The following four maps provide examples of how resource managers can use a geographic information system to analyze data and show links among different data sets.

Areas of Planned Increase in Land-Use Intensity 35

This map is the result of comparing two maps shown previously in the atlas: Existing Land Use and Future Land-Use Plan. To create this map, we grouped all possible land uses into five basic categories and assigned each category a number, ranking them from lowest- to highest-intensity use.

1 - Farm, Forest and Open Space
2 - Rural Residential
3 - Single-Family Residential
4 - Multi-Family Residential
5 - Commercial and Industrial

By using GIS to compare or overlay the rankings in the existing land-use data with the future land-use data, we calculated a resulting number, ranging from +1 to +4. For example, a property that is currently a farm (ranking = 1) and is slated for industrial zoning in the future (ranking = 5) received a +4. A ranking of +3 could mean that a farm is slated to become multi-family residential or that a rural residential area is slated for commercial development. In the map legend, the bright red color represents land that could see the highest intensity of change (+4).

Also displayed on this map are urban reserves adopted by the Metro Council and reserves designated by the city of Sandy. These areas may eventually be included inside the Metro or Sandy urban growth boundaries and developed to accommodate an increasing population. Once these areas are developed, they would experience an increase in land-use intensity. However, because local comprehensive plans have not been updated since reserves were adopted, the map does not show specific areas within the urban reserves where growth will occur.

Streams that provide spawning or rearing habitat for anadromous salmonid fish, as observed during Oregon Department of Fish and Wildlife surveys, are also highlighted on the map. During the master planning process for future urban areas, local and regional planners can use maps like this to make decisions about the effects of urban expansion on natural ecosystems.

***Note:** This map shows only the actual areas where coho, chinook and steelhead are known to be distributed. Nonhighlighted streams may or may not contain these or other fish.*

Road-Stream Crossings and Known Impediments to Fish Passage 36

This map shows both potential impediments to fish movement, known as road-stream crossings, and known impediments such as dams and waterfalls.

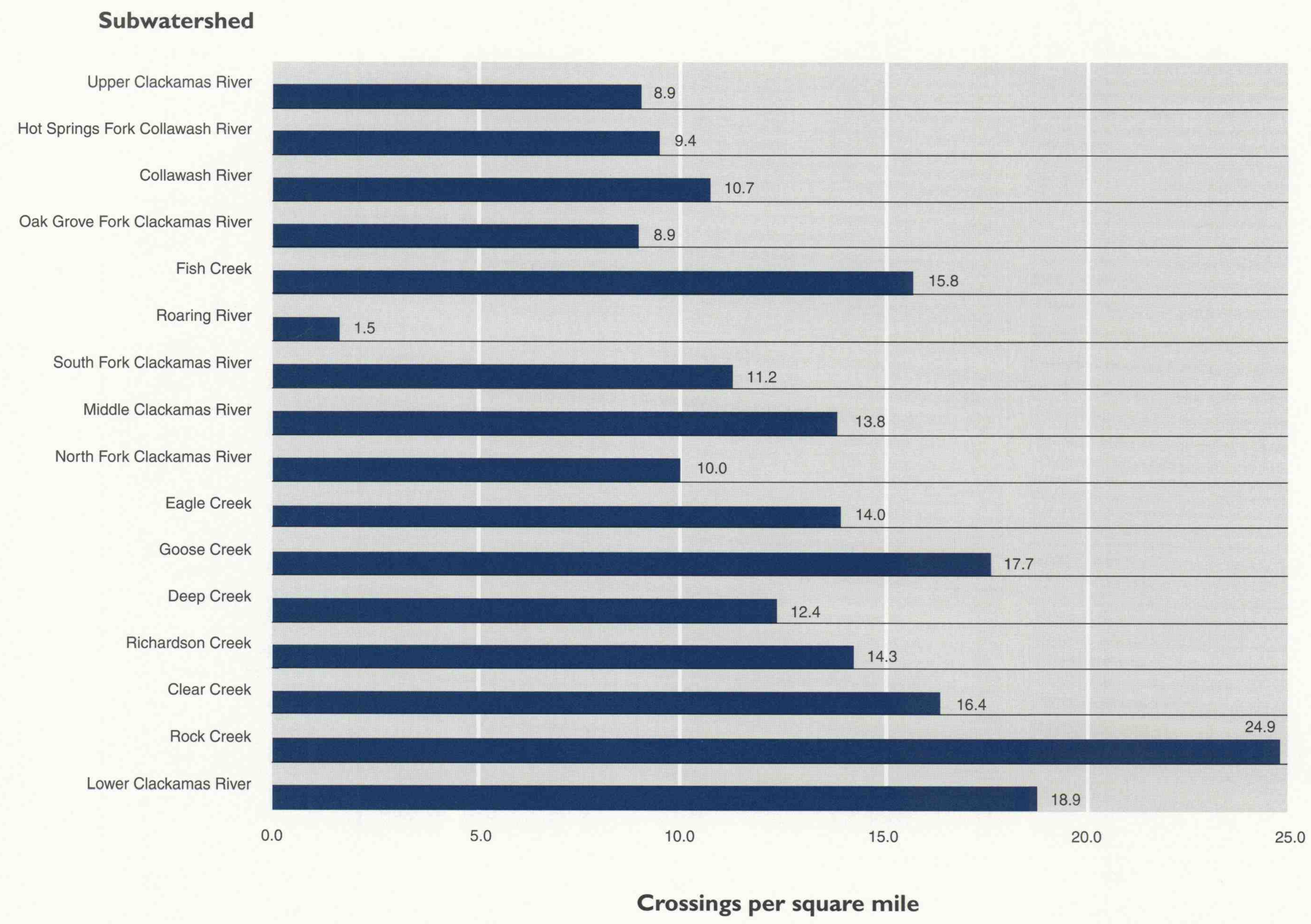
Road-stream crossings are important to fish habitat because streams are often diverted into pipes, called culverts, to pass under roads. Some culverts – particularly small diameter pipes, culverts that are improperly installed, and culverts with a large drop on the downstream side – can prevent fish from moving further upstream.

It would be very time consuming for field crews to walk every road and stream to identify where they meet, especially in a watershed as large as the Clackamas. Instead, resource managers can use a GIS (geographic information system) to locate probable road-stream crossings. These computer-generated crossings, marked wherever a road and a stream come within five feet of each other, are shown on the map.

Not all of the road-stream crossings shown consist of culverts. Some road-stream crossings may have bridges, while very small or intermittent streams may flow across a road. Also, areas where a stream runs

Figure 9

Road-stream crossings



alongside a road (within five feet) for some distance could show up as several road-stream crossings, even though the stream may not actually cross under the road. In contrast, urban streams that have long ago been routed underground are not mapped and thus would not show up as road-stream crossings, even when streams are piped directly underneath roads.

Also shown on the map are known impediments to fish passage, such as waterfalls, dams and large culverts, as identified by the Oregon Department of Fish and Wildlife and the U.S. Forest Service. The number of known fish impediments is small compared to the number of potential barriers indicated by the road-stream crossings. (Whether an impediment actually blocks fish passage depends on the size of the waterfall, whether the dam has a fish ladder and the fish species trying to pass.)

***Note:** The most detailed stream data available were used to locate the crossings. Roads and streams are mapped in greater detail on federal lands than on non-federal lands; as a result, more road-stream crossings appear on federal lands. Individual road-stream crossings were not verified in the field. For more information about the base data displayed on this map, refer to the base map description.*

Figure 9 shows the number of road-stream crossings per square mile for each subwatershed. A high number of crossings can be attributed to (a) more actual roads (see Figure 3 for road density in each subwatershed); (b) more detailed road data, such as the gravel road data kept by the USFS; (c) more streams; or (d) streams that run close to roads. For example, Fish Creek subwatershed in the Mt. Hood National Forest shows more road-stream crossings (15.8 per square mile) than the rural residential subwatershed of Richardson Creek (14.3 per square mile), even though the Fish Creek subwatershed appears to have fewer road miles per square mile than the Richardson Creek subwatershed (see Figure 3).

The Roaring River subwatershed, also in the Mt. Hood National Forest, has the lowest number of road-stream crossings (1.5 per square mile), likely because of its low road density (0.7 road miles per square mile).

***Note:** The road density data were produced in 1988-1996 and may not reflect current conditions. For example, because USFS road data were produced in 1994, they do not include logging roads abandoned or removed since then. New roads built since 1996 in urban areas are also not included.*

Relative Susceptibility to Mass Wasting 37

This map shows the relative susceptibility of different areas in the watershed to mass wasting, the large movements of soil that occur as landslides and debris flows.

Mass wasting can transport vast amounts of soil, and often trees and rocks, from hillsides to nearby streams. This process can affect fish habitat by clogging streams with sediment, washing out habitat pools and woody debris, and scouring riparian areas.

Mass wasting happens naturally, although infrequently, in all watersheds, including undisturbed, forested watersheds. The two major factors that affect the frequency and severity of natural mass wasting are geology and slope.

Geology is important because some types of geologic materials, particularly certain rock types, are very strong and stable and thus resistant to sliding. Other types of geologic materials are mechanically rather weak or unstable, and thus susceptible to landslides.

The geologic units in the Clackamas watershed can be classified by their stability:

Unstable: Qls, Tfc, Tu, Tus

Moderate: Qts, Qs

Stable: All other geologic units shown on the Geology Map

Slope is also a factor, because rock and soil of any type on steep slopes are more susceptible to mass wasting than rock and soil on gentle slopes. The slope categories used for this map were:

Gentle slope: 0-24 percent

Moderate slope: 25-49 percent

Steep slope: 50-69 percent

Very steep slope: 70 percent or greater

To create this map, we combined the inherent stability of each geology unit with slope categories, forming a geology-slope matrix with rankings for each combination (Booth; King County). For example, an area with unstable, old landslide deposits (Qls) and steep slopes would show up as "high susceptibility." An area with moderately stable sedimentary rocks (Qts) could show up as either "medium susceptibility" or "low susceptibility" depending on slope. In the Lower Clackamas area, the abundance of gentle slopes means that the entire area is considered to have "low susceptibility" to mass wasting, even though some geologic materials found there are only moderately stable.

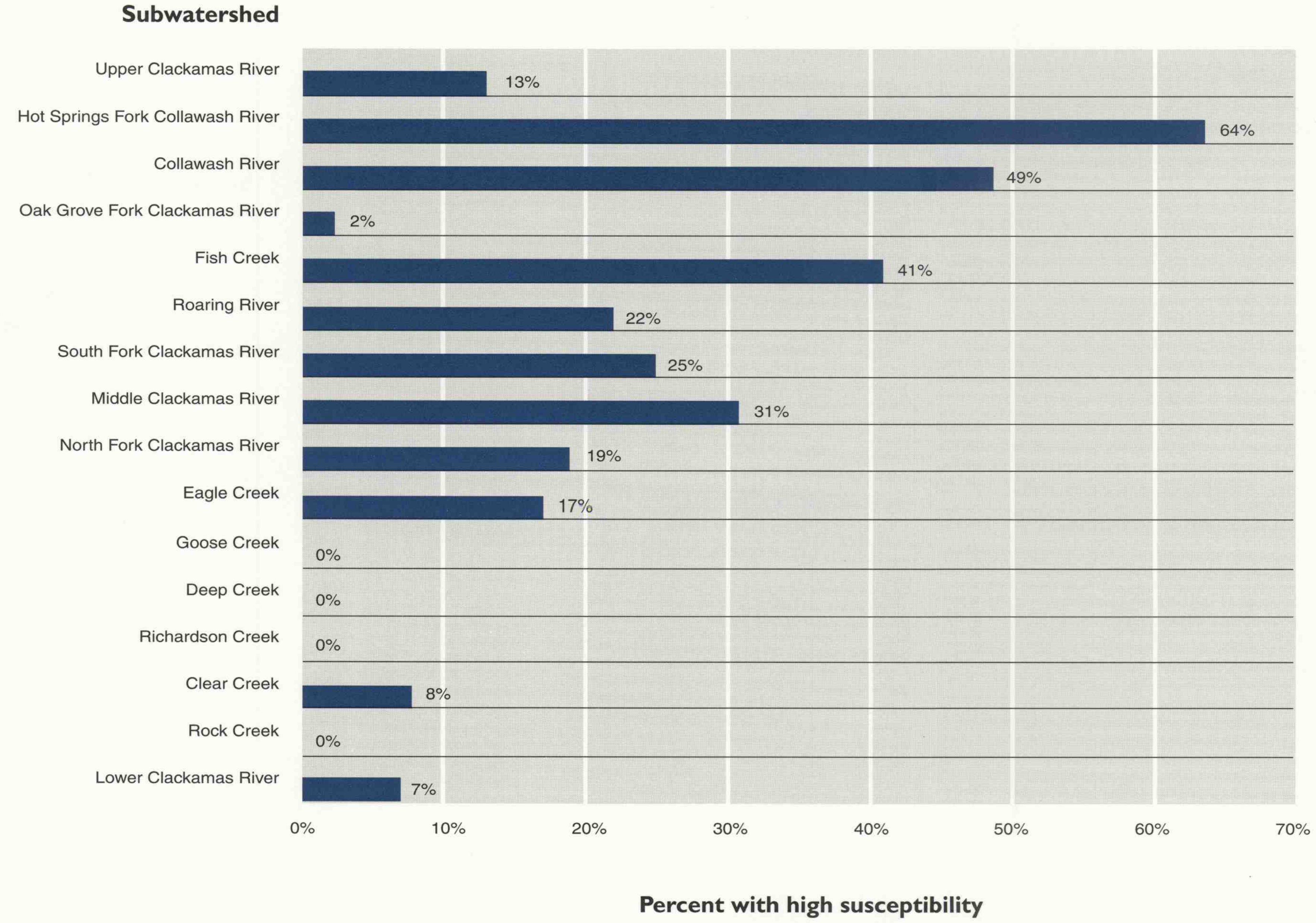
Mass wasting events are also influenced by factors other than geology and slope. Heavy rainfall, rain-on-snow events, and certain soil types, textures and thickness can make an area more susceptible to mass wasting. Mass wasting can also be aggravated by human activities such as land clearing, road building and some timber harvesting practices. These factors were not included in the analysis because current data is not available for the entire watershed.

The map also shows ancient landslide deposits, including debris flows, rock falls, earth flows and active slumps. Because soil in these areas has already been disturbed, they are susceptible to further sliding. This landslide data was provided by the U.S. Forest Service and covers only sites located on federal forest lands.

Note: *Because mass wasting depends on so many factors, this map can be used to indicate general areas susceptible to landslides, but not to predict sites where slides will occur. In addition, because this map was derived from the geology data, it is subject to the limitations of a coarse scale (1:500,000). The USFS has more refined geology information for federal forest lands, information that is more appropriate for site-specific analyses.*

Figure 10

High susceptibility to mass wasting



As shown in Figure 10, the subwatersheds in the upper Clackamas (top of graph) generally show a greater percentage of areas with high susceptibility to mass wasting. Two exceptions are the Oak Grove Fork of the Clackamas River and the Upper Clackamas River. These two subwatersheds include high plateaus, which provide gentle slopes comparable to those found in the lower watershed. Such gentle slopes minimize the susceptibility to mass-wasting, even in areas with unstable geologic materials. In contrast, the two subwatersheds with the largest percentages shown – the Hot Springs Fork of the Collawash River (64 percent high susceptibility) and the Collawash River (49 percent high susceptibility) – both have steep slopes, as indicated on the Slope map.

Generalized Stream Gradient 38

This map provides another example of how a GIS can combine data from several sources to help resource managers analyze a particular issue. In this case, the stream gradients can be used to analyze possible relationships between sediment production in one part of the watershed and fish habitat downstream.

Because of the coarse scale of the digital elevation and slope data, this map can be used only to illustrate large-scale, watershed-wide patterns of sediment transport, but not to identify specific locations where sediment is being produced or carried downstream.

Sediment can enter waterways through surface erosion or through large mass wasting events such as landslides, which can deliver the disturbed soil to nearby streams. Stream channels with fast moving water then act as conduits to carry the sediment downstream (Montgomery and Buffington).

Generally, sediment carried by the water will be deposited in stream reaches where the flow slows down. These reaches, which often contain pools, are also used by anadromous salmonids for spawning and rearing. Sediment deposits can affect fish habitat by burying spawning beds and degrading water quality.

The Generalized Stream Gradient map shows five types of areas:

Areas with high mass wasting susceptibility: potential sources of sediment from landslides and other mass wasting events (see the Relative Susceptibility to Mass Wasting map for more information).

Stream gradient of 11-20 percent (transport reaches): these stream reaches with steep gradients are likely to have fast-flowing water, rapids, or cascades that can quickly transport sediment delivered from upstream.

Stream gradient of 5-10 percent (secondary response reaches): Depending on the topography and sediment loads, these these stream reaches may either transport sediment or allow sediment to settle.

Stream gradient of 0-4 percent (primary response reaches): in these areas with gentle stream gradients, the stream often widens and slows down, allowing sediment to settle. These low-gradient reaches also provide an ideal habitat for salmonid spawning and rearing.

Known salmonid habitat: observed areas of spawning and rearing habitat for coho, chinook or steelhead (see the Salmonid Fish Distribution map for more detailed information).

The transition zone between a transport reach and a response reach is particularly important because a transport reach usually deposits sediment into the first downstream reach that can no longer carry the sediment load. In primary response reaches, sedimentation can have prolonged impacts, changing the shape of the stream channel and bottom as well as affecting habitat for fish and other aquatic animals.

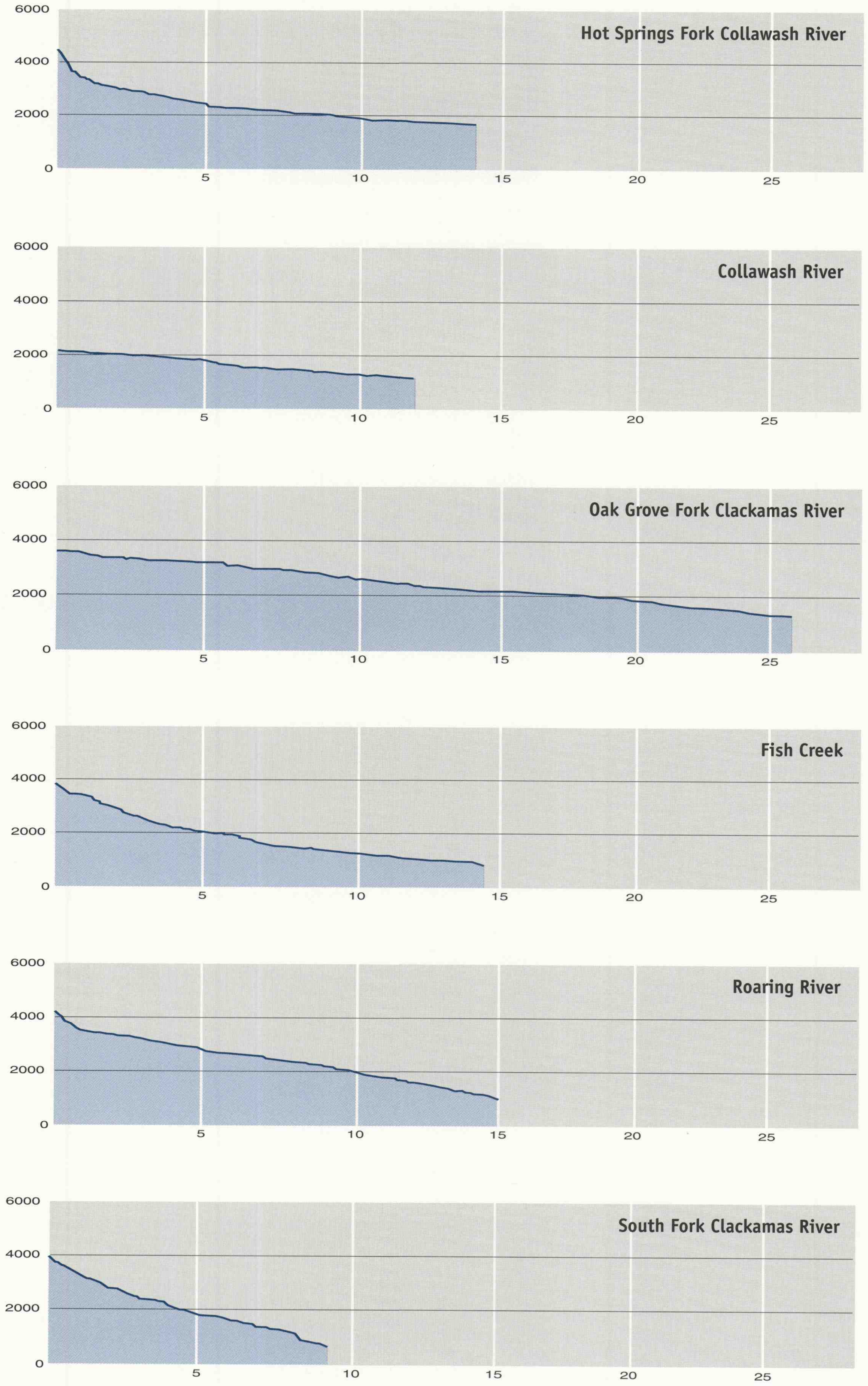
When evaluating possible impacts from sedimentation, it is important to consider the physical link between sediment sources and response reaches. For example, some subwatersheds are landslide-prone, but the map may show that sediment-produc-

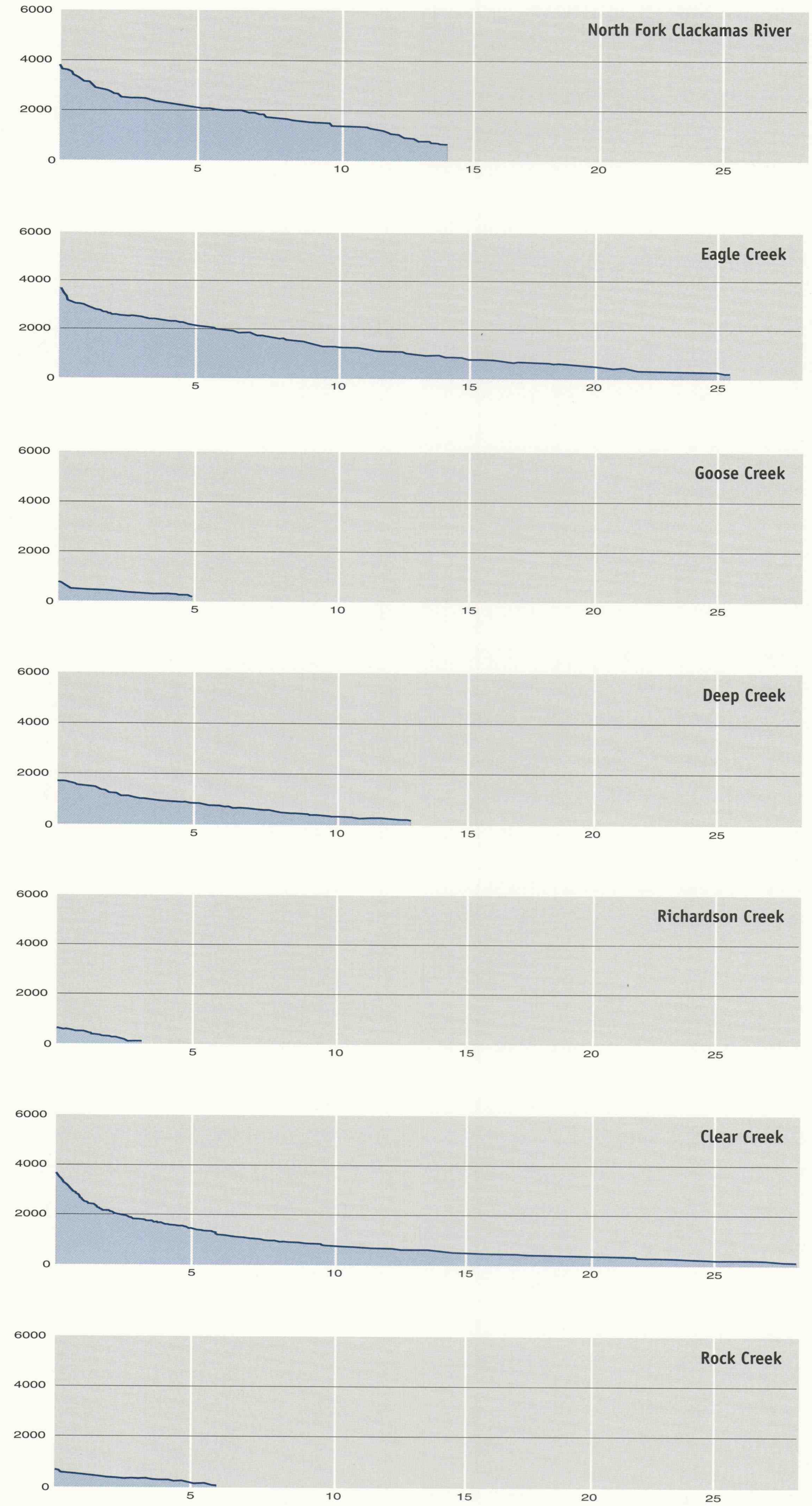
continued on page 39

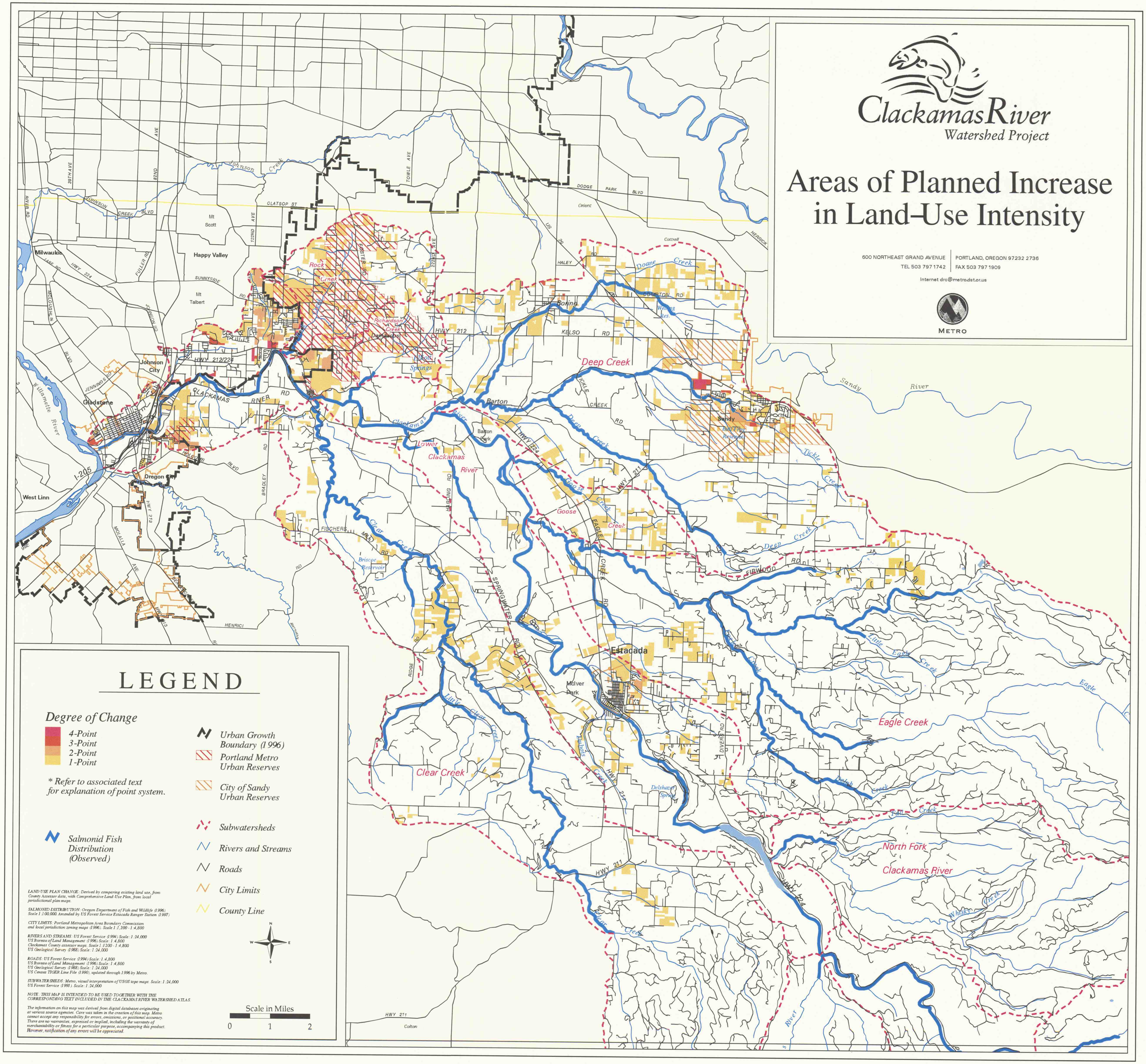
Figure 11 (see text on page 39)

Stream elevation profiles for Clackamas tributaries

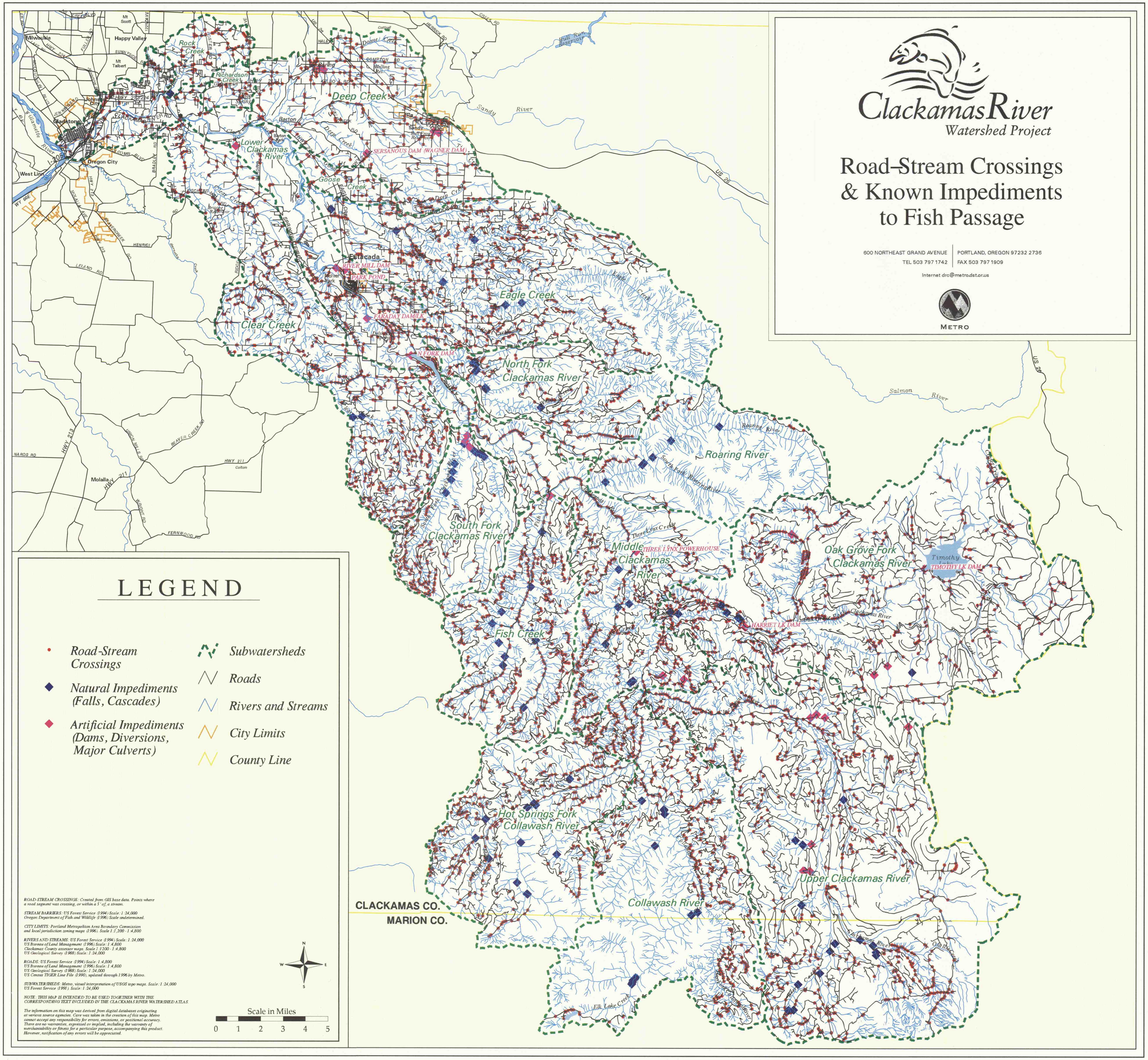
Note: *Stream elevations in feet are shown on the left side of each graph. River miles (in these graphs, measured from the source of each tributary) are shown along the bottom of each graph.*



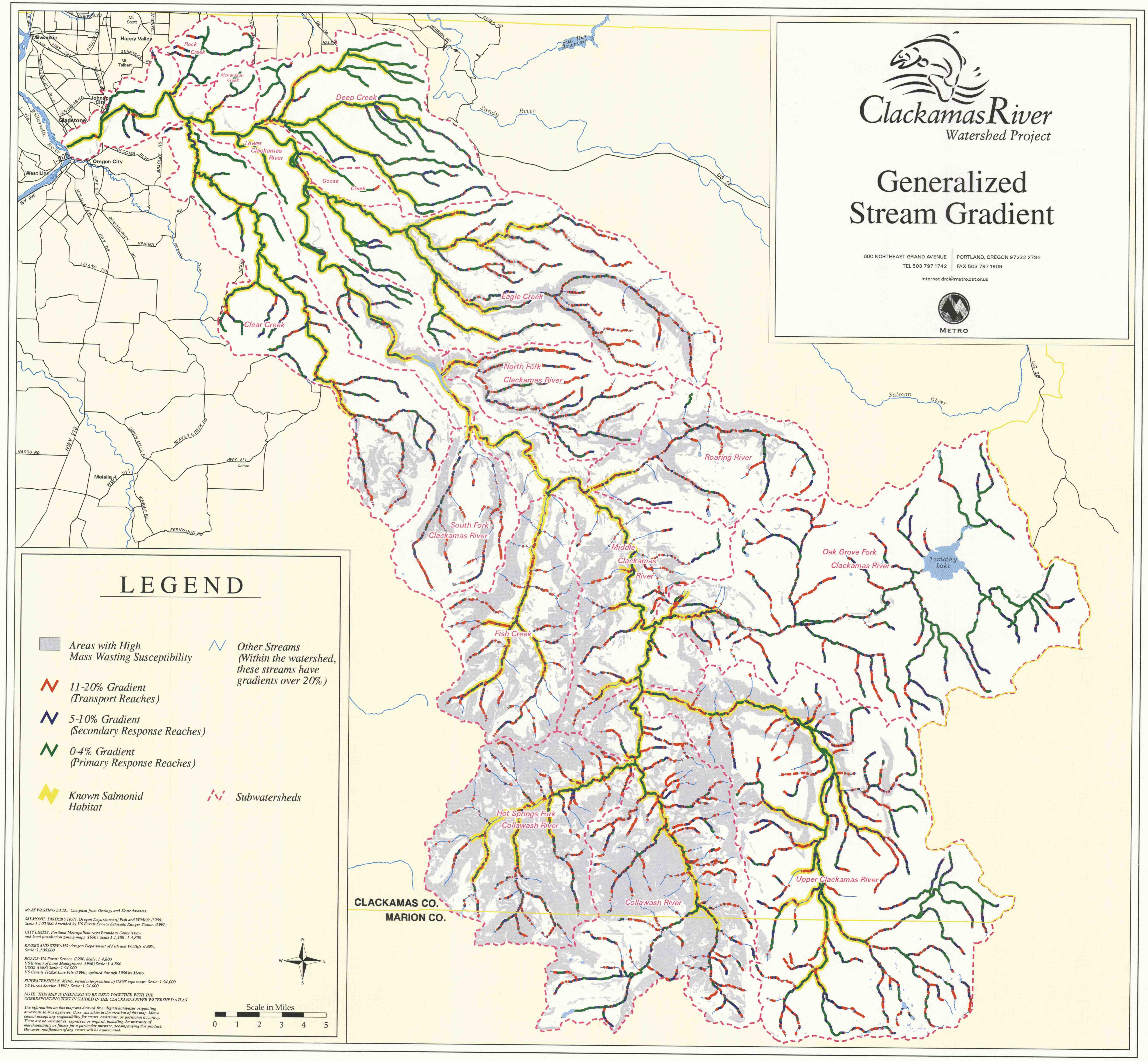




Clackamas River
Watershed Project
Areas of Planned Increase in Land-Use Intensity
600 NORTHEAST GRAND AVENUE | PORTLAND, OREGON 97232 2736
TEL 503 797 1742 | FAX 503 797 1909
Internet drc@metro.dst.or.us
METRO
LEGEND
Degree of Change
4-Point
3-Point
2-Point
1-Point
* Refer to associated text for explanation of point system.
Urban Growth Boundary (1996)
Portland Metro Urban Reserves
City of Sandy Urban Reserves
Subwatersheds
Salmonid Fish Distribution (Observed)
Rivers and Streams
Roads
City Limits
County Line
LAND USE PLAN CHANGE: Derived by comparing existing land use, from County Assessor data, with Comprehensive Land-Use Plan, from local jurisdictional plan maps.
SALMONID DISTRIBUTION: Oregon Department of Fish and Wildlife (1996) Scale 1:100,000. Amended by US Forest Service Estacada Ranger Station (1997)
CITY LIMITS: Portland Metropolitan Area Boundary Commission and local jurisdiction zoning maps (1996). Scale 1:1,200 - 1:4,800
RIVERS AND STREAMS: US Forest Service (1994) Scale: 1:24,000
US Bureau of Land Management (1996) Scale: 1:4,800
Clackamas County assessor maps. Scale 1:1200 - 1:4,800
US Geological Survey (1988) Scale: 1:24,000
ROADS: US Forest Service (1994) Scale: 1:4,800
US Bureau of Land Management (1996) Scale: 1:4,800
US Geological Survey (1988) Scale: 1:24,000
US Census TIGER Line File (1990), updated through 1996 by Metro.
SUBWATERSHEDS: Metro, visual interpretation of USGS topo maps. Scale: 1:24,000
US Forest Service (1991). Scale: 1:24,000
NOTE: THIS MAP IS INTENDED TO BE USED TOGETHER WITH THE CORRESPONDING TEXT INCLUDED IN THE CLACKAMAS RIVER WATERSHED ATLAS.
The information on this map was derived from digital databases originating at various source agencies. Care was taken in the creation of this map. Metro cannot accept any responsibility for errors, omissions, or positional accuracy. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, accompanying this product. However, notification of any errors will be appreciated.
Scale in Miles
0
1
2
N
S
E
W
Milwaukie
Happy Valley
Johnson City
Gladstone
Oregon City
West Linn
Boring
Damascus
Barton
Sandy
Estacada
McIver Park
Colton
Deep Creek
Clear Creek
Eagle Creek
North Fork
Clackamas River
Lower Clackamas River
Sandy River
Johnson Creek
Doane Creek
Rock Creek
Goose Creek
Tickle Creek
Little Eagle Creek
Little Clear Creek
Willamette River
HWY 212
HWY 224
HWY 211
HWY 212/224
I-205


Clackamas River
Watershed Project
Road–Stream Crossings
& Known Impediments
to Fish Passage
600 NORTHEAST GRAND AVENUE | PORTLAND, OREGON 97232 2736
TEL 503 797 1742 | FAX 503 797 1909
Internet drc@metro.dst.or.us
METRO
LEGEND
Road-Stream Crossings
Natural Impediments (Falls, Cascades)
Artificial Impediments (Dams, Diversions, Major Culverts)
Subwatersheds
Roads
Rivers and Streams
City Limits
County Line
ROAD-STREAM CROSSINGS: Created from GIS base data. Points where a road segment was crossing, or within a 5' of, a stream.
STREAM BARRIERS: US Forest Service (1994) Scale: 1:24,000
Oregon Department of Fish and Wildlife (1996) Scale undetermined.
CITY LIMITS: Portland Metropolitan Area Boundary Commission and local jurisdiction zoning maps (1996). Scale 1:1,200 - 1:4,800
RIVERS AND STREAMS: US Forest Service (1994) Scale: 1:24,000
US Bureau of Land Management (1996) Scale: 1:4,800
Clackamas County assessor maps. Scale 1:1200 - 1:4,800
US Geological Survey (1988) Scale: 1:24,000
ROADS: US Forest Service (1994) Scale: 1:4,800
US Bureau of Land Management (1996) Scale: 1:4,800
US Geological Survey (1988) Scale: 1:24,000
US Census TIGER Line File (1990), updated through 1996 by Metro.
SUBWATERSHEDS: Metro, visual interpretation of USGS topo maps. Scale: 1:24,000
US Forest Service (1991). Scale: 1:24,000
NOTE: THIS MAP IS INTENDED TO BE USED TOGETHER WITH THE CORRESPONDING TEXT INCLUDED IN THE CLACKAMAS RIVER WATERSHED ATLAS.
The information on this map was derived from digital databases originating at various source agencies. Care was taken in the creation of this map. Metro cannot accept any responsibility for errors, omissions, or positional accuracy. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, accompanying this product. However, notification of any errors will be appreciated.
Scale in Miles
0 1 2 3 4 5
Rock Creek
Richardson Creek
Deep Creek
Lower Clackamas River
Goose Creek
Clear Creek
Eagle Creek
North Fork Clackamas River
Roaring River
South Fork Clackamas River
Middle Clackamas River
Oak Grove Fork Clackamas River
Timothy Lake
Fish Creek
Hot Springs Fork Collawash River
Collawash River
Upper Clackamas River
SERSANOUS DAM (WAGNER DAM)
RIVER MILL DAM
PARK POND
FARADAY DAM
N FORK DAM
THREE LYNX POWERHOUSE
HARRIET LK DAM
TIMOTHY LK DAM
Estacada
Oregon City
Gladstone
West Linn
Milwaukie
Happy Valley
Molalla
Sandy River
Salmon River
CLACKAMAS CO.
MARION CO.

ClackamasRiver
Watershed Project
Relative Susceptibility to Mass Wasting
600 NORTHEAST GRAND AVENUE
PORTLAND, OREGON 97232 2736
TEL 503 797 1742
FAX 503 797 1909
METRO
LEGEND
Mass Wasting Susceptibility
Low
Moderate
High
Ancient Landslide Deposits
Subwatersheds
Roads
Rivers and Streams
City Limits
County Line
Scale in Miles
0 1 2 3 4 5
Rock Creek
Richardson Creek
Deep Creek
Lower Clackamas River
Goose Creek
Clear Creek
Eagle Creek
North Fork Clackamas River
Roaring River
South Fork Clackamas River
Middle Clackamas River
Oak Grove Fork Clackamas River
Timothy Lake
Fish Creek
Hot Springs Fork Collawash River
Collawash River
Upper Clackamas River
CLACKAMAS CO.
MARION CO.
Sandy River
Salmon River
Milwaukie
Happy Valley
Gladstone
Oregon City
West Linn
Estacada
Molalla


Clackamas River
Watershed Project
Generalized Stream Gradient
600 NORTHEAST GRAND AVENUE
PORTLAND, OREGON 97232 2736
TEL 503 797 1742
FAX 503 797 1909
Internet drc@metro.dst.or.us
METRO
LEGEND
Areas with High Mass Wasting Susceptibility
11-20% Gradient (Transport Reaches)
5-10% Gradient (Secondary Response Reaches)
0-4% Gradient (Primary Response Reaches)
Known Salmonid Habitat
Other Streams (Within the watershed, these streams have gradients over 20%)
Subwatersheds
MASS WASTING DATA: Compiled from Geology and Slope datasets.
SALMONID DISTRIBUTION: Oregon Department of Fish and Wildlife (1996) Scale 1:100,000. Amended by US Forest Service Estacada Ranger Station (1997)
CITY LIMITS: Portland Metropolitan Area Boundary Commission and local jurisdiction zoning maps (1996). Scale 1:1,200 - 1:4,800
RIVERS AND STREAMS: Oregon Department of Fish and Wildlife (1996), Scale: 1:100,000
ROADS: US Forest Service (1994) Scale: 1:4,800
US Bureau of Land Management (1996) Scale: 1:4,800
USGS (1988) Scale: 1:24,000
US Census TIGER Line File (1990), updated through 1996 by Metro.
SUBWATERSHEDS: Metro, visual interpretation of USGS topo maps. Scale: 1:24,000
US Forest Service (1991). Scale: 1:24,000
NOTE: THIS MAP IS INTENDED TO BE USED TOGETHER WITH THE CORRESPONDING TEXT INCLUDED IN THE CLACKAMAS RIVER WATERSHED ATLAS.
The information on this map was derived from digital databases originating at various source agencies. Care was taken in the creation of this map. Metro cannot accept any responsibility for errors, omissions, or positional accuracy. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, accompanying this product. However, notification of any errors will be appreciated.
Scale in Miles
0 1 2 3 4 5
N
W
E
S
Milwaukie
Happy Valley
Mt Talbert
Johnson City
Gladstone
Oregon City
West Linn
Molalla
Colton
Rock Creek
Richardson Creek
Deep Creek
Lower Clackamas River
Goose Creek
Sandy River
Salmon River
Clear Creek
Eagle Creek
North Fork Clackamas River
Roaring River
South Fork Clackamas River
Middle Clackamas River
Oak Grove Fork Clackamas River
Timothy Lake
Fish Creek
Hot Springs Fork Collawash River
Collawash River
Upper Clackamas River
CLACKAMAS CO.
MARION CO.
HWY 213
HWY 211
US 26