always straightforward or easy to do. Depth may vary greatly across a river, width is sometimes hard to pinpoint if it is a shallow meandering river, and velocity is often a logistical challenge to measure. Field scientists follow specific methods and use specialized instruments to measure these variables. But for the person who just wants to observe a river over time, estimating these variables can help unravel some of the questions behind a river's behavior, especially during floods.

How much rock can the river carry?

The river's velocity and volume of water determines how large a particle or rock it can move. Other factors also affect movement including the incline of the riverbed and forces of friction. But for this general discussion, put simply, the faster the water, the larger the submerged rocks that can be moved. The inverse is also important to think about: the slower the water moves, the less it can carry and will therefore drop its load of rock and sediment, in some cases, very suddenly. Both swift moving rocks and suddenly dropped rocks can pose serious threats to life and property.


NANCY DESCHU

Headwaters of Nisqually River in Mount Rainier National Park.

What Happens When a River Floods?

Rivers flood for many reasons – extreme rainfall, rapid snowmelt, rain falling on snow, glacier or lake outbursts and tidal surge moving upriver. Most floods in Washington occur due to persistent heavy rainfalls, heavy rainfall on a snowpack and rapid snowmelt during very hot weather. In addition to these climatic factors, floods happen or are exacerbated by manmade alterations of a river's channel or floodplain.

Flooding can occur in the Western Cascades and the Olympic Range year round. In watersheds lower than 1,000 feet, precipitation is primarily rain and most of that falls in the winter months. Therefore floods caused by rain are more likely to occur in these lower elevations in winter. At elevations higher than 3,500 feet, the predominant precipitation in the winter is snow, so larger floods occur more often in the spring when snow melts during a period of hot weather or when spring rains hit the snowpack.

Flooding from rain is determined by more than just how much rain falls. The intensity of the rainfall is important. For example, a long drizzle may drop the same volume of rain as a short-lived severe storm but over a much longer period of time. When the ground and the river have more time to slowly receive and adjust, as they do during a long drizzle, the less likely there will be severe flooding.

A large amount of precipitation that falls does not directly run off to rivers. Instead it falls on vegetation and evaporates. Also rain and snowmelt is wicked up by plants and transpired to the atmosphere, absorbed and held by the soil, or passed through the soil where it moves slowly underground.

The condition of the ground affects how water reaches a river. If the ground is already saturated and cannot absorb more water, water quickly runs off to the river. Likewise, if the ground is frozen, water is less able to soak in

Aerial view of an alluvial fan, near Packwood.

and so more water runs off quickly to the river.

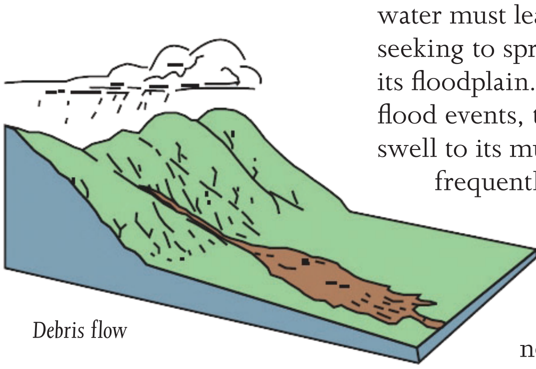
Rivers can carry a certain volume of water. Before a flood becomes widely apparent to the public, the river has already used its capacity to store additional flood waters. This floodwater storage can be in gravel, sand or other loosely consolidated material surrounding the channel. The water may also move into river banks and wetlands and ponds along the river where it is temporarily stored.

When the volume of water becomes so great that the river and its storage is full, the water must leave its channel, seeking to spread out over its floodplain. In extreme flood events, the river can swell to its much wider, less frequently used historic floodplain. The lateral movement of a channel across its floodplain is called channel migration.

At extreme flows a river can also widen and deepen its channel, jump to old channels and even cut new channels. While the river is carving new channel shapes, it is also picking up and dropping its heavy load of rock and sediment. During these high flows, channels can become filled with rock which can lead to damming and redirection of the river. The river is always working, even in extreme floods, to find its equilibrium between erosion and deposition of its load of rock and sediment.

Debris flows are extreme cases of floodwater carrying and depositing rock and sediment. When a hillslope becomes water-saturated and unstable, a mixture of water, earth and rock can move downslope, often very fast. A specific type of debris flow is an alluvial fan flood. This happens when a flooded stream carrying a heavy load of rock and sediment leaves a mountainous canyon and suddenly drops its huge load.

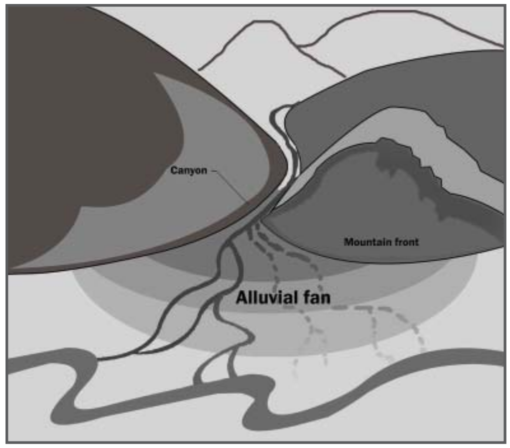
To the casual observer, an



GRAPHIC COURTESY OF USGS

Debris flow

alluvial fan might simply appear as a stream flowing out of the mountains on to a fan-shaped, gently sloping hill. Often there is vegetation, including large trees, making it difficult to identify an alluvial fan. But the landscape speaks the history of a stream that has raced down the canyon carrying tons and tons of mud and rock. Both debris flows and alluvial fan flows are not uncommon in Western Washington. Both are more difficult to predict than normal river flooding and both are extremely dangerous to people and structures in their paths.



NATIONAL ACADEMIES PRESS

Alluvial Fan

Trees can become part of a flood when riverbanks erode, new channels are cut, or when landslides or avalanches carry trees into the river channel. Although these downed trees can be hazardous during a flood, they are a natural and important part of a river system. The large root wads, when embedded into the river bed and bank, help stabilize the channel and work to capture rock and sediment. Embedded root wads and downed trees, in turn, provide nutrients to the river and help the river establish healthy fish habitat.

What are the Likely Effects of Climate Change on River Flooding in Western Washington?

It is predicted that climate warming in Western Washington will cause more autumn and winter precipitation to fall as rain rather than snow. This increased autumn and winter rainfall would produce higher river flows and result in increased flooding between October and March. In a


STEVE SUTTON

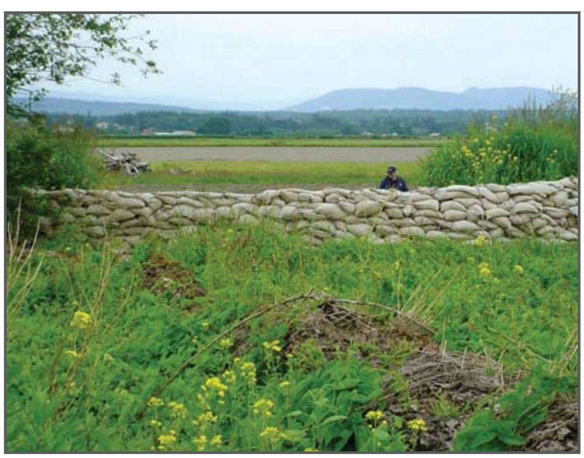
Nisqually River, downed trees, November 2006 flood.

normal temperature pattern, this winter snow would be stored in the mountains in snowpacks or glaciers, which would melt more slowly in springtime.

Another result of warming temperatures is that any existing mountain snow would melt earlier in the springtime and more of it would melt. This increased snowmelt would also contribute water to late winter and early springtime flooding. Faster melting combined with less snowfall would cause snowfields and glaciers to become noticeably smaller.

Warming temperatures could also cause glacier meltwater to pool at the foot of a glacier, forming a lake. As meltwater continues to accumulate in the lake, the lake could break through its wall causing an outburst flood, an often devastating event for people or structures downstream.

NANCY DESCHU



Stillaguamish River, sea dike emergency repair.

What are the Effects of Development in the Watershed?

In an ideal world, a river would have its broad natural floodplain where it could travel unimpeded, dropping its load of rock and sediment, constantly reshaping itself. But a naturally functioning river and floodplain are rare to find these days.

We have altered rivers and floodplains in many ways, sometimes unknowingly and sometimes knowingly with the intent to control flooding. Across the country, we have built all types of buildings and infrastructure in floodplains, even schools and hospitals. Parking lots, highways and roofs have prevented floodwater from slowly soaking into the ground. When there is less ground area to absorb water, rain and snowmelt are forced to find alternative ways to run to a river. This leads to tremendous amounts of rain and snowmelt flowing swiftly across the landscape, seeking a body of water.

Floodplains and rivers have also been altered by mining, agriculture and forest practices through the removal of native vegetation, changes to channel width and depth, changes to ground permeability and alterations to the storage capacity of floodplains.

Although many structures such as dikes, dams and levees have been built in watersheds to help prevent flood damage, often these structures fail. This can occur because the structures were originally under-designed or poorly designed; are old and not maintained; or do not function as expected. Another reason why flood control structures fail is that land use conditions upstream have changed, so now the river behaves very differently than when the structure was designed and built.

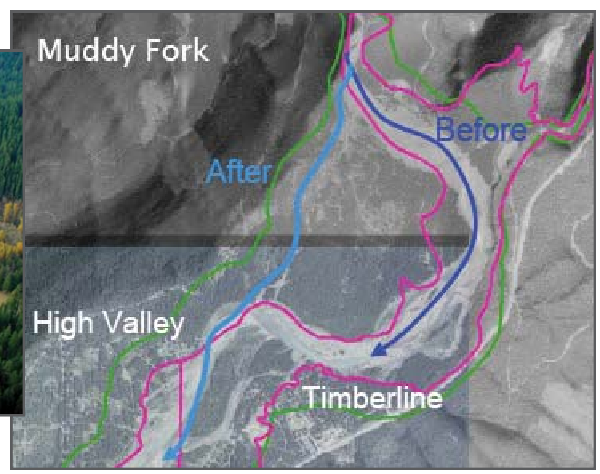
Rivers are powerful and tend to have their own way during a flood. There is little we can do beforehand to control the river's powerful path during an extreme flood event. Yet, we live and work in these watersheds throughout Western Washington. Though we can not reliably control a river's flood, we can plan ahead for our safety and protect the economic and ecological values of our rivers. Perhaps the most important rule, first and foremost: Avoid building in a flood hazard area.

Stories of Western Washington Flood Hazards

The Muddy Fork

The Muddy Fork begins in snowfields and glaciers on the southern flank of Mount Rainier. Along its 12-mile course, The Muddy Fork steeply descends 5,000 vertical feet to meet the Cowlitz River at a point 4 miles upstream of the town of Packwood. Because of its mountainous headwaters and glaciers, the Muddy Fork often carries tremendous loads of sediment and rock. Erosion, glacier-melting and sediment movement work to form the ever-shifting braided channels in the lower reach. In these braided areas the channel migration zone is very wide. The land cover in the Muddy Fork watershed is mostly dense forest.

In November, 2006 a severe storm caused flooding on the Muddy Fork. Near its confluence with the Cowlitz River, the Muddy Fork jumped west to an old channel where it last flowed in the 1930's. The new channel was cut 3 to 5 feet deeper than the old channel. When the rapid channel change occurred, the water sheared a wide corridor through the riparian forest. Downed trees washed into the new channel and became embedded in the newly deposited sediment.



Aerial views of the Muddy Fork-Cowlitz River confluence.

During the 2006 flood, riverfront land was eroded and houses were damaged at two small communities at the confluence of the Muddy and Cowlitz. As of December, 2006, the new Muddy Fork channel appeared to be relatively stable for now.

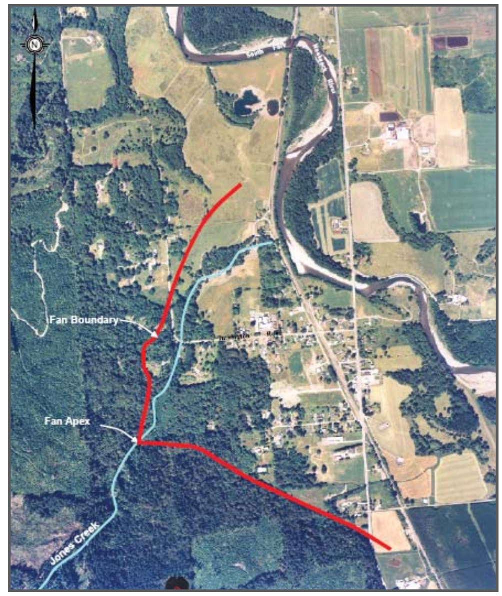
The braided channels at the confluence of the Muddy Fork and the Cowlitz River will always be shifting to some degree within the channel migration zone – this is the natural behavior of these types of rivers. The challenge to these communities is to find innovative and safe ways to live alongside such dynamic rivers.

Jones Creek Alluvial Fan

The South Fork of the Nooksack River begins in the mountains on the south side of Mount Baker in Whatcom County. The river flows over 70 miles east to Bellingham Bay. About 40 miles upstream from Bellingham Bay a small tributary, Jones Creek, steeply descends 2000 vertical feet. Jones Creek watershed is only 2.6 square miles but it is dynamic and dangerous.

The underlying rock in the Jones Creek watershed is brittle. It breaks easily and weathers quickly, making conditions in the watershed unstable. During severe storms, floodwater races down the steep canyon carrying rock, sediment and trees. When the creek exits the canyon, it opens on to a wider, more level area. At this point the raging floodwater suddenly slows down and drops its load. This area is the Jones Creek alluvial fan.

On occasion, landslides from unstable slopes along Jones Creek dam the creek. In this situation, water can back up and then break through as an outburst flood. Earthquakes can also cause rockfall and subsequent outburst flooding. Whether flooding is caused by severe rain storms, landslides or earthquakes,



Jones Creek alluvial fan zone (within triangle area) at South Fork Nooksack River.

the result can be the same – a violent and destructive event. Where there is weak rock, a canyon and a sudden opening like the conditions in the Jones Creek watershed, there is potential danger.

Unfortunately alluvial fan flooding is difficult to predict. When it happens, it occurs suddenly, often with no time for warning. The last significant debris flow on Jones Creek occurred in 1983. There are also accounts of smaller events in 1953 and 1990.

The natural conditions in the Jones Creek watershed make it a dangerous place. Climate change predictions- increased rainfall at lower elevations in Western Washington – will only make this already dangerous situation worse. Wetter conditions would increase the likelihood of landslides, rockfalls and flooding in watersheds like Jones Creek.

Ross Lake Dam, Upper Skagit River

The difficulty of predicting alluvial fan floods combined with the likelihood of increased landslides in the future make alluvial fans a great hazard in Western Washington.

There are currently 99 houses on the Jones Creek alluvial fan. The community lives with this hazard and is considering options of how to reduce their risk to a highly destructive alluvial fan flood that could occur in the future.

Skagit River

The Skagit River is one of the longest and most flood-dangerous rivers in the Pacific Northwest. The river begins in British Columbia and flows southwest from the Cascades Range for 163 miles to its fertile outwash plain at Skagit Bay. Except for its steep headwaters, the Skagit River has a low gradient, dropping only 1,600 feet over its long journey to the sea. The large watershed covers 3,140 square miles. In places, the lower Skagit River floodplain is over 20 miles wide.

The Lower Skagit River valley is a checkerboard of many land uses. The fertile lowlands provide some of the best farmland in the State. Urban towns, rural communities, major highways, a railroad line, wastewater plants, petroleum refineries and natural- gas pipelines can all be found in the Lower Skagit River valley. In the Upper Skagit watershed natural meadows, dense forests and glacier-fed tributary streams are predominant.

Since the mid-1800s, when settlers reached the Skagit River valley, people have worked to tame and direct the river and its flooding. Dams, sea dikes and levees were built over time and are now common throughout the watershed.

More than 110,000 people were living in Skagit County in 2006. Over 30% of the people live in the river's floodplain and the wide Skagit delta.

The Skagit has flooded more than 60 times in the past century. In October 2003, a flood crested at record levels in three communities, surging 14 feet above flood stage. Nearly 4,000 people had to evacuate their homes. Bridges, roads, and houses were damaged or destroyed. In November 2006, major flooding returned to the Skagit River and similarly caused severe damage and loss of life.

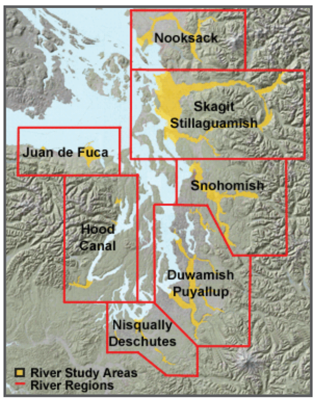
COURTESY OF SKAGIT COUNTY PUBLIC WORKS DEPARTMENT

Log Jam on the Skagit River near Sedrow Wooley, October 2003 flood

A 100-year flood event on the Skagit River would be dangerous and highly destructive. Interstate-5, railroads, water and power supplies and petroleum refineries could be damaged, leading to a shutdown of services. The economic impacts to the region would be severe. With this specter looming, Skagit County and local government officials are working to protect public facilities from future flood damage and educating the public about how to protect their homes and increase their personal safety.

Learning About Your Watershed and River

☑ Checklist



Historic imagery of Western Washington:
http://riverhistory.ess.washington.edu
Go to link: Data

Shoreline Aerial Photos
http://apps.ecy.wa.gov/shorephotos/

To understand flooding in your watershed and to identify flood hazards at your location, it is helpful to know: the type of land cover and land uses in your watershed; your location in relation to the river channel and floodplain; and the specific geologic and hydrologic features at your location. When you review your watershed information along with your site specific information, you will be able to make better decisions on how to reduce your risk from flood hazards.

There are four sources of information that may be very helpful before you begin your watershed and site investigation:

Local Government Maps: Your local government may have zoning maps outlining flood hazard zones and critical hazard areas (For more information on flood maps, see "Sources of Information on Floods and Floodplains"). Talk to your county engineer to learn about maps and data that may be available on flood hazards in your county.

Aerial photographs and satellite imagery: A series of images taken over decades can provide great information about your watershed and the changes that have taken place over time. You may observe features such as the historic natural meanders of the river; rock flow onto an alluvial fan; the effects of reservoir construction; new areas of pavement or buildings in the floodplain; and changes in channel patterns after construction of flood control structures. Some historic imagery of Western Washington watersheds is available at University of Washington's Puget Sound River History Project: *http://riverhistory.ess.washington.edu*

Technical Studies: Local, State or Federal governments may have conducted flood or debris flow studies in your area. Although you may not find a hazard zone drawn on a government map, you may be able to gather useful flood hazard information about your location from a flood or debris flow technical study. (See "Sources of Information on Floods and Floodplains".)

Locals' Knowledge: Long-time residents whose families have been in an area for generations can often provide good local information on historic flood height, river behavior during flood events, riverbank stability, and debris flow hazards.

Explore your neighborhood: Take a walk and get a sense of the local topography and vegetation. Take notes on the location of streams, wetlands and ponds; where mountains and rolling hills are in relation to your neighborhood; if there are rocky cliffs nearby; and the names of topographic features that may tell you something about the natural history and topographic features of your surroundings (for example, Canyon Creek).

You can visit websites to learn about your watershed. Aerial photographs, topographic maps and watershed information are available at:

EPA, "Surf Your Watershed"
http://www.epa.gov/surf

USGS, "Science in Your Watershed"
http://water.usgs.gov/wsc/map_index.html

Coastal Atlas:
http://www.ecy.wa.gov/programs/sea/sma/atlas_home.html

TerraServer:
http://terraserver.microsoft.com

Microsoft Live (oblique aerial photographs):
http://maps.live.com

USGS Geospatial data Layers:
http://seamless.usgs.gov

☑ Investigate Your Watershed

- ☐ Determine the boundary of your watershed. You may find a map of your watershed on a local, State or Federal government website that covers your area. An alternative is to use a USGS topographic map and outline your watershed.

- ☐ Determine what types of land cover and land use are in your watershed. (For example: glacier, rocky mountain slope, forest, meadow, clear-cut, gravel mining, farmland, urban development.) A Washington land cover and land use map can be found online at: *http://wdfw.wa.gov/wlm/gap/landcov.htm*

- ☐ Determine how much of your watershed is in a relatively natural condition versus how much is developed or disturbed. Information on changes in land use is available for most areas west of the Cascade Range on the Washington Department of Ecology: *http://www.ecy.wa.gov/programs/sea/sma/atlas_home.html*

- ☐ Determine what river-control structures have been built in your watershed. (For example: dikes, levees, dams, floodwalls, channels hardened by concrete, reservoirs, water diversions) Determine what control structures located in your immediate vicinity may affect your section of the river.

- ☐ Pinpoint on the watershed map where your home or business is located.

☑ Investigate the Geologic and Hydrologic Features at Your Location

Are you in an area where there may be a river flood hazard?

- ☐ Is there a flowing river within a quarter mile?
  Observations: ____________________________
  ____

- ☐ If you walk from the river towards your home or worksite, is there much change in elevation? Is it noticeably flat or do you sometimes climb uphill?
  Observations: ____________________________
  ____

- ☐ If you walk from the river towards your home or worksite, do you cross wetlands, swales, or old, overgrown river channels?
  Observations: ____________________________
  ____

- ☐ Does ice form in the river in winter? Have you seen ice on the river sometimes break-up, pile up and back up the river's flow?
  Observations: ____________________________
  ____

- ☐ When you dig in the upper layer of your ground, what material do you find? Well-formed organic soil? Or mainly sand, silt, gravel and cobbles?
  Observations: ____________________________
  ____

☐ Is there a gravel mining pit nearby in a river's floodplain?
Observations: ____________________________
____

☐ How deep must you drill to reach the water table?
Observations: ____________________________
____

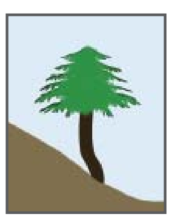
Are you in an area where there may be a debris flow or alluvial fan hazard?

☐ Do you see mountain foothills, a canyon, a narrow valley or a steep slope close by when you look around the property?
Observations: ____________________________
____

☐ Is there a fan-shaped, low-lying hill that sits at the base of the canyon or narrow valley?
Observations: ____________________________
____

☐ Are there large boulders scattered amongst trees nearby?
Observations: ____________________________
____

☐ Are there trees on the hill-slope that may have been crushed by rockfalls or rock-slides in the past? Are there trees that are growing at a leaning angle? Are there trees growing with a noticeable angle in their trunk?
Observations: ____________
____
____



☐ When you dig a garden or dig a post hole, do you encounter a lot of gravel and larger rounded cobble rock near the surface?
Observations: ____________________________
____

☐ Do you see large rounded rocks in road-cuts nearby?
Observations: ____________________________
____

☐ Is there a gravel mining pit in the area located near the base of a narrow mountain valley or canyon?
Observations: ____________________________
____

After you have gathered general information about your watershed and specific information about your location, some answers about the type and degree of flood hazard may become clear to you. An important final step to understand your flood hazards is to hire a professional geologist, geomorphologist or hydrologist. Professionals in these fields can look at maps, aerial photographs, technical reports and then walk the property with you to identify and discuss your flood hazards.

With this background information you can now plan carefully whether you should build or live in the area. If you already have a home or building in the area, you can still benefit greatly from gathering accurate watershed and local site information so you can reduce your risks to flood and river erosion hazards.

Sources of Information on Floods and Floodplains

MARVIN NAUMAN - FEMA

Drawing Boundaries of the Floodplain

The word "floodplain" is used in different ways by different groups of people. To a hydrologist, floodplain refers to the extent of the lowland along a river that periodically floods within a given frequency of time. This definition is based on river science and statistics. A hydrologist uses this numerical approach to delineate a floodplain boundary.

Local, State and Federal regulatory agencies may define a floodplain from the viewpoint of zoning and managing the growth of their community. Science and statistical definitions of floodplain may be adopted by regulatory agencies to determine a "regulatory floodplain" but the two types of floodplain definitions are not necessarily the same. A regulatory floodplain is often not as wide as the river's known natural floodplain. For example, science may numerically define a very broad 500-year floodplain (0.2% chance of flooding in any year), however, a local government may designate a regulatory floodplain for development that is much narrower.

Structural versus Non-Structural Flood Control

Society has historically tackled flood control by building structures with the intent to direct and tame the river. Levees, dams, reservoirs, dikes, floodwalls, and riprapping riverbanks are a few examples. These structures sometimes fail, causing a loss of life and property. The economic costs of failed flood control structures can be enormous to local, State and Federal taxpayers. More recently the environmental damages to rivers and floodplains from these structures have become apparent, as have the costs related to health, safety and a community's quality of life.

Because of the great economic and environmental costs of failed flood control structures, society is now moving towards ways of reducing the likelihood of flood damage through other approaches - better community planning, zoning and public education. These planning, zoning and educational approaches are called "non-structural".

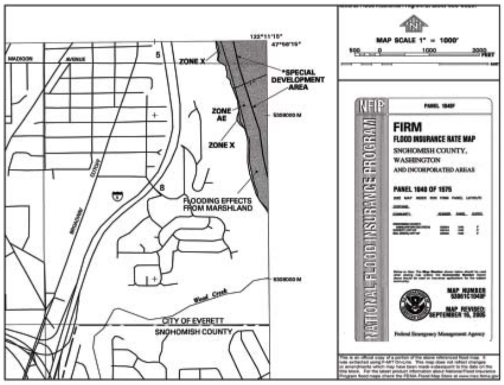
Examples of non-structural approaches to reduce the risk of flood damage include:

- Regulations to prevent new development in the floodplain
- Elevation of buildings that already exist in the floodplain
- Relocation of houses out of flood prone areas
- Government purchase of houses in dangerous flood prone areas
- Restoration of riverine wetlands to increase floodwater storage capacity
- Control and detention of stormwater runoff from developed areas
- Preservation of open space that supports natural river functions
- Stricter zoning and building codes for new subdivisions
- Education programs for all community members on how to reduce flood hazards

Floodplain maps are produced by several government agencies. Some of these maps are geomorphic floodplain maps showing the full natural range of the floodplain while others are "regulatory floodplain" maps that are generally narrower than the natural floodplain delineation.

> One of the most important things you can do to reduce your flood risk is to learn about your local and State floodplain programs. Listed below are sources of information on floodplain policies and regulations. Learning about these programs may save you a lot of money and heartache in the long run.

A type of floodplain map is the **Flood Insurance Rate Map (FIRM)**. FIRMs de-



Example of a Flood Insurance Rate Map.

lineate flood hazards including the Special Flood Hazard Areas. A Special Flood Hazard Area is an area where there is a 1-in-100 chance that a certain size flood will occur in any year. (This type of flood is also referred to as the 100-year flood or the 1% flood). A **Flood Insurance Study** is produced along with each Flood Insurance Rate Map. The study contains information about flood history in a community and the engineering methods used to produce the flood map.

FIRMs and Flood Insurance Studies are produced by the Federal Emergency Management Agency (FEMA) **National Flood Insurance Program (NFIP)**. The NFIP sells flood insurance to property owners in 20,000 communities in the U.S. who have adopted State and local floodplain management regulations. If your community participates in this program, FIRMs can be found on the web at FEMA's Map Service Center (*http://msc.fema.gov*) and at your county's floodplain management office. Some towns and counties, such as King County, produce their own detailed flood hazard maps which in turn are used by the Federal government to update the FIRMs for that county.

Because homeowners' insurance does not cover damage from floods, National Flood Insurance is essential to protect property in flood prone areas. Anyone at the slightest risk of flooding should purchase NFIP insurance. Information on NFIP can be

A Note About Flood Map Accuracy:

Check the date when the flood map for your area was produced. Some maps may be decades old and produced with primitive technology compared to what is available today. There may be much better information now which could change flood predictions in your area. Significant land cover and land use changes may have occurred since your watershed was mapped - more highways and parking lots paved, new river control structures built, forest lands cleared. In addition to substantial land use changes that have occurred over decades, warming temperatures associated with climate change can affect the behavior of rivers. As discussed in the section "What Happens When a River Floods", warming temperatures will likely increase the already heavy rainfall and frequent wintertime flooding in Western Washington.

found at FloodSmart.gov or at Washington State Department of Ecology regional offices that serve your area (*http://www.ecy.wa.gov*).

Channel Migration Zone (CZM) Maps depict the area within which a river is likely to move horizontally over a defined period of time. In some rivers this can be a very wide distance, in other rivers that are more constricted by adjacent landforms, the migration zone may be relatively narrow. Channel migration zones are determined through field studies and study of aerial photography and satellite images taken over decades. Studies suggest images of a river over the past 100 years can provide a meaningful picture of a river's CMZ.

As of 2004, seven counties in Washington have been actively determining and mapping channel migration zones. In 1999, King County enacted a Public Rule to regulate land use where CMZ maps have been completed. As of 2005, King County had mapped 49 river miles of CZMs. In those 49 miles alone, there were 389 structures, with a total assessed value of $179,228,513 (2006 King County Flood Hazard Management Plan).

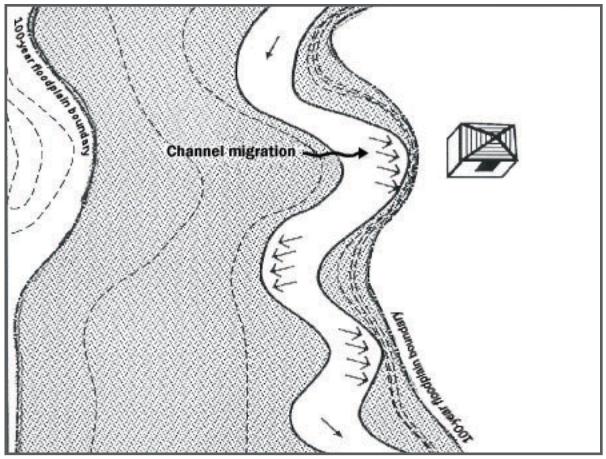


Diagram of a channel migration towards the 100-year floodplain boundary (courtesy King County)

Communities and tribes can chose to participate in a flood-prevention program called the **Community Rating System (CRS)**. The community adopts practices and activities that go beyond the minimum requirements of the National Flood Insurance Program. There are four types of activities under which a community can receive CRS credits: mapping and regulations; flood damage reduction; public information; and flood preparedness. Examples of activities where credit might be awarded to a community include acquisition of flood prone buildings and strict zoning regulations for flood hazard areas.

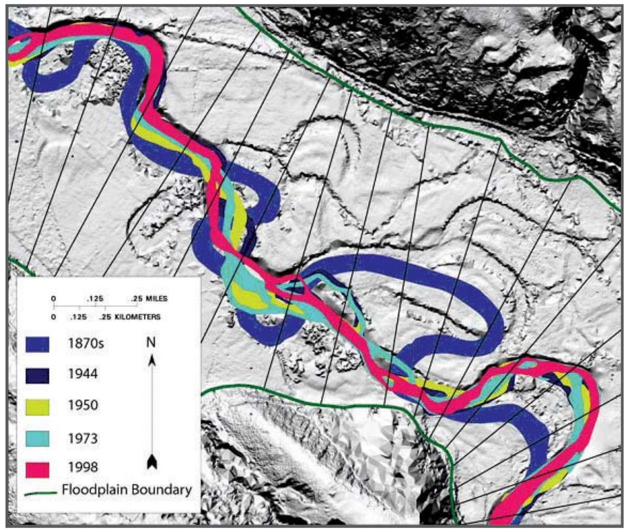
A community is assigned to one of 10 classes based on their type and level of flood-prevention activities. The more a community demonstrates good practices, the higher the class rating they are assigned. Each time a community rises in its classification, there is a 5% reduction in flood insurance rates for policy holders in that jurisdiction. In 2005 King County and Pierce County received two of the highest ratings in the nation. The rating for King County will be upgraded even further to Class 2 in 2007. The Lower Elwah Tribe is one of two tribes in the nation who actively participate in the Community Rating System.

Hazard Mitigation Plans are written by local, State and Tribal governments to describe all the types of hazards, including floods, in their areas. The plans also describe the risk of the hazards and strategies to reduce the risks through community planning and projects. The intention of hazard mitigation planning is to break the cycle of repeated damages in the same area or to the same structures. The State of Washington has a Hazard Mitigation Plan which is updated every three years. Your county or local community may have a specific hazard mitigation plan for your area. It is important to have an updated hazard mitigation plan to qualify for certain types of mitigation grants.

Comprehensive Flood Hazard Management Plans are prepared by local and Tribal governments in Washington. These plans describe in detail the flood threats to the community and how the community could prevent flood damage. Public participation in the development of the plan is required by law. The plan must address certain topics including: local topography and hydrology related to flooding; history of flooding in the area; current flood problems; alternatives for reducing flood effects; environmental impacts of the alternatives; and a priority for recommended actions. A community or tribe is required to have a Comprehensive Flood Hazard Management Plan to be eligible to apply for flood control assistance grants through the Washington State Department of Ecology.

The **Washington Shoreline Management Act** was passed in 1971 to prevent "harm associated with an uncoordinated, piecemeal development of the State's shorelines" (*http://www.dnr.wa.gov/htdocs/aqr/shoreline/index.html*). This Act directs local communities to develop plans for all their shorelines, including shorelines of navigable rivers. These plans are reviewed by the Washington Department of Ecology.

Two directives of the Shoreline Management Act are particularly applicable to river shorelines and floodplains: 1) ensure environmental protection and 2) foster water-dependent uses. Protection of floodplains from unregulated development is one way to ensure environmental protection. Recognizing floodplains as vital areas for floodwater storage and for river channel migration is an example of water-dependent uses.



GRAPHIC ADAPTED FROM JIM O'CONNOR

Channel migration over 120 years, Quinault River, Olympic Peninsula.

The Shoreline Management Act also requires communities to generally define the channel migration zone in their area and defines activities that are not allowed in the zone.

The **Washington State Growth Management Act** was passed in 1990 to increase local planning and to address regional planning issues as the State's population rapidly increases. The Act was amended in 1995 to require protection of "critical areas". Critical areas include: designated fish and wildlife habitat; wetlands; hazardous geologic areas; aquifer recharge areas; and frequently-flooded areas. When the Growth Management Act listed "frequently-flooded areas" as a type of critical area, the Act recognized that protecting floodplains and managing growth are important ways to reduce flood damages.

Sometimes when one type of critical area is protected, such as stream buffers for fish habitat, frequently-flooded areas are also protected. In many cases local ordinances also serve to protect these same critical areas.

County and municipal zoning and floodplain codes are in effect for Washington's 39 counties and for 143 municipalities in the State. These codes set regulations for activities such as building and construction; subdivision allowances and restrictions; special flood hazard areas; setback requirements; and riparian landscaping. These county and municipal codes can be found on the web at the Municipal Research and Services Center for Washington (*http://www.mrsc.org/codes.aspx#county*).

The **International Building Code (IBC)**, published in 2000, has been adopted by all Washington State communities. Part of the code strives to reduce flood damage to buildings by integrating building design, building safety and floodplain management. The International

COURTESY OF SEATTLE MUNICIPAL ARCHIVES

Aerial view of the Skagit River near Concrete, showing a patchwork of land cover and land use.

Building Codes Council, the American Society of Civil Engineers and the Federal Emergency Management Agency worked cooperatively on these flooding provisions to help communities meet floodplain management regulations as required by the National Flood Insurance Program.

The Washington Shoreline Management Act, passed in 1971, can be found on the Washington Department of Ecology website. Sections of the Act and its amendments have requirements specific to rivers and streams:

Critical Areas: Requires that Critical Areas, which includes aquatic habitat, will be managed and provided a level of protection *WAC 173-26-221(2)*

Flood Hazard Reduction: Limits development that would affect channel migration zones; describes specific flood hazard prevention; generally prohibits new dikes and levees in channel migration zone *WAC 173-26-221(3)*

Shoreline Modifications: Requires that fill design and location be placed so as to protect ecological functions of the shoreline; requires a conditional use permit for disposal of dredge material within channel migration zone; requires a conditional use permit for mining in the channel migration zone *WAC 173-26-231(3) and WAC 173-26-241(3)*

How to Reduce Your Flood Hazard Risk

Many people innocently buy, build or rent structures that are located in flood prone areas, not aware of the flood hazard around them.

If you decide to buy, build or rent a structure, remember these five important rules:

1. Learn about the flood hazards and flood history in your area
2. Stay out of the currently defined flood hazard area
3. Elevate the structure off the ground
4. Build with a flood-proofing design and materials
5. Consider how climate change may affect your watershed in the future

If you already own a building in a flood prone area, there are still ways to reduce your flood hazard. Some of the following practices may be part of your municipal or county codes.

Elevate

Raising a building so that the lowest floor is above the typical flood level is a good way to reduce flood risk. The building may still flood in extreme events but much less so than before it was elevated. Learn the characteristics of typical floods in your area before you elevate a building. Important flood characteristics to understand include: how often flooding occurs; the depth and velocity of floodwaters; how fast floodwaters rise and fall; and the type of debris that might be carried by the flood. Ask yourself if you want to elevate your building to protect against the 1-in-100 chance flood, 1-in-500 chance flood, or some other level of flooding. Once you have weighed these factors, discuss your options with your local building authorities and licensed contractor.

Relocate

Moving your house or building out of the flood hazard area provides the greatest protection from flooding. It is, however, one of the most expensive options. If you are planning to move a building, you need to evaluate its size, shape and its condition; routes available for the move; natural hazards at the new location; public utility connections at the new site; local zoning ordinances; and what work is needed to restore the old site to meet your local regulations.

Demolish and Rebuild

Demolition is sometimes the best and easiest option when a building has been severely damaged by floods. If the house is in the regulatory floodplain, trying to salvage it can be an expensive and complicated process. Rebuilding a new flood-safe building on the same property is one option. The better option, though more expensive, is to rebuild on a different, more flood-safe property.

Land and Vegetation Management

Flood risk can be reduced through careful land management. If you remove impervious ground cover, such as asphalt and concrete, the natural ground will become available to absorb floodwater. Restoration of wetlands that were damaged or destroyed during building construction is another way to reduce flood risk. Wetland vegetation and soils have the ability to absorb and hold water. Restoration of wetland plants and native, hardy vegetation can also slow the velocity of floodwaters and act to capture debris that is moving with the floodwater.

Build Small Flood-Protection Structures

Small flood-protection structures on a property, if properly designed and built, can reduce flood risk. These small structures can redirect floodwater and increase storage capacity. Examples of small flood-protection structures include: water detention ponds; diversion-walls around a building; and drainage paths and culverts to guide floodwaters around and away from buildings. Check with your municipal and county code officials before building any of these small structures in to learn about any restrictions.

Elevate

Relocate

Demolish

Rebuild

Anchor Moveable Objects

Floodwaters can lift and carry objects such as fuel tanks, storage sheds, playground equipment and trailers. Securing these objects is important not only to save the object but to prevent the object from ramming walls and causing severe building damage. A fuel spill is another possible hazard when an unanchored fuel tank is knocked over or shifted by a flood. Even a buried fuel tank can be pushed to the surface by the buoyant effect of saturated soil. A moveable object can be anchored by attaching it to a large concrete slab or by running metal straps over the object and attaching the straps to ground anchors.

Remodel with Flood Resistant Materials

You can reduce flood damage and make flood cleanup easier by using flood-resistant building materials when you remodel or put an addition on your building. Building materials are considered flood-resistant if they can withstand direct contact with flood waters for at least 72 hours without being significantly damaged. Flood-resistant materials can be used for walls, floors and other parts of a building. Commonly available flood-resistant materials include: ceramic tile, clay tile, terrazzo tile, vinyl tile, rubber tile, concrete, brick, glass block, stone, pressure-treated wood, marine grade plywood, naturally decay-resistant lumber, cement board, foam insulation and metal doors.

Flood-proof the Building

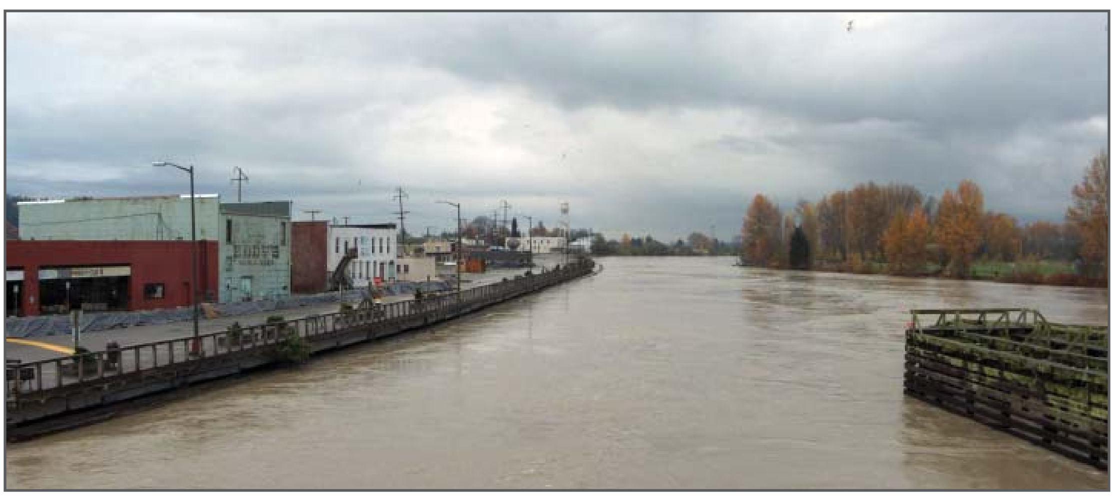
One way to protect a building and its contents from flood damage is to seal the building so that floodwater cannot enter. Examples of flood-proofing measures include: application of a waterproof coating or membrane to the exterior walls of a building; installation of watertight shields over doors, windows, and other openings; installation of a sump pump and foundation drain system; and strengthening walls so they can withstand the pressures of floodwaters and impacts of rocks, trees and building debris entrained in the flood.

Raise Electrical Units

Electrical, heating, ventilation, plumbing and air conditioning units and wiring can be damaged or destroyed if they are inundated even for a short time. There is also a fire danger associated with short circuits in flooded electrical systems. Elevating electrical components at least 1 foot above the 1-in-100-chance flood level will significantly reduce your flood hazard. An added benefit to raising electrical units is that they might still function immediately after a flood, helping you to recover from other flood damages on your property. A less effective way of protecting electrical components is to leave the unit in place and build a floodwall with waterproof-membrane around the unit.

Install Sewer Backflow Valves

Flooding can cause sewage to back up through a building's drain pipes and flow into the building. In addition to being a source of flood damage, sewage backup is also a serious health hazard. One way to protect your house or business from sewage backup is to install backflow valves. These valves are designed to block drain pipes temporarily, preventing



JOSEF KUNZLER

Skagit River at floodstage, Mount Vernon, November 2006.

flow into the building. There are several types of backflow valves on the market.

Protect Wells from Contamination

Floodwater often carries contaminants like sewage, animal waste, gasoline, and pesticides. A well can become contaminated by floodwater and these effects can last long after the flood has receded. A licensed well-drilling contractor can inspect your well and suggest ways to reduce the possibility of well contamination during floods. These changes might include: extending the well casing above the highest known flood elevation; surrounding the well casing at ground level with a watertight seal; placing grout between the casing and the sides of the bore hole; installing a backflow valve in the water line; protecting well-pump electrical controls from flood water; or drilling a new well on higher ground.

Build Flood Passageways

Flood passageways are features that are intentionally built to allow floodwaters to pass through uninhabited areas of a building. When floodwaters are allowed to pass, pressure on the vertical surfaces of the building is released and the building is more likely to remain standing. Openings equipped with screens, louvers, breakaway walls, latticework or trellises on the ground level are examples of passageways where floodwaters can automatically enter and exit.

Summary

Rivers are in a constant state of change. Their powerful waters are always seeking balance - adjusting steepness, changing width and depth, picking up and dropping rock and sediment, reshaping their channels and floodplains. The intent of this booklet, "Living With the River", is to raise awareness about river behavior in Western Washington and to provide ideas on how to protect your property and yourself from the damaging effects of floods.


NANCY DESCHU

Lower Elwah River on north end of Olympic Peninsula.

Learn About Your Watershed and River

An important step to reducing your flood hazard and increasing your personal safety is to learn about your watershed, the nearby river and your location within the watershed. There are a few basic hydrology concepts that can help make your river a more familiar, interesting and perhaps, more predictable, place. Understanding river behavior and potential flooding can help you prepare your land and buildings before a flood someday races through your area.

Conduct a Flood Hazard Inventory of Your Land and Buildings

It is fairly easy to gather information that can help you understand the flood hazards in your watershed and the more specific hazards near your land and buildings. After gathering this information, you may choose to consult with a professional geologist, geomorphologist or hydrologist to expand or interpret this flood hazard information.

Learn About Programs Available to Help Reduce Flood Risk

There are several local, State and Federal flood programs that provide guidance and sometimes funding to help you reduce your flood hazards. After you have conducted your personal flood hazard inventory, you can then look into these government programs that may be able to help you carry out your plans for flood protection.

Act to Reduce Your Flood Risk

Once you have all your background information gathered, it is time to take action to reduce your risk to flood hazards. Your local zoning and code officials can provide useful information as you begin your work. If you engage contractors, be sure they are licensed and reputable.

The most important rule to follow to reduce your risk of flood damage is simple: stay out of flood prone areas. If you are already in a flood prone area, there are still many ways to reduce the likelihood that you will face serious damages from flooding.

It makes sense to reduce your risk to flooding. The next time a flood comes your way your building and property will be less vulnerable to damage and, importantly, you will be safer from the harm of destructive flooding.

Glossary

Alluvial fan:
A fan-shaped deposit of rock and sediment that forms at the base of a mountain range when a fast mountain stream flows out of the mountains to a less steep valley slope and suddenly slows, spreads out and drops its load; if two or more alluvial fans begin to overlap, it is referred to as a compound alluvial fan

Aspect:
The direction which a mountain slope faces

Braided river:
A river made of a network of small constantly shifting channels that are separated by shoals, bars and islands; braided streams commonly occur where a valley gradient significantly decreases and the river deposits its sediment load

Channel migration:
The lateral movement of a river channel within a valley due to the continual process of land and channel erosion and deposition of sediment and rock

Channel migration zone (CMZ):
The area within which a river channel moves laterally over time

Channel capacity:
The maximum flow of water that a channel is capable of carrying before its banks are overtopped

Debris flow:
A mixture of water-saturated earth that flows downslope, often very rapidly; debris flows can be destructive to buildings and deadly to people in the flow path

Evaporation:
The process of water moving from a liquid to a vapor state; evaporation includes vaporization from water body surfaces, land surfaces, and snow fields; "evaporation" does not include the vaporization of water released from the surface of vegetation (see "transpiration")

Floodplain:
The relatively flat lowland that borders a river, stream or lake (formed under the current climate regime) which is usually dry but is subject to flooding; the sediment and rock materials on a floodplain are actually deposits from earlier floods

Geomorphologist:
A person who studies the topography, geology and geologic features of the surface of the Earth

Gradient:
A measure of the slope of the water surface of a river per unit distance; usually measured as a ratio of feet of change in water slope over feet of change of river length from a point upstream to a point downstream

Groundwater:
Water that is located beneath ground in soil pore spaces, among pebbles, cobbles and boulders, and in fractures of geologic formations

Headwaters:
The source (or sources) of a river or stream; headwater sources include lakes, springs, wetlands, glaciers or groundwater seeps

Historic floodplain:
The full width of a river's lateral movement over geologic time

Hydrologist:
A scientist who studies the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere

Land Cover:
That which physically covers the surface of the earth at a specific place; forests, glaciers, water surfaces, sandy beaches, irrigated croplands and major asphalt highways are examples of land cover; land cover is determined through field surveys and analysis of remote sensing imagery

Land Use:
A description of how people utilize land and the socio-economic activity associated with how they utilize it; urban housing and agriculture are two common land uses

Mitigation:
Actions taken to reduce or eliminate the risk of a hazard such as flooding; mitigation actions attempt to prevent flood hazards from developing into disasters, or to reduce the effects of flooding when it occurs

Meandering river:
A river with distinct series of alternating bends that forms a snaking pattern as it flows through a wide valley or flat plain; the formation and the shape of the bends in a meandering stream are a result of erosion and deposition of sediment and rock

Oxbow lake:
The type of lake that is formed when a wide river meander is cut off from the main flow of the river

Outburst flood:
An abrupt, and often tremendous, release of water from a river or lake that has been blocked by a glacier, landslide, logjam, moraine or similar feature (also know as outbreak flood)

Permeability
The ability of geologic material to transmit water

Porosity:
The ratio, expressed as a fraction or percentage, of the volume of the void spaces (pores) of a material (such as a rock, soil layer or sedimentary stratum) to the total volume of its mass

Riparian zone:
The interface between the land and a body of flowing surface water; vegetation along these river margins is referred to as riparian vegetation

Riprap:
A pile or layer of stones intended to prevent erosion, scour, or sloughing of an embankment, in efforts to protect or stabilize a structure

Risk:
The identification of a hazard and the mathematical analysis of the chances of that hazard occurring

Runoff:
Water from rainfall or melting snow that flows across the surface of the ground but does not infiltrate into the ground

Scree:
Loose rock covering a slope, commonly found at the base of a cliff or steep incline

Sediment:
Particulate that is transported by flowing water and may be deposited on the riverbed during low flows and re-suspended in higher flows

Sinuosity:
A measure of the degree of meandering of a river; it is calculated as the ratio of the length of a river to the length of the river valley through which it flows

Transpiration:
The process where water absorbed by a plant (usually through its roots) is evaporated into the atmosphere from the surface of the plant; in plants with leaves, transpiration occurs through pores in the leaves

Topography:
The shape of the surface of an area of land including its relief and positions of natural and manmade features

Watershed:
A region of land, separated from adjacent basins by a ridge or mountain, that captures rain, snowmelt and glacier-melt and feeds it to a particular river; a watershed also includes the underground area that feeds groundwater to the river; a groundwater watershed, however, may differ in surface area from the surface-water watershed that feeds the same river

Recommended Reading

Association of State Floodplain Managers and Interagency Floodplain Management Taskforce. 1996. Addressing your Community's Flood Problems: A Guide for Elected Officials. Prepared by The Floodplain Management Group, J. Wright, Knoxville, TN 54 pp

Department of Ecology, State of Washington. March 2004. Floodplain Management in the State of Washington. Publication # 04-06-016. 12 pp Available at *http://www.ecy.wa.gov/pubs.shtm*

Federal Emergency Management Agency. Floodplain Management: The National Flood Insurance Program. Available at *http://online.fema.net/fima.htm*

Federal Emergency Management Agency. State and Local Mitigation Planning: Building Stronger and Safer. Available at *http://online.fema.net/fima.htm*

Gori, P., C. Driedger and S. Randall. U.S. Geological Survey. 1999. Learning to Live with Geologic and Hydrologic Hazards. WRI Report 99-4182. 4pp Available at http: wa.water.usgs.gov

Kresch, D. and K. Dinicola, U.S. Geological Survey. 1996. What Causes Floods in Washington State? Fact Sheet 228-96. 2 pp Available at *http://wa.water.usgs.gov*

Leopold, L. B. 1994. A View of the River. Harvard University Press, Cambridge, MA, 298 pp

Leopold, L.B., G. Wolman and J.P. Miller. 1995. Fluvial Processes in Geomorphology. Dover Publications, Inc., New York. 522 pp

Rapp, C.F. and T.B. Abbe. 2003. A Framework for Delineating Channel Migration Zones. State of Washington Department of Ecology Publication #03-06-027. 135 pp
Available at *http://www.ecy.wa.gov/pubs.shtm*

Stanley, S., J. Brown and S. Grigsby. 2005. Protecting Aquatic Ecosystems: A Guide for Puget Sound Planners to Understand Watershed Processes. State of Washington Department of Ecology Publication #05-06-027. 160 pp Available at *http://www.ecy.wa.gov/pubs.shtm*

Task Force on the Natural and Beneficial Functions of the Floodplain. 2002. The Natural and Beneficial Functions of Floodplains: Reducing Flood Losses By Protecting and Restoring the Floodplain Environment. A Report for Congress. 84 pp