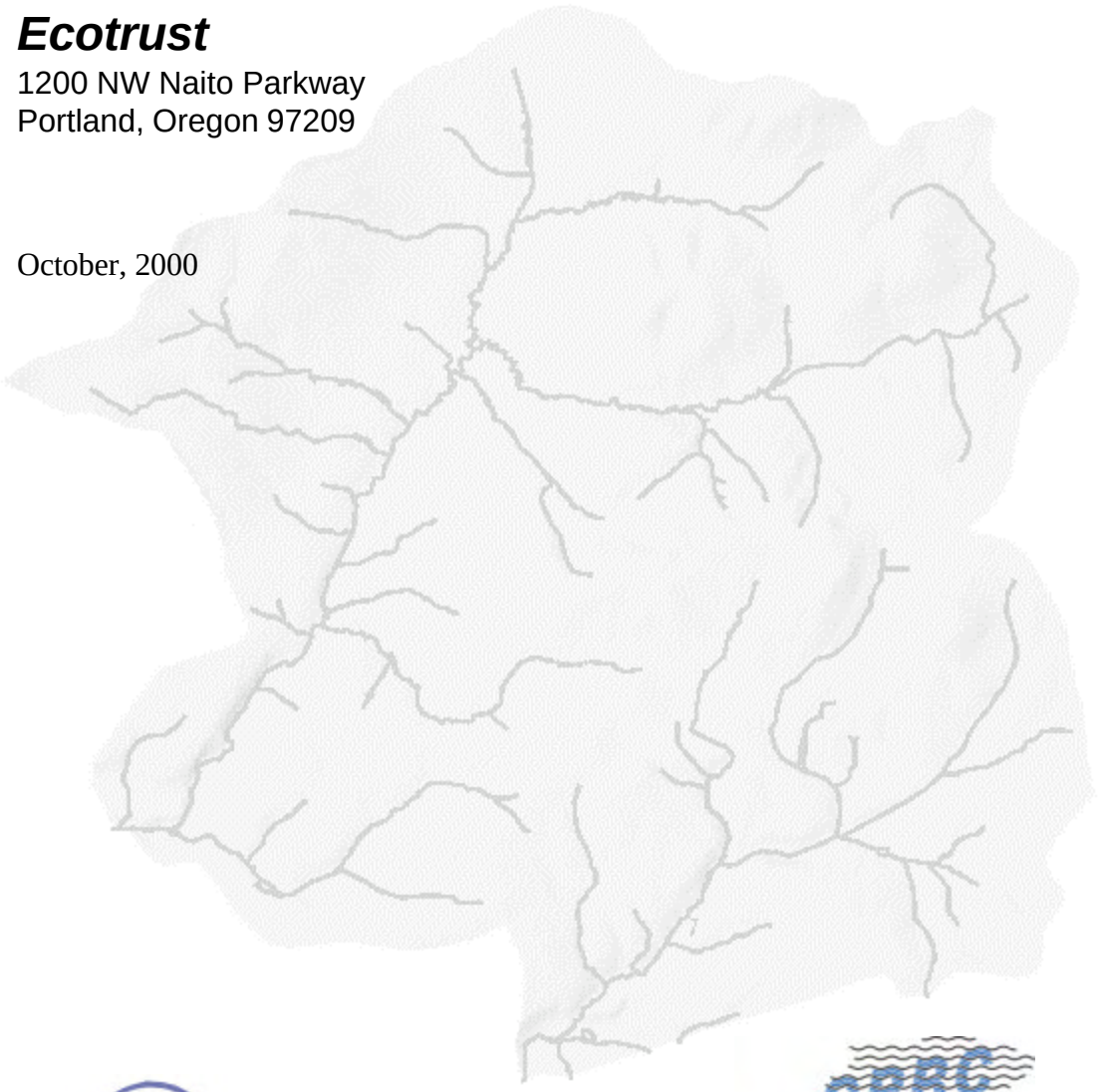
Rock and Richardson Creek Watershed Assessment

Ecotrust
1200 NW Naito Parkway
Portland, Oregon 97209

October, 2000



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Clackamas River Basin Council

ACKNOWLEDGMENTS

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P.O. Box 1869
Clackamas, Oregon 97015
503-650-1256
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PREFACE

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Failure to meet the challenge to create urban communities in harmony with natural processes will certainly result in conventional urban development and its various deleterious effects on these watersheds.

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INTRODUCTION

Purpose

Rock and Richardson Creek watersheds comprise a small, but important part of the Clackamas basin. The total land area of both watersheds is just less than 9,000 acres, compared to the over 500,000 acres of the basin. The total current distribution of anadromous fish of two to three miles within Rock and Richardson Creeks is a mere fraction of the total habitat available in other basin streams.

The importance of these two small streams lies in their unique position at the edge of the Portland urban area and the fact that this area will be substantially urbanized over the next two to twenty years. In a very real sense, it represents an opportunity to demonstrate a new commitment, ability and will to modify human cultural practices to maintain a sustainable landscape through the intersection of healthy ecosystems, healthy communities and vibrant economies.

The Clackamas River Basin Council initiated this watershed assessment to catalyze community involvement in watershed restoration and to offer and alternative to conventional urban development. Conventional urban development destroys or at best severely damages aquatic ecosystems. As land is covered with roads and buildings, rainfall runs quickly off the surface into pipes, then to streams. It flows fast and furious, carrying all manners of dirt, grime, oil, and chemicals directly into streams. Winter and spring flows are higher than they ever were before, resulting in bank erosion, downcutting, and the loss of connection between the stream and floodplain. Riparian areas become weed and trash choked wastelands. Pools silt in, spawning gravels are washed away, and summer flows may dry up altogether. Many urban creeks including neighboring Johnson Creek, were quite good salmon habitat in the 1950's, now they are testimony to the severity and problems posed by conventionally urbanized watersheds.

Oregonians have recognized the impacts of our activities on salmonids, aquatic ecosystems and, more broadly, the watersheds and ecosystems that sustain us. The Oregon Watershed Enhancement Board has led the way in developing a process for assessing watershed conditions, and devising means to repair and protect watersheds. Clackamas County has developed a stream protection ordinance and surface water regulations. The Oregon Legislature passed Senate Bill 1010 to improve agricultural practices near streams. Metro has adopted Title 3 stream protection rules, which were incorporated into the May 1, 2000 Clackamas County Service District #1 Surface Water Management Rules and Regulations. The State Forestry Board is developing new stream buffer protections for forest practices. The State's “Three Basin Rule” limits point discharges into the Clackamas Basin. Citizens have become more aware of the magnitude of the challenge. But now that we know better, can we do better? What will it take to do so?

The intent of this assessment is to provide a framework for action based on a review of the many recent studies that have been completed in this area. The Clackamas Basin Atlas, funded by the Environmental Protection Agency and coordinated by Metro, provides a basin-wide perspective on the entire area. Metro followed up this effort with a landscape study focused on Rock and Richardson Creeks. Pacific Rivers Council and the Oregon Department of Fish and Wildlife (ODFW) have done fish surveys and analyzed the health of aquatic life. During the development of this assessment Clackamas County was in the midst of completing a stormwater management plan for the proposed urban areas. This assessment summarizes the findings of these and several other studies, and provides a context for moving forward with creek protection and restoration.

This assessment is based on the watershed assessment framework in the Oregon Watershed Assessment Manual. As a brief summary of existing studies it represents a snapshot of our current knowledge of Rock and Richardson watersheds. New studies continue to generate new information about these watersheds even as this assessment is completed. While this document is static, the assessment process itself should be viewed as dynamic. As new information develops, knowledge and understanding of the status and conditions of these watersheds will continue to evolve.

Background: Watershed Landscapes and History

Rock and Richardson Creek watersheds are part of the ecosystem known as the East Buttes and Boring Lava Domes of southeast Multnomah and North Clackamas Counties. These hills, rising 500 to 1000 feet above the valley floors, were created by lava flows some two million years ago. They are part of the same eruption cycle that built Mt. Hood. The low, mostly forested hills meet level to gently sloping valley floors, including Pleasant and Sunshine valleys. The streams cut down into narrow canyons as they reach the more erodable soils south of Sunnyside Road and Highway 212.

These two watersheds have several differences as well as similarities. Rock Creek watershed is more than twice as large in area as Richardson Creek watershed. Richardson Creek itself has a consistently steep gradient and flows in large part through a forested zone. Rock Creek is more of a meandering stream, particularly where it winds across Pleasant Valley, but falls more steeply in the lower reaches through a forested canyon. Both watersheds are dominated by rural residential land uses with a housing density no greater than one house per acre, but some high density housing -- with three or more houses per acre -- is present in the southwestern portion of the Rock Creek watershed. As illustrated by the table below, both watersheds have very similar land cover characteristics. Agriculture dominates over one third of the landscape, and more than two fifths of both watersheds are covered by forest canopy.

Land Cover Characteristics by Watershed *

	Rock		Richardson	
Land cover	**acres**	**percent**	**acres**	**percent**
Urban / built up	679	11	321	12
Agriculture	2,245	36	907	34
Forest	2,633	42	1,123	42
Shrub	352	6	135	5
Grassland, golf courses, parks, meadows	352	6	218	8
Total	6,262	100	2,704	100

**Source: Metro (1998).*

The US Environmental Protection Agency has identified “ecoregions” based on similarities of topography, soils, climate, and vegetation. The area north of Highway 212 is identified as Valley Foothills, while the area south is called “Prairie Terraces.” Both of these were historically forested, primarily with Douglas-fir. Hemlock and red cedar grow in cooler, wetter areas. Oregon white oak was found on the more well-drained terraces.

Both basins have soils and gravels deposited by past flood events, including the Bretz floods that reached up to 400 feet in the Willamette Valley. The basaltic lava flows lie under these soils to a depth of up to 100 feet in the valleys, deeper in the hills. Under these is the Troutdale formation, the most important aquifer for east Multnomah and North Clackamas Counties.

Soils tend to be poorly drained, brown silty loams and clays. They stay wet much of the year, then dry out completely by late summer. These soils have frustrated farmers for many years, but they are reasonably fertile if the drainage issue is resolved.

Rural roads and highways follow the valley floors and wind between the hills. The land is a patchwork of forest, pasture, nurseries, berry fields, and Christmas tree farms intermingled with suburban homes on one half to two acre lots. Views range from intimate, pastoral valley scenes to stunning vistas of Mt Hood and the Cascade Range to the east.

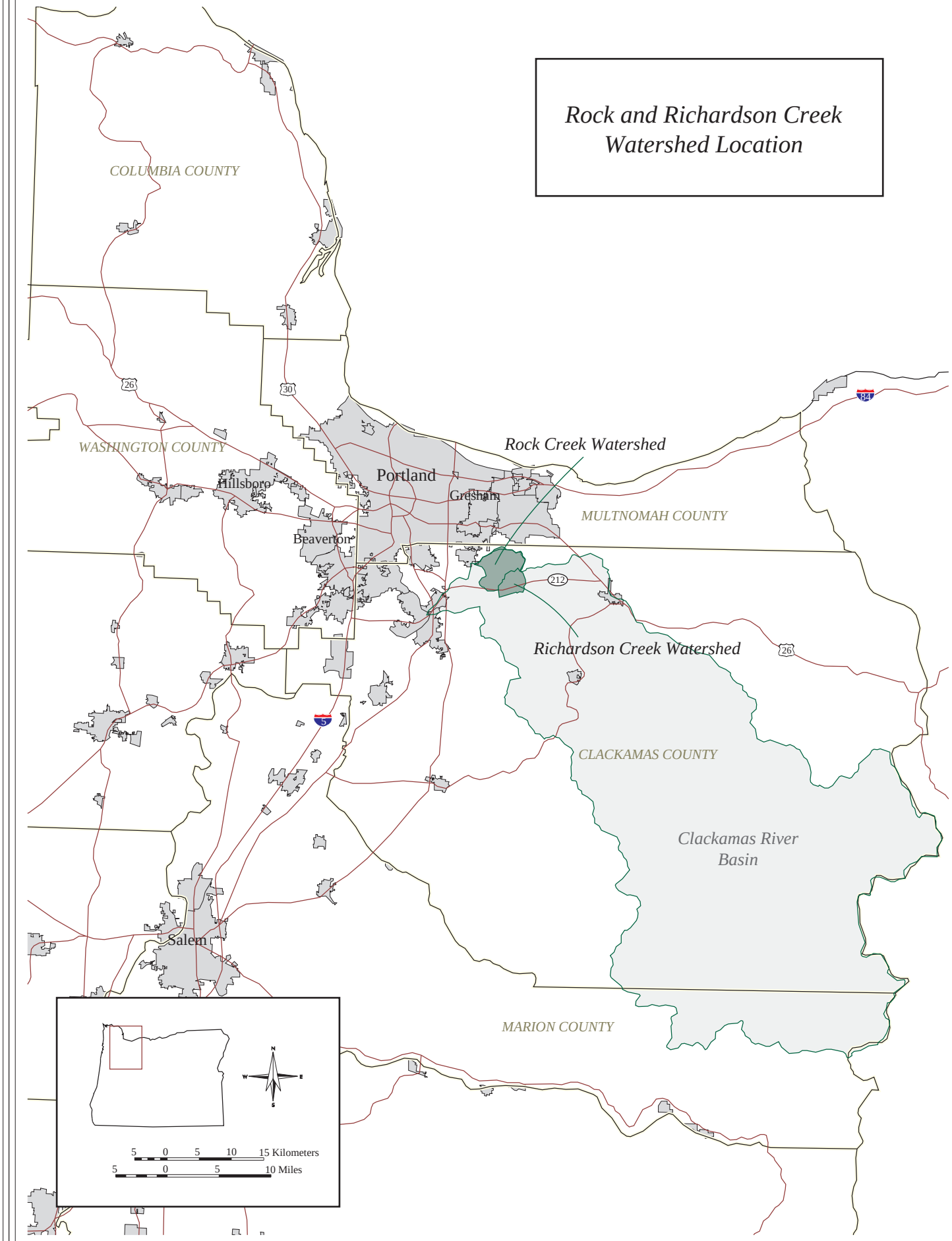
The Clackamas and Mollala Indians inhabited these watersheds, as well as land all through the Basin, for thousands of years. They fished at Willamette Falls and other sites. They traveled through the Lava Dome forests, hunting deer and collecting berries, hazelnuts, acorns, and camas. They likely set fire to the woods to burn off the undergrowth, thus increasing deer forage and making travel easier.

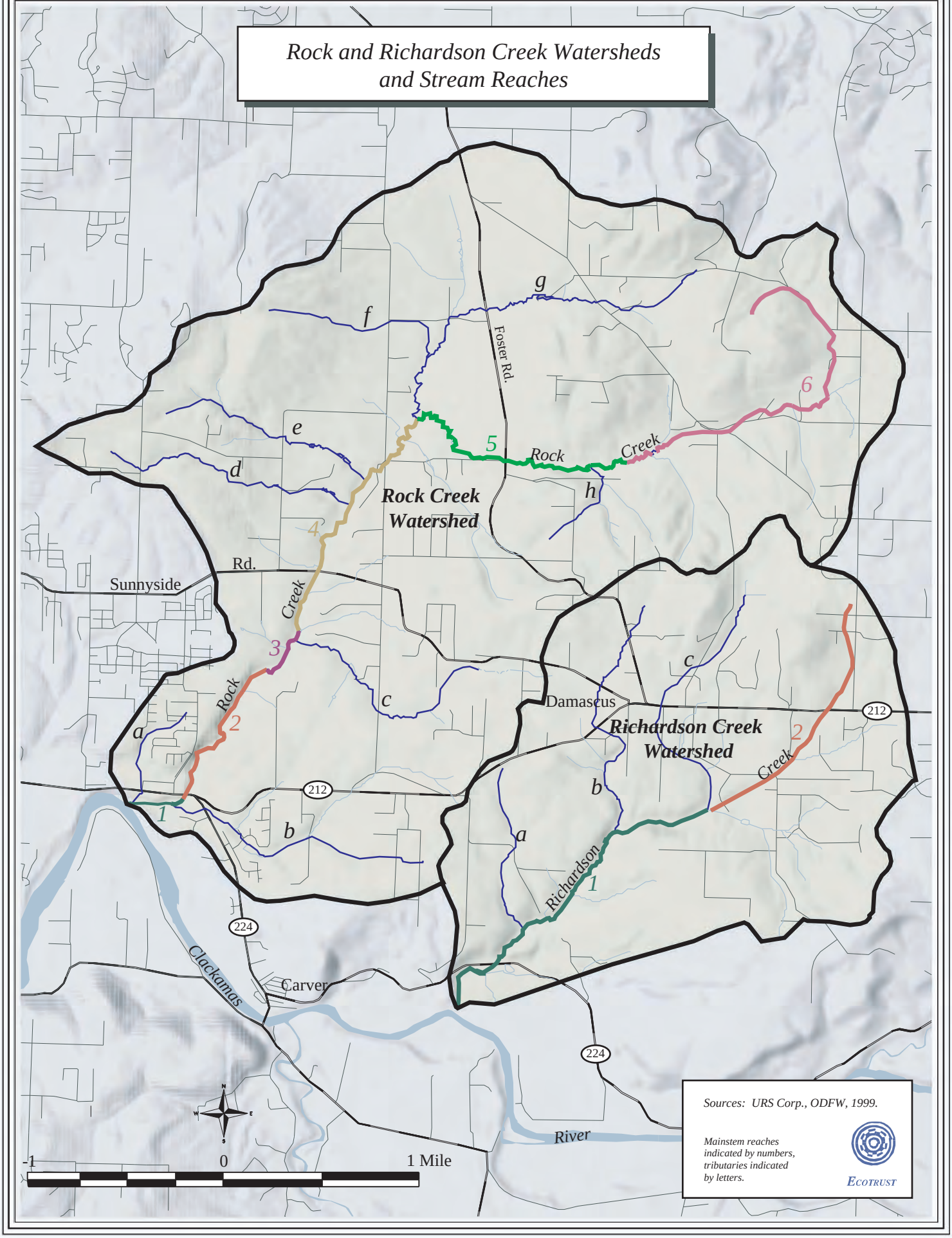
Euro-American settlers arrived in large numbers in the mid-nineteenth century. They found a landscape mostly empty of humans, since European diseases had already decimated the Clackamas and other valley bands. They quickly set about clearing the forest away in order to establish farms and villages. They did not have the opportunity to pause, evaluate the ecosystem they were claiming, and learn from the previous inhabitants. Had they done so, they might have understood the importance of protecting the creeks and wetlands, and they might have learned that the forest helps regulate the flow of water. They might also have learned about the “First Salmon” ritual, held each year by the Indians to celebrate the return of their most important food, and a show of respect for these mysterious creatures.

Aquatic Ecosystem

Area creeks begin as steep first order seasonal streams that flow off of the lava domes. Typically steep slopes lead to shallow swales that become gravel-bottomed creeks within a few hundred yards. Other creeks join these as they tumble through the hills. They emerge onto broad, fairly level to rolling valley floors, where there is room to meander and join with wetlands. This tends to be the most impacted part of the stream system, where farms and nurseries have drained, channeled, and cut riparian vegetation to increase space for crops or forage. Once the creeks find their way to the prairie terraces, they cut down into the land and in effect find refuge from surrounding land uses. The riparian zone is once again forested, spawning gravels secure, and fish migrate up from the Clackamas and back again in their seasonal cycle.

Overall, landscape change has compromised the aquatic ecosystem, but not fatally so. There is time to set these watersheds on a course towards improvement.


Rock and Richardson Creek Watershed Location
COLUMBIA COUNTY
WASHINGTON COUNTY
MULTNOMAH COUNTY
CLACKAMAS COUNTY
MARION COUNTY
Rock Creek Watershed
Richardson Creek Watershed
Clackamas River Basin
Portland
Gresham
Hillsboro
Beaverton
Salem
26
30
84
212
5
N
W
E
S
5 0 5 10 15 Kilometers
5 0 5 10 Miles


Rock and Richardson Creek Watersheds
and Stream Reaches
Rock Creek
Watershed
Richardson Creek
Watershed
Foster Rd.
Rock Creek
Rock Creek
Richardson Creek
Sunnyside Rd.
Damascus
Carver
Clackamas River
212
224
1
2
3
4
5
6
a
b
c
d
e
f
g
h
N
W
E
S
-1
0
1 Mile
Sources: URS Corp., ODFW, 1999.
Mainstem reaches indicated by numbers, tributaries indicated by letters.
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HISTORICAL CONDITIONS

Background

Rock and Richardson Creek watersheds are located in a transition zone between the conifer forests of the Cascade Mountains and the oak/prairie grasslands of the Willamette Valley. Research into Government Land Office Surveys (GLO) by the Natural Resource Heritage program of the Nature Conservancy indicates that prior to Euro-American settlement Douglas-fir forest and woodland dominated most of the area of both watersheds. The uplands of the lava domes were characterized by closed canopy old growth Douglas-fir, grand fir, and bigleaf maple. Hazelnut, Pacific dogwood, vine maple, and Pacific yew composed the understory. The valley floors were similar, but also included western hemlock and western red cedar.

Flood plains along or near the Clackamas River had closed hardwood forests, including Oregon ash, cottonwood, alder, maple, and white oak. There were small patches of conifer, including Douglas-fir and western red cedar.

Upper Richardson Creek appears to have had quite a lot of open canopy Douglas-fir forest. This may have been an area more intensively managed with fire by native Americans. It would have included oak trees, and possibly ponderosa pine.

Patches of heavily burned forest were scattered throughout the area. These could have been created by Indians to facilitate hunting and food gathering, or may have resulted from white settlers clearing land for farms. The downcut canyons of lower Rock and Richardson Creeks would have had similar composition and structure to what we find there today, a mixed conifer and deciduous riparian woodland. A few old growth conifers still exist in lower Richardson Creek.

The Clackamas Band, related to the larger Chinookan language group of the lower Columbia River, were likely the primary residents of the Rock and Richardson Creek areas. They left little direct evidence of their presence, but their primary use of the area would have been fishing in the lower areas of both creeks. The current site of the BI-MART in Damascus was formerly a seasonal gathering area for native peoples. By burning the uplands periodically, they would have facilitated hunting and travel, as well as gathering of acorns, hazelnuts, and wild berries. Generally, the Chinookans had semi-permanent or seasonal village sites at key fishing areas (such as Willamette Falls.) Their use of upland areas overlapped with other bands. Uplands had “use rights” agreed upon between bands, but were not considered to be owned by anyone in particular.

The area was crisscrossed with important Indian travel routes that were later incorporated into Euro-American settlement patterns. Among these were the Foster-Barlow trail that connected Mt Hood, Oregon City, Milwaukie and Portland. Generally these routes follow the valley floors and gaps between the lava domes.

Landscape Conversion

During the late 1800s and early 1900s, Euro-Americans gradually converted the forested landscape to a patchwork of farms, including cropland, pasture, and orchards. The soils of Rock and Richardson Creek watersheds were not ideal for farming, so they were not the first to be cleared and tilled. Interviews with long time residents of upper Pleasant Valley indicate that their grandparents practiced a combination of logging and subsistence agriculture rather than large-scale commercial farming. Dairy farming was fairly important in this area in the 1920s and 1930s. The early farmers of the area had to deal with these over-saturated soils by devising extensive tile drainage systems. A current resident of Pleasant Valley unearthed a hollow cedar

drainage pipe that dates back to the early 1900's (Olson, et. al., 2000). Farmers channelized creeks, drained wetlands, and built communities. At the turn of the twentieth century a local pottery industry based in upper Richardson Creek used local clay as source material and may have been responsible for some channel modifications.

Farming peaked just before World War II, and then gradually declined as the area became drawn into the post-war suburban housing boom. Large farms were subdivided again and again. Areas with relatively well-drained soils suitable for septic fields were developed as large lot (one half to two acres) home sites that are fairly common in the land use pattern today.

Recent Trends

Many former farms have reverted to early successional hardwood forests over the past 40-50 years. Other farms have shifted from food production to nurseries or Christmas trees. Statewide land use planning initiated in the 1970s brought a halt to new subdivisions in areas outside of established urban growth boundaries. Urban development has encroached on the west edge of lower Rock Creek. About 50 percent of both watersheds will likely be urbanized over the next two to twenty years. Damascus will become a densely developed "town center" according to present plans. Recent news articles point to a further expansion of the urban growth boundary to a point several miles east of Damascus in order to incorporate land suitable for industrial development.

The accompanying map on page 9 showing the current urban growth boundary and the urban reserve zone indicates the extent of this planned urbanization.

Historic Fish Counts and Distribution

The Euro-American history of the Clackamas River fishery dates from the late 1800s. At that time a commercial fishery was located at the confluence of the Willamette and the Clackamas Rivers. Harvests were recorded to be as high as 12,000 chinook salmon in 1894. In fact, prior to 1899 the Clackamas River was considered to be the premier spring chinook fishery in the entire Pacific Northwest (ODFW 1992). Hatcheries were developed in the Clackamas basin in the late 1800s, used primarily to augment spring chinook populations, which were already in decline. Large numbers of salmon and steelhead were introduced into the lower Clackamas in the 1950s and 1960s as attempted mitigation for passage problems at the PGE hydro complex near Estacada (Beyer, 1992). There are no published accounts of historic fish populations specific to Rock and Richardson Creeks.

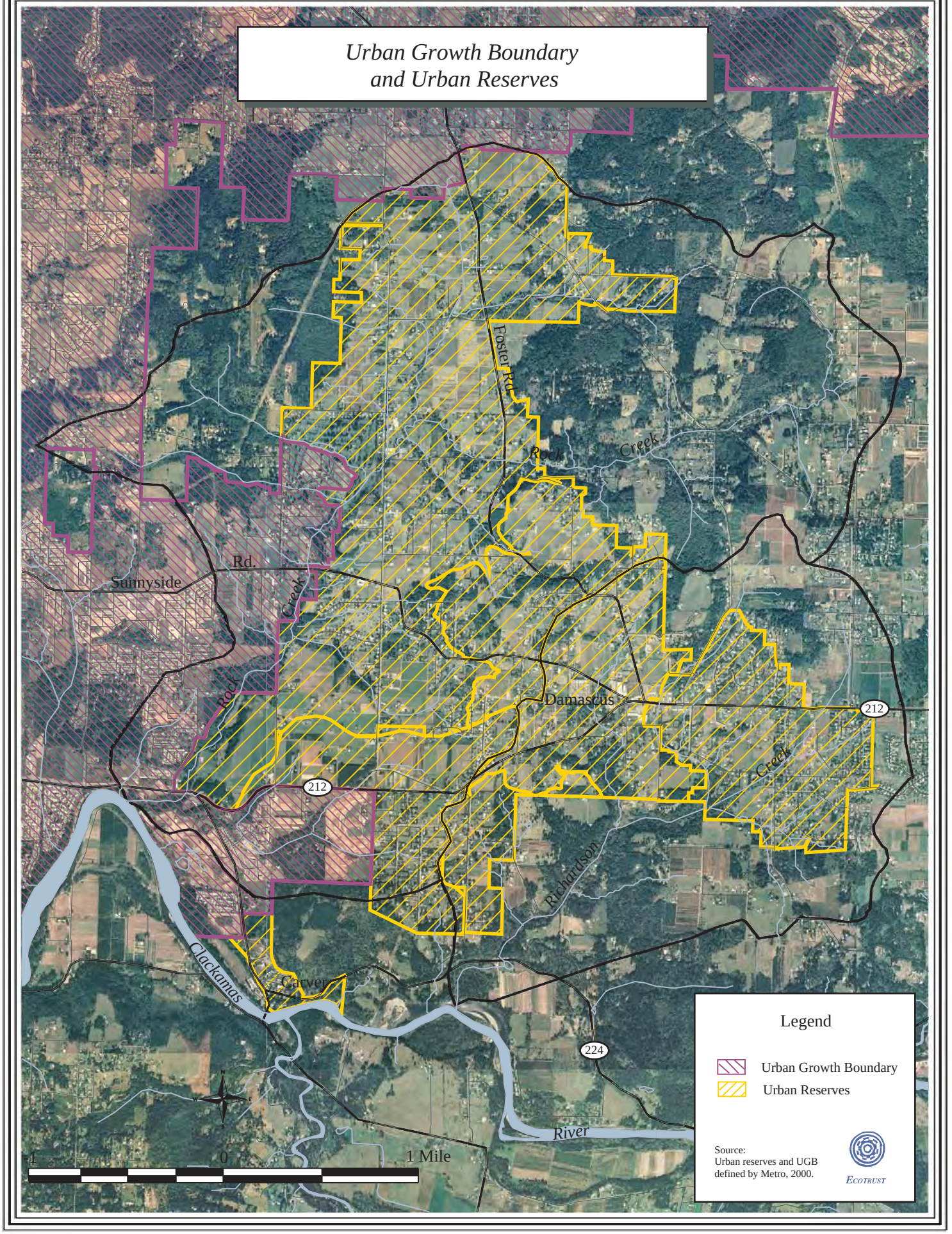
Historical Conditions Timeline

- 10,000-13,000 years ago: "Clovis" peoples arrive in the Rock and Richardson Creek area. Closed forest develops in the Cascade region.
- 300-10,000 years ago: Indian culture gradually develops new technologies and land use patterns. Deliberate burning of prairies and forests likely begins 4,000 years ago. Clackamas Band population at 2,500.
- 150-300 years ago: Age of European exploration and discovery reaches Northwest Coast. Trade between Europeans and Indians. Diseases begin to reduce Indian populations. Large fires sweep down Clackamas Basin, resulting in forest stand replacement over wide areas.
- 150 years ago: Settlers arrive across Oregon Trail, some crossing right through Rock and Richardson Creek watersheds. Indian populations severely reduced in size. Clackamas Band down to 80 people.

- 100-150 years ago: Euro-American settlers gradually clear forests of Rock/Richardson Creeks and establish roads, villages, and farms. Extensive drain tiling installed.
- 50-100 years ago: Area farms subdivided. Many are abandoned and return to forest cover.
- 25-50 years ago: Post-war suburban housing boom results in population growth in Rock Richardson Creek watersheds. Dense network of paved roads established, including culverts that block fish migration. Nurseries and Christmas tree farms displace food production.
- Present-25 years: Highway 212 and 224 widened. Urban development encroaches on the westside of Rock Creek watershed. Land use planning established. Salmon listed as threatened and Clackamas River Basin Council formed.

Recommendations for additional historical information

- See oral histories gathered from interviews of Pleasant Valley residents in Olson, S., et al, (2000).
- The Damascus Historical Society and the Oregon Historic Society may have more detailed available information.
- Interview long time residents to research past fish occurrence, stream channelization, and other issues.
- Contact the Northwest Pottery Research Center (503-287-6733) to assess the location and role of pottery industry in upper Richardson Creek.
- Examine historic photos from the Clackamas County surveyor's office (dating from 1941) and others made available from local residents.


Urban Growth Boundary
and Urban Reserves
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Creek
Rock
Damascus
212
212
Creek
Richardson
Clackamas
River
Carver
224
N
W
E
S
1
0
1 Mile
Legend
Urban Growth Boundary
Urban Reserves
Source:
Urban reserves and UGB
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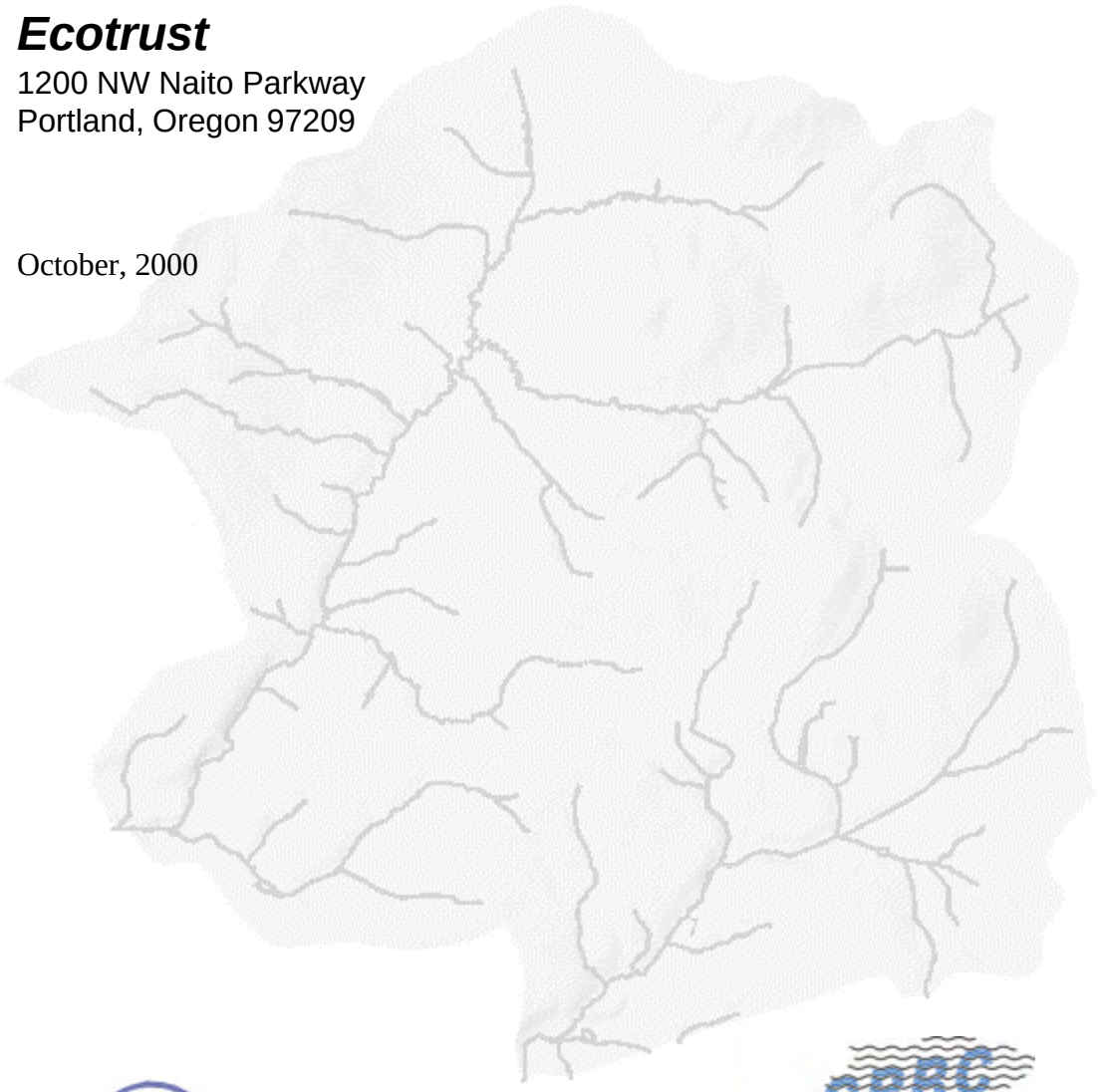

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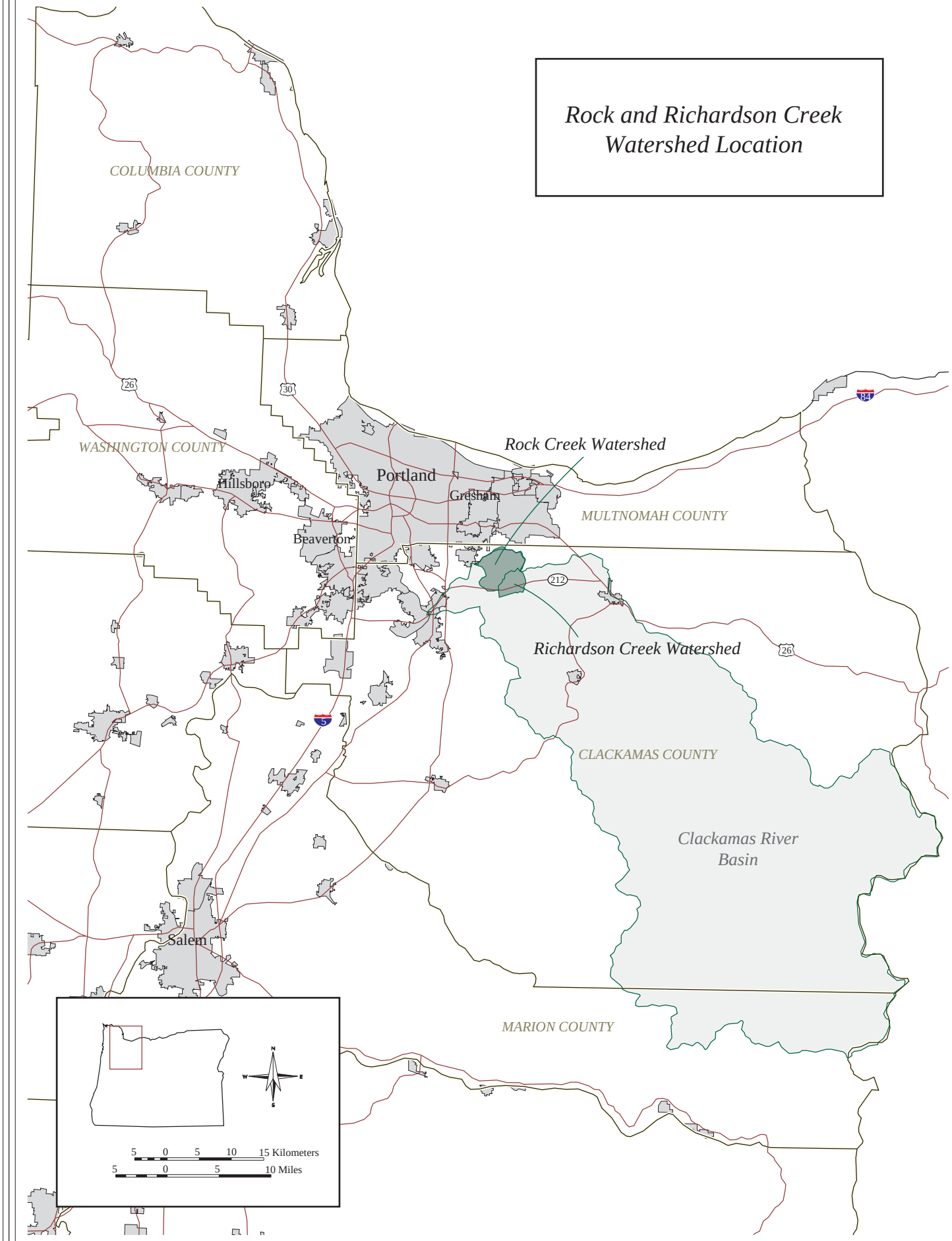
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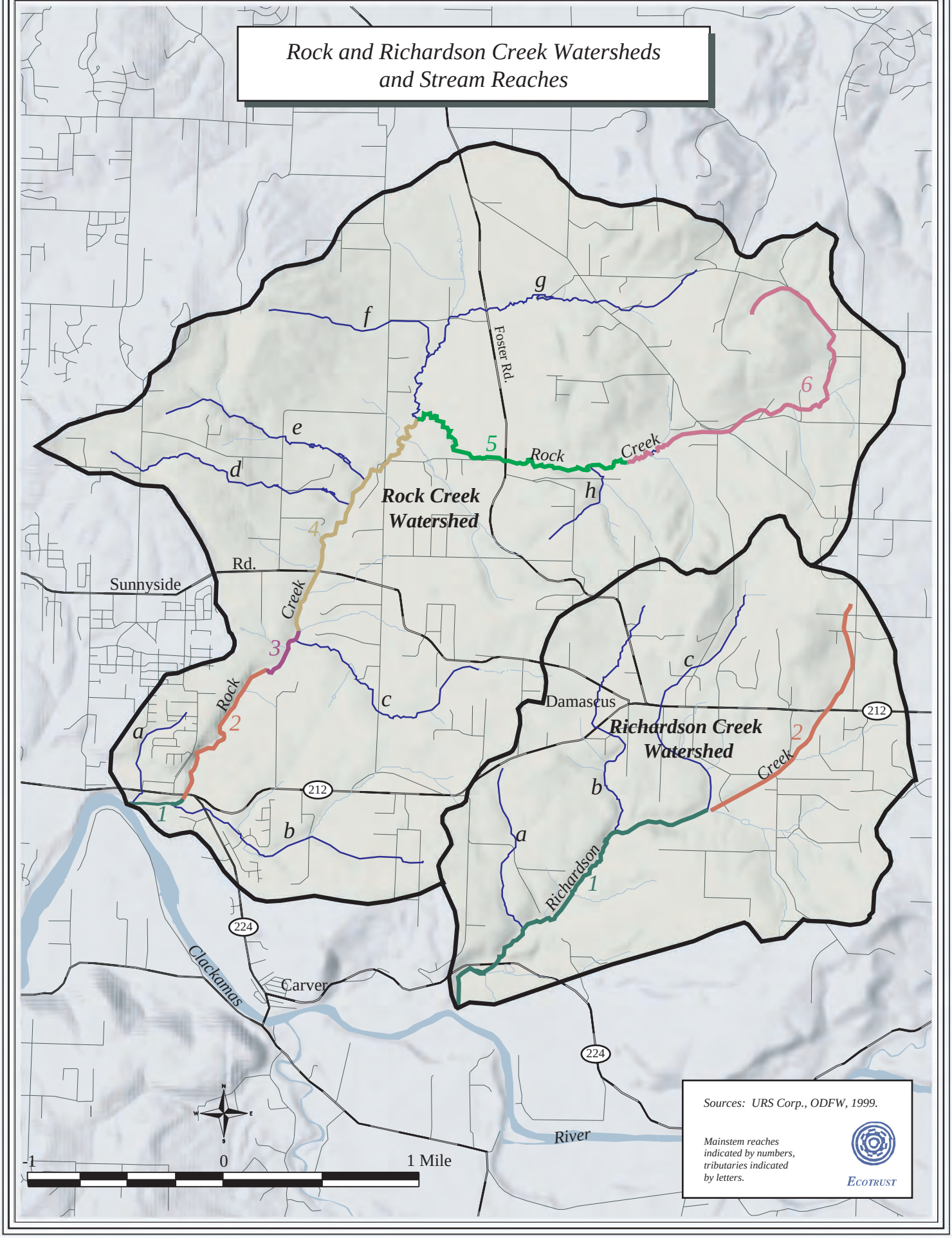
S
5 0 5 10 15 Kilometers
5 0 5 10 Miles


Rock and Richardson Creek Watersheds
and Stream Reaches
Rock Creek
Watershed
Richardson Creek
Watershed
Foster Rd.
Rock Creek
Rock Creek
Richardson Creek
Sunnyside Rd.
Damascus
Carver
Clackamas River
212
224
1
2
3
4
5
6
a
b
c
d
e
f
g
h
N
W
E
S
-1
0
1 Mile
Sources: URS Corp., ODFW, 1999.
Mainstem reaches indicated by numbers, tributaries indicated by letters.
ECOTRUST

HISTORICAL CONDITIONS

Background

Rock and Richardson Creek watersheds are located in a transition zone between the conifer forests of the Cascade Mountains and the oak/prairie grasslands of the Willamette Valley. Research into Government Land Office Surveys (GLO) by the Natural Resource Heritage program of the Nature Conservancy indicates that prior to Euro-American settlement Douglas-fir forest and woodland dominated most of the area of both watersheds. The uplands of the lava domes were characterized by closed canopy old growth Douglas-fir, grand fir, and bigleaf maple. Hazelnut, Pacific dogwood, vine maple, and Pacific yew composed the understory. The valley floors were similar, but also included western hemlock and western red cedar.

Flood plains along or near the Clackamas River had closed hardwood forests, including Oregon ash, cottonwood, alder, maple, and white oak. There were small patches of conifer, including Douglas-fir and western red cedar.

Upper Richardson Creek appears to have had quite a lot of open canopy Douglas-fir forest. This may have been an area more intensively managed with fire by native Americans. It would have included oak trees, and possibly ponderosa pine.

Patches of heavily burned forest were scattered throughout the area. These could have been created by Indians to facilitate hunting and food gathering, or may have resulted from white settlers clearing land for farms. The downcut canyons of lower Rock and Richardson Creeks would have had similar composition and structure to what we find there today, a mixed conifer and deciduous riparian woodland. A few old growth conifers still exist in lower Richardson Creek.

The Clackamas Band, related to the larger Chinookan language group of the lower Columbia River, were likely the primary residents of the Rock and Richardson Creek areas. They left little direct evidence of their presence, but their primary use of the area would have been fishing in the lower areas of both creeks. The current site of the BI-MART in Damascus was formerly a seasonal gathering area for native peoples. By burning the uplands periodically, they would have facilitated hunting and travel, as well as gathering of acorns, hazelnuts, and wild berries. Generally, the Chinookans had semi-permanent or seasonal village sites at key fishing areas (such as Willamette Falls.) Their use of upland areas overlapped with other bands. Uplands had “use rights” agreed upon between bands, but were not considered to be owned by anyone in particular.

The area was crisscrossed with important Indian travel routes that were later incorporated into Euro-American settlement patterns. Among these were the Foster-Barlow trail that connected Mt Hood, Oregon City, Milwaukie and Portland. Generally these routes follow the valley floors and gaps between the lava domes.

Landscape Conversion

During the late 1800s and early 1900s, Euro-Americans gradually converted the forested landscape to a patchwork of farms, including cropland, pasture, and orchards. The soils of Rock and Richardson Creek watersheds were not ideal for farming, so they were not the first to be cleared and tilled. Interviews with long time residents of upper Pleasant Valley indicate that their grandparents practiced a combination of logging and subsistence agriculture rather than large-scale commercial farming. Dairy farming was fairly important in this area in the 1920s and 1930s. The early farmers of the area had to deal with these over-saturated soils by devising extensive tile drainage systems. A current resident of Pleasant Valley unearthed a hollow cedar

drainage pipe that dates back to the early 1900's (Olson, et. al., 2000). Farmers channelized creeks, drained wetlands, and built communities. At the turn of the twentieth century a local pottery industry based in upper Richardson Creek used local clay as source material and may have been responsible for some channel modifications.

Farming peaked just before World War II, and then gradually declined as the area became drawn into the post-war suburban housing boom. Large farms were subdivided again and again. Areas with relatively well-drained soils suitable for septic fields were developed as large lot (one half to two acres) home sites that are fairly common in the land use pattern today.

Recent Trends

Many former farms have reverted to early successional hardwood forests over the past 40-50 years. Other farms have shifted from food production to nurseries or Christmas trees. Statewide land use planning initiated in the 1970s brought a halt to new subdivisions in areas outside of established urban growth boundaries. Urban development has encroached on the west edge of lower Rock Creek. About 50 percent of both watersheds will likely be urbanized over the next two to twenty years. Damascus will become a densely developed "town center" according to present plans. Recent news articles point to a further expansion of the urban growth boundary to a point several miles east of Damascus in order to incorporate land suitable for industrial development.

The accompanying map on page 9 showing the current urban growth boundary and the urban reserve zone indicates the extent of this planned urbanization.

Historic Fish Counts and Distribution

The Euro-American history of the Clackamas River fishery dates from the late 1800s. At that time a commercial fishery was located at the confluence of the Willamette and the Clackamas Rivers. Harvests were recorded to be as high as 12,000 chinook salmon in 1894. In fact, prior to 1899 the Clackamas River was considered to be the premier spring chinook fishery in the entire Pacific Northwest (ODFW 1992). Hatcheries were developed in the Clackamas basin in the late 1800s, used primarily to augment spring chinook populations, which were already in decline. Large numbers of salmon and steelhead were introduced into the lower Clackamas in the 1950s and 1960s as attempted mitigation for passage problems at the PGE hydro complex near Estacada (Beyer, 1992). There are no published accounts of historic fish populations specific to Rock and Richardson Creeks.

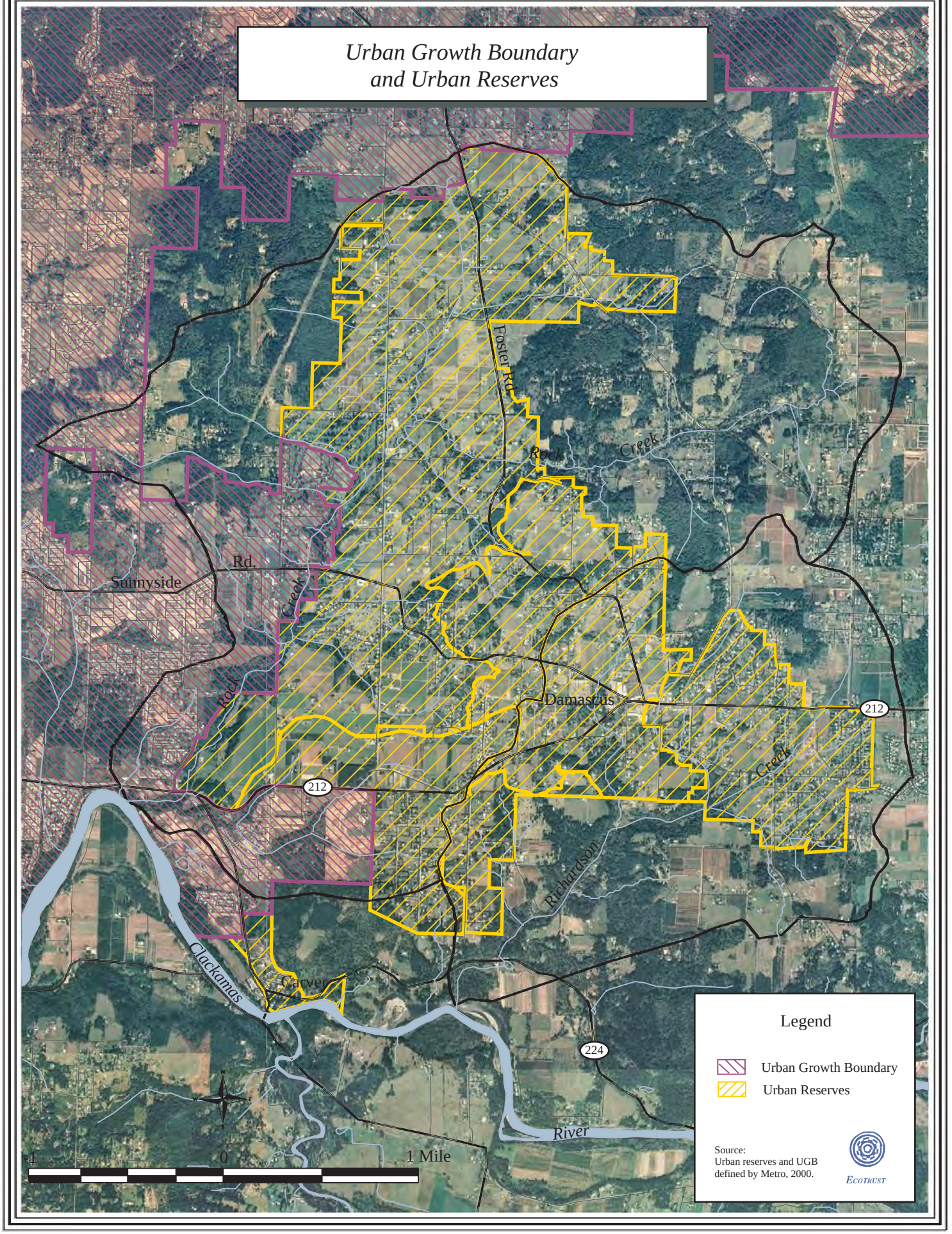
Historical Conditions Timeline

- 10,000-13,000 years ago: "Clovis" peoples arrive in the Rock and Richardson Creek area. Closed forest develops in the Cascade region.
- 300-10,000 years ago: Indian culture gradually develops new technologies and land use patterns. Deliberate burning of prairies and forests likely begins 4,000 years ago. Clackamas Band population at 2,500.
- 150-300 years ago: Age of European exploration and discovery reaches Northwest Coast. Trade between Europeans and Indians. Diseases begin to reduce Indian populations. Large fires sweep down Clackamas Basin, resulting in forest stand replacement over wide areas.
- 150 years ago: Settlers arrive across Oregon Trail, some crossing right through Rock and Richardson Creek watersheds. Indian populations severely reduced in size. Clackamas Band down to 80 people.

- 100-150 years ago: Euro-American settlers gradually clear forests of Rock/Richardson Creeks and establish roads, villages, and farms. Extensive drain tiling installed.
- 50-100 years ago: Area farms subdivided. Many are abandoned and return to forest cover.
- 25-50 years ago: Post-war suburban housing boom results in population growth in Rock Richardson Creek watersheds. Dense network of paved roads established, including culverts that block fish migration. Nurseries and Christmas tree farms displace food production.
- Present-25 years: Highway 212 and 224 widened. Urban development encroaches on the westside of Rock Creek watershed. Land use planning established. Salmon listed as threatened and Clackamas River Basin Council formed.

Recommendations for additional historical information

- See oral histories gathered from interviews of Pleasant Valley residents in Olson, S., et al, (2000).
- The Damascus Historical Society and the Oregon Historic Society may have more detailed available information.
- Interview long time residents to research past fish occurrence, stream channelization, and other issues.
- Contact the Northwest Pottery Research Center (503-287-6733) to assess the location and role of pottery industry in upper Richardson Creek.
- Examine historic photos from the Clackamas County surveyor's office (dating from 1941) and others made available from local residents.


Urban Growth Boundary
and Urban Reserves
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Creek
Rock
Damascus
212
212
Creek
Richardson
Clackamas
River
Carver
224
N
W
E
S
1
0
1 Mile
Legend
Urban Growth Boundary
Urban Reserves
Source:
Urban reserves and UGB
defined by Metro, 2000.
Ecotrust

SEDIMENT SOURCE ASSESSMENT

Background

Stream sediment results from erosion that may be part of a natural process or one influenced by cultural activities. It can be deceptively difficult to identify sediment sources and to distinguish natural from human-caused sources. Potential sources of erosion and sedimentation can be visually identified as gullying, landscape scars, road and bridge washouts, and risky cultural practices such as till agriculture on steep slopes. The relative risk of erosion can also be predicted as a function of soil type, slope and other factors.

Findings

No comprehensive data on sediment sources in Rock or Richardson Creeks were available for this assessment. Moreover, the ongoing stormwater study commissioned by Clackamas County Water Environment Services is not intended to comprehensively address erosion or stream sedimentation.

Stream sedimentation is a significant issue in parts of these watersheds, and high levels of silt, sand and fine organic matter may adversely impact successful spawning of both salmonids and lamprey in some areas (ODFW, 1999). Excess sedimentation was observed in lower Rock Creek, and is considered to be one of several factors creating sub-optimal salmonid habitat below the falls in Reach 1 (Fowler and Davis, 2000). Limited field observation indicates gully and surface erosion occurring in the steeper slopes of the Prairie Terrace zone west of Damascus currently under till agriculture, and in the steeper road-side ditches in the upland areas of Rock creek watershed as seen along Foster Road. Bank erosion and silt deposition is particularly significant in Reach 5 of Rock Creek (Wolfe, K. et al, 1999). Bank erosion in this particular portion of Rock Creek is degrading potential spawning and rearing habitat for cutthroat trout. Bank instability has been aggravated by the removal of riparian cover in this reach. Some bank erosion is also apparent in Upper Richardson Creek. The lack of adequate riparian buffers and vegetation in the upper reaches of both watersheds poses a risk of future sedimentation.

Soils and elevation were used to develop the map of Steep Slopes and Erosion Hazards, showing slopes greater than 25 percent and soils rated with a high erosion potential by the Natural Resource Conservation Service. The lower canyon areas of both Rock and Richardson Creeks include considerable overlap between steep slopes and high erosion potential soils. The mid-slope of the Boring lava domes in northeast Rock Creek watershed and northern Richardson watershed are also characterized by steep slopes.

The potential for stream sedimentation in both watersheds to increase in the future is quite high. A model developed by URS Corporation to estimate pollutant and sediment loads under future urbanization indicated a six-fold increase in suspended sediment loads (Wu and Fowler, 2000).

The channel condition assessment in the URS Corporation natural resources technical memorandum provides some specific information on individual reaches and tributaries in both Rock and Richardson Creek relative to potential sediment sources (Wolfe, K. et al, 1999, pgs. 5-9).

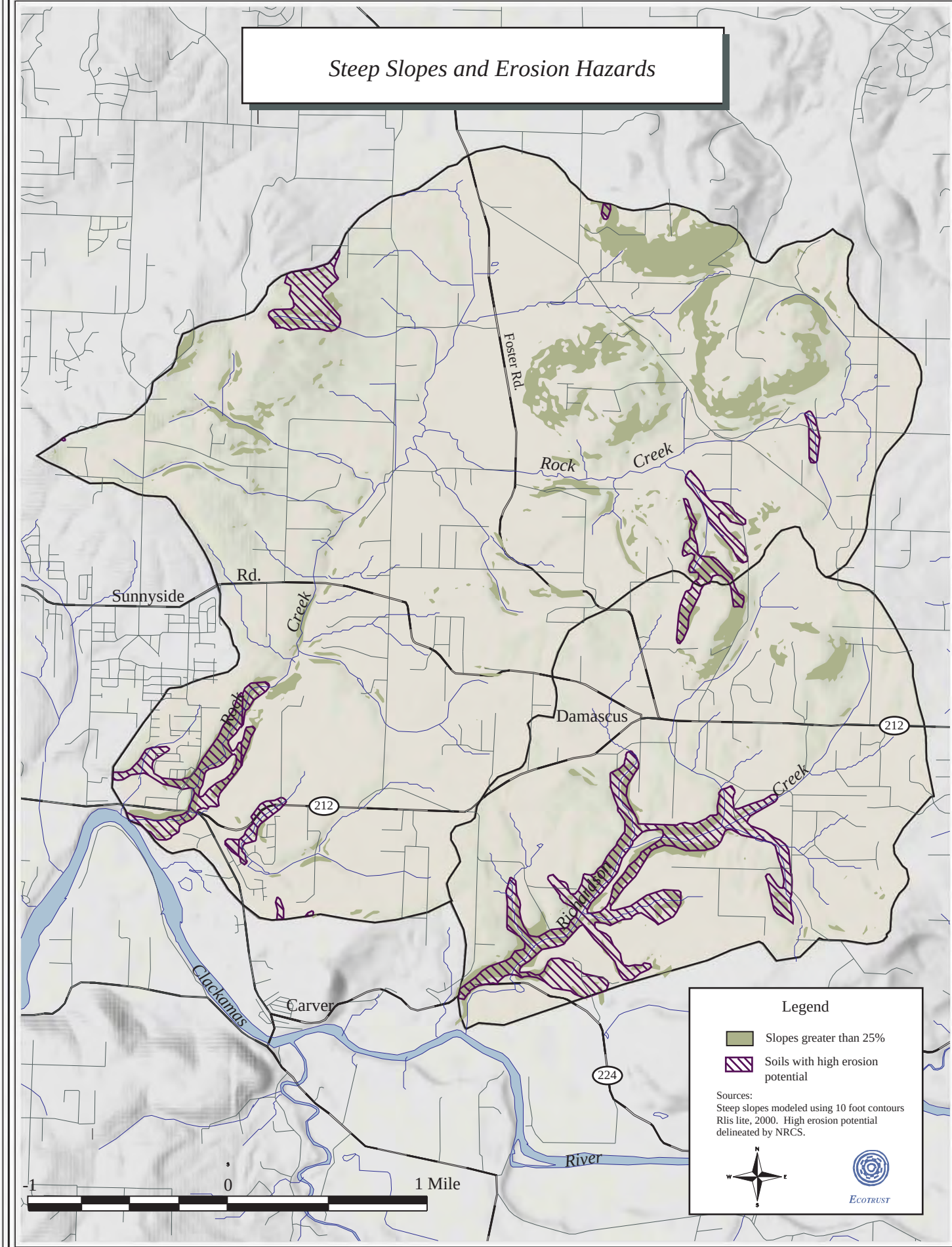
Information Gaps

- Empirical data on erosion and stream sedimentation is lacking.
- The relationship between observed erosion and stream sedimentation is unknown.

- ❖ Ancillary data necessary to assess sedimentation, such as peak stream flows, debris flow potential and landslide inventories, are lacking.
- ❖ The impact of new impervious surfaces and urbanization more generally on sedimentation has not been analyzed.

Recommendations

- ❖ Work with interested residents and landowners to identify visible erosion sites and cultural practices that may lead to sedimentation.
- ❖ Work to educate residents, landowners, and developers on best management practices to limit erosion and sedimentation and develop local groups to monitor activities.
- ❖ Work with appropriate planning agencies and landowners to protect areas with steep slopes and high erosion potential soils through maintenance and enhancement of stabilizing forest cover.
- ❖ Encourage tree planting in sensitive riparian zones.


Steep Slopes and Erosion Hazards
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Creek
Rock
Damascus
212
212
Creek
Richardson
Clackamas
Carver
224
River
-1
0
1 Mile
Legend
Slopes greater than 25%
Soils with high erosion potential
Sources:
Steep slopes modeled using 10 foot contours Rlis lite, 2000. High erosion potential delineated by NRCS.
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RIPARIAN AND WETLAND ASSESSMENT

Background

Riparian and wetland areas are two of the most critical elements within watersheds that influence the health of the aquatic ecosystem. As mentioned in the History section, Douglas-fir forests characterized much of Rock and Richardson Creek watersheds prior to Euro-American settlement. Riparian areas, or the vegetation zone that influences stream conditions, varied in width depending on the stream channel type and surrounding topography. For the purposes of this analysis, we have assumed a uniform width of 200 feet on either side of streams, regardless of channel type.

Findings

The characteristics of riparian vegetation within Rock and Richardson watersheds can be described in terms of three general geomorphic zones: (1) the upland lava dome and first order streams, (2) the valley floor second and third order streams, and (3) the lower creek canyon mainstems and floodplain.

The lava dome upland riparian zones are mostly forested, with second or third growth deciduous and coniferous trees in the overstory, mostly alder, maple, and Douglas-fir. Tree canopy ranges from 30 to 90 feet in height. Understory plants include hazel, dogwood, and blackberry brambles. In some areas, roads wind along these streams (Borges, Tillstrom) and thus disrupt the riparian cover. A utility corridor on Scouter Mountain cuts across the riparian zones of two upland creek sections. Culverted driveway crossings are numerous, particularly in the hills east of Pleasant Valley. In other areas, particularly in upper Richardson Creek tributaries, pastures and fields come right to the edge of streams.

The valley floor riparian areas are only moderately forested. Agriculture, subdivisions, golf course construction, and roads have heavily altered the valley floor riparian zones. Generally, these areas are characterized by a narrow (10 to 30 feet) band of shrubs and small trees (willow, dogwood, ash, and blackberry). Sections of valley streams have been channelized, further impacting the riparian zone. Some areas have no riparian cover at all, including parts of the golf course, the stream that flows through Damascus, and several stream sections in Pleasant valley. Other areas have orchards, nurseries, and berry fields crossing right over streams.

The lower creek canyon mainstems of both Rock and Richardson Creeks are mostly forested. This forest is fairly mature, and even includes individual old growth conifers, as well as cottonwood, alder, maple, and oak. The riparian zone of lower Richardson seems to be of higher quality than that of Rock, but both are in fairly decent condition. The floodplains along the Clackamas, at the mouth of both creeks, also have mostly forested riparian zones.

The table below showing riparian zone vegetation is a summary of vegetation types within 200 feet of all streams in the two watersheds. The 200-foot zone is an arbitrary estimation of the true riparian area. The land cover map data used for this analysis is designed for regional analyses and is not appropriate for assessments of stream shading or in-depth local riparian characteristics. Nonetheless, this broad analysis provides a rough picture of riparian conditions. The map of Land Use and Land Cover shows the distribution of broad vegetation and cover types across the entire landscape.

Riparian Zone Vegetation Characteristics by Watershed *

Land cover	Rock Creek		Richardson Creek	
	acres	percent total	acres	percent total
Urban / built up	121	9.10	58	9.30
Agriculture				
Low structure agricultural	316	23.88	100	16.10
High structure agricultural	14	1.03	27	4.40
Forest				
Closed canopy deciduous	239	18.02	38	6.11
Closed canopy mixed	261	19.70	215	34.41
Closed canopy coniferous	28	2.11	20	3.18
Open canopy deciduous	56	4.20	39	6.33
Open canopy mixed	74	5.58	18	2.83
Open canopy coniferous	3	0.22	1	0.17
Deciduous scattered	44	3.29	20	3.15
Mixed scattered	20	1.49	8	1.24
Coniferous scattered	3	0.22	0	0.06
Shrub				
Closed canopy shrub	40	2.99	16	2.51
Open canopy shrub	18	1.36	8	1.26
Scattered shrub	23	1.71	9	1.51
Grassland, golf courses, parks, meadows	67	5.06	46	7.41
Total (riparian zone)	1,324		623	

**riparian zone based on 200 foot buffer on all major streams. Source: Metro (1998).*

The URS Corporation natural resources technical memorandum provides some brief descriptions of riparian conditions by reach based on limited visual observations in both Rock and Richardson Creek (Wolfe, K. et al, 1999, pgs. 2-5).

More detailed riparian condition data will soon be available pending completion of Metro's regional riparian mapping project, which will assess vegetative and land use conditions along streams and rivers in analysis units directly tied to stream channel types. The resulting inventory and database is intended to support Metro's Title 3 fish and wildlife programs and meet Statewide Planning Goal 5 inventory standards. Rock Creek watershed is the pilot area for this project.

Wetlands

Historically, wetlands of Rock and Richardson Creeks were also likely dominated by forests, primarily ash, alder, cottonwood, and red cedar. The historic distribution of wetlands in this area is unknown. Maps showing the present distribution of wetlands come from the National Wetlands Inventory (USFW) and from Clackamas County Water Environment Services. Some wetland delineation was done as part of the Sunrise Corridor environmental impact statement.

Wetlands occur primarily as small patches located on the valley floors and along the floodplains of both creeks. Most are adjacent or near streams. They range in size from little more than 1,000 square feet to 12 acres, the largest being located on the floodplain of lower Richardson Creek. This shows on a 1961 USGS quad map as Lake Pigeon. It appears to be a grassy swamp, or bog surrounded by shrubs and forest. It may be intermittently flooded, and provide refuge habitat for salmonids and other aquatic wildlife.

Several wetlands appear to have been diked, drained, or otherwise altered as a consequence of housing development. Clackamas County has identified a cluster of four wetlands just east of the Highway 212-224 junction.

A number of artificial ponds have been created. There are several in the middle Richardson Creek area, south of Damascus. The golf course in northern Rock Creek watershed also has created at least two ponds. Another can be found along upper Rock Creek.

The Pleasant Valley floor has a large area of hydric soils that may indicate former wetlands. These are presently pastureland, and show sedges and other signs of surface water in winter. Interviews with long time residents in upper Pleasant Valley (Kelly Creek Watershed) indicate that the water table may have risen in this area as a consequence of removing the forest cover (Olson, et al, 2000).

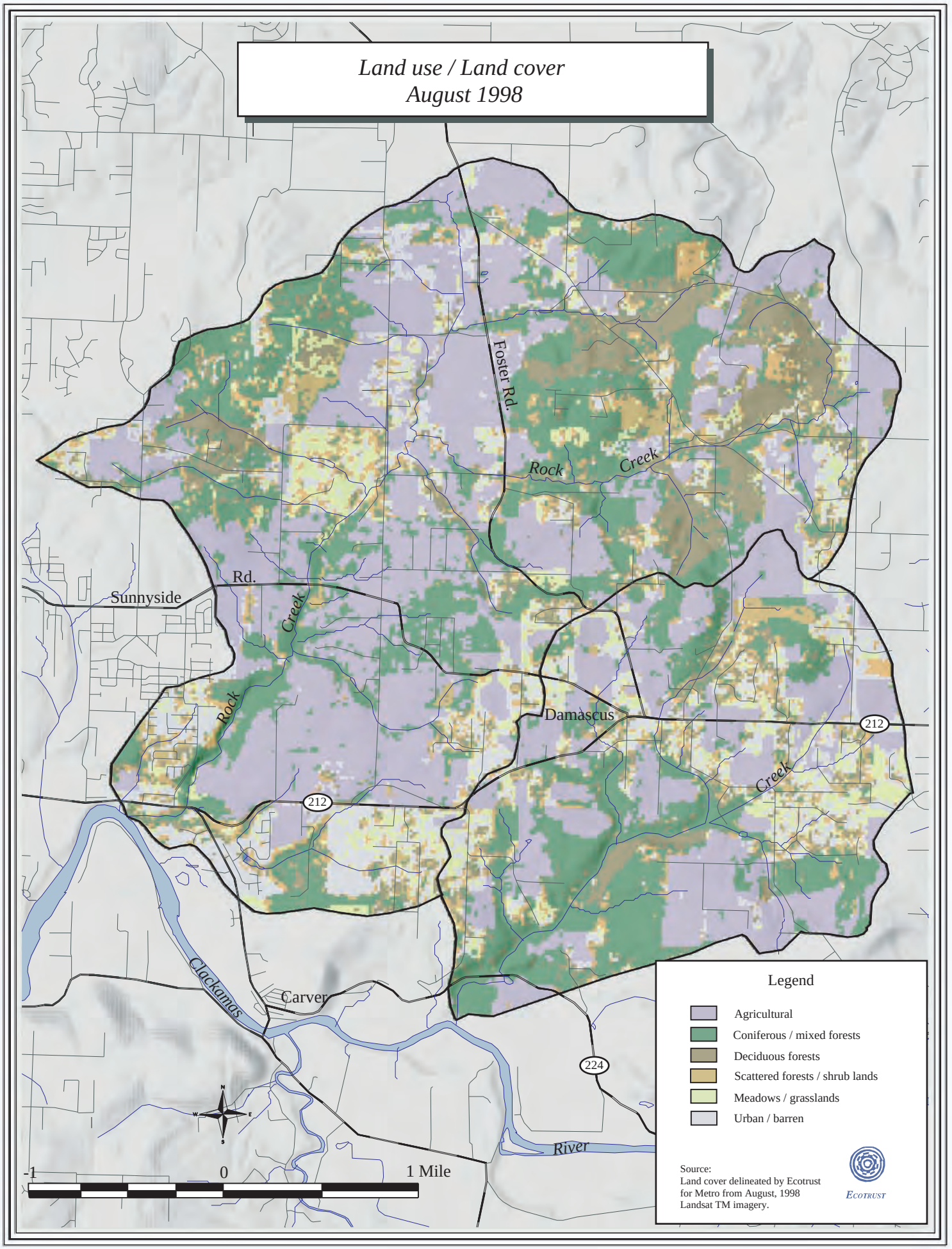
The location and distribution of known wetlands and hydric soils is shown on the accompanying map.

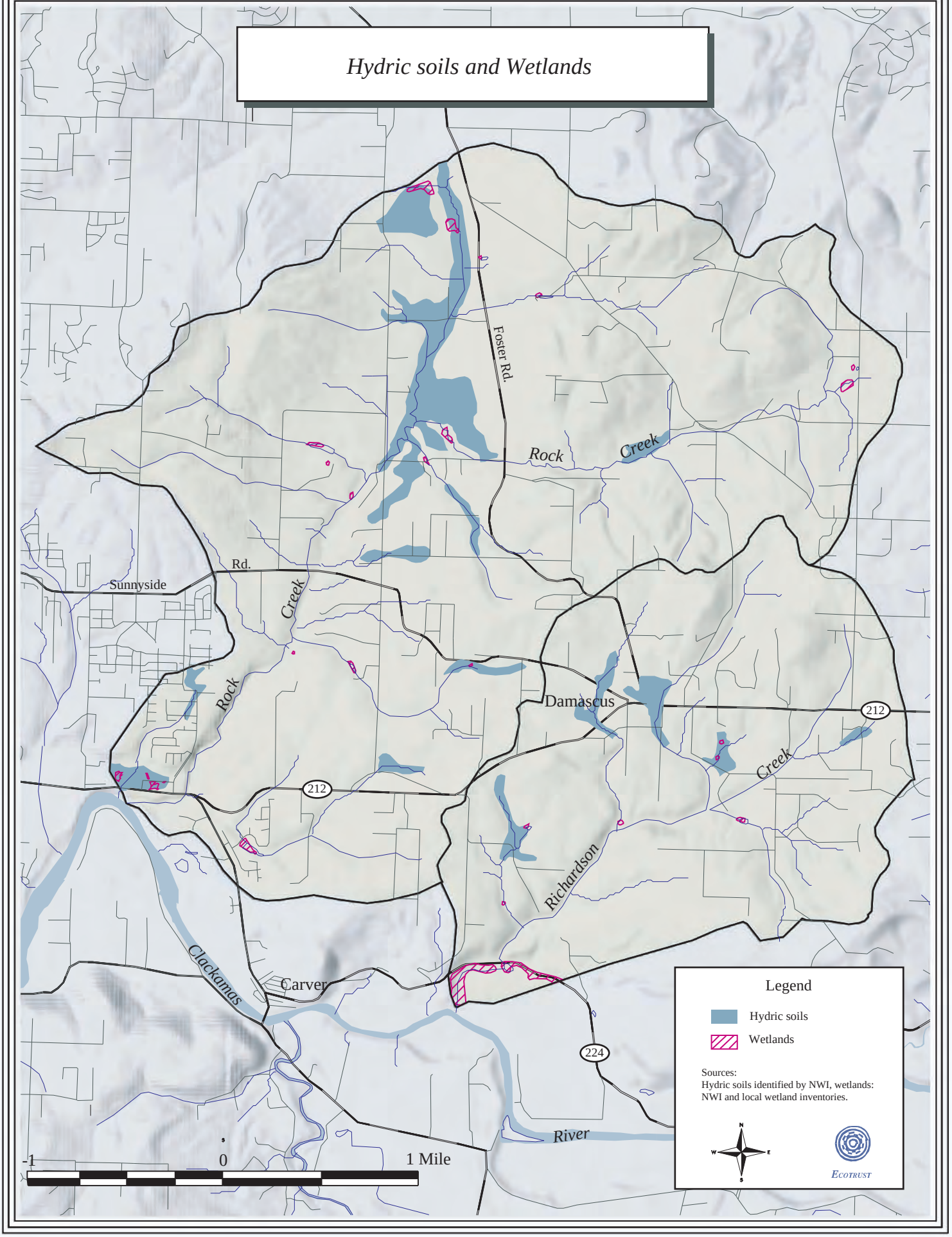
Information Gaps

- Riparian vegetation has not been classified or related to Channel Habitat Types.
- Riparian vegetation has not been broken into condition units.
- Stream shading has not been measured or analyzed.
- Field verification of riparian conditions, particularly on valley floors and in the lava domes, is lacking.
- Reference ecosystems to guide restorative work have not been developed.
- The link between hydric soils and former wetlands has not been confirmed.
- The condition of existing wetlands has not been analyzed.
- The ecological role of wetlands in these watersheds is not fully understood.

Recommendations

- Coordinate with Metro's ongoing regional riparian mapping project designed to assess vegetative conditions and land uses along streams and rivers.
- Develop further analysis to establish desired widths for restored functional riparian areas throughout each watershed.
- Research the historic presence and condition of wetlands in these watersheds.
- Research the role of hydric soils in storing water for summer base flows.
- Work with private landowners and community to protect and enhance wetland areas and seek to expand functional wetlands in areas with hydric soils.
- Consider wetland enhancement and stream protection below Foster road to include critical cutthroat habitat.


Land use / Land cover
August 1998
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Creek
Rock
Damascus
212
212
Creek
Clackamas
Carver
224
River
N
W
E
S
-1
0
1 Mile
Legend
Agricultural
Coniferous / mixed forests
Deciduous forests
Scattered forests / shrub lands
Meadows / grasslands
Urban / barren
Source:
Land cover delineated by Ecotrust
for Metro from August, 1998
Landsat TM imagery.
Ecotrust


Hydric soils and Wetlands
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Rock
Creek
Damascus
212
212
Creek
Richardson
Clackamas
Carver
224
River
-1
0
1 Mile
Legend
Hydric soils
Wetlands
Sources:
Hydric soils identified by NWI, wetlands:
NWI and local wetland inventories.
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Ecotrust

WATER QUALITY

Background

Water quality is assessed in terms of chemical, physical, and biological elements. The primary goal in assessing water quality is to identify the general condition, and to flag obvious areas of concern or deficiency.

There are a number of overlapping, often confusing federal and state regulations that influence standards for water quality in Rock and Richardson Creeks. The 1972 Federal Clean Water Act sets the overriding regulatory framework. Essentially, this law requires each state to set reasonable standards for each water body. It also asks states to list all rivers, lakes, and streams that fail to meet the standards. This is known as the 303(d) list, which is administered in Oregon by the Department of Environmental Quality (DEQ).

The State of Oregon has also established special status for the entire Clackamas Basin because it is an important drinking water source and provides critical habitat for many sensitive species of plants, fish and wildlife. This is known as the "Three Basin Rule," and limits new or increased point source discharges such as industrial or sewer outfalls.

Standards for streams are set based on "beneficial uses." The most demanding or sensitive beneficial use is the one that dictates where the standard is set. Beneficial uses for Rock and Richardson Creeks include domestic consumption, industrial supply, irrigation, livestock, salmonid and other aquatic habitat, and other wildlife. Of these, the requirements for salmonids tend to be the strictest. A complex set of standards applies to Rock and Richardson Creeks, as illustrated in the table below. The standards vary based on the time of year that salmonids may be spawning in the creeks.

Water Quality Standards*

Water Quality Parameter	**Non-spawning Periods** (mid-July to August)	**Spawning Periods** (August to mid-July)
Water Temperature	17.8°C (64°F) [a]	12.8°C (55°F) [a]
Dissolved Oxygen (mg/L)	8.0 [b,c], 6.5 [d], 6.0 [e]	11.0 [f, g] ,11.0 [h]
pH (units)	6.5 - 8.5	6.5 - 8.5

** State of Oregon water-quality standards for water temperature, dissolved oxygen and pH for the Clackamas River Basin, Oregon (table modified from Carpenter, draft report).*

mg/L = milligrams per liter
°C = degrees Celsius
°F = degrees Fahrenheit

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[a] *Based on the 7-day average of the daily maximum temperatures.*
[b] *Based on a 30-day mean minimum concentration.*
[c] *If conditions of barometric pressure, elevation, and temperature preclude achievement of the indicated concentration, then the 90% saturation standard applies.*
[d] *Based on a 7-day minimum mean concentration.*
[e] *Absolute minimum.*
[f] *I Absolute minimum, if intergravel DO is less than 8.0 mg/L.*
[g] *If conditions of barometric pressure, elevation, and temperature preclude achievement of the indicated concentration, then the 95% saturation standard applies.*
[h] *If the intergravel DO is greater than or equal to 8.0 mg/L.*

Findings

Various studies of water quality indicate that there may be some problems in both Rock and Richardson Creeks. High temperature, low dissolved oxygen (DO), excess sediment, excess nitrates, and high levels of bacteria have been found in either Rock or Richardson Creeks at some point. These measurements have not been systematic or detailed enough to warrant 303(d) listing to date. Generally, water quality appears to be adequate for salmonids and other beneficial uses, but there are some indications that Rock Creek may be close to the edge, particularly with stream temperature. In addition, a recent study by URS Corporation for Clackamas County developed a predictive model for what may happen to each creek as a consequence of urbanization. This model predicted that sediment loads will increase more than six times, total phosphorus loads will increase more than three times, and total copper loads will increase by more than ten times (URS Corporation, 2000b).

Water quality measurements to date have been sporadic and project driven, rather than systematic and long term. The table below summarizes key aspects of these studies.

Water Quality Studies in Rock and Richardson Creek

Study	Location	Dates	Parameters	Findings
ODFW	Lower Rock	Summer 1997-98	Temperature, DO, turbidity.	High summer stream temperature (15C), summer DO levels of 7-10 mg/L., problems with turbidity and sediment.
USGS	Lower Rock	Summer 1998	---	---
SWRP	Lower Rock	1992-00	Water chemistry, macroinvertebrates, stream channel habitat, and riparian plant.	High concentrations of fecal coliform, high stream temperature, problems with DO.
Jeanna Leavitt	Lower Rock	Summer 1997	Summer stream temperature.	High summer stream temperature (17C).
Pacific Rivers Council	Lower Rock and Richardson	1997-98	Macroinvertebrate sampling, IBI indexing.	Low diversity of macroinvertebrates (19 species), low to moderate IBI counts.
ODFW	Upper Rock	unknown	Visual survey of riparian conditions.	Bank erosion, sediment, lack of shade.
ODOT	Richardson	unknown	Septic tanks impacts.	High bacteria.
DEQ (Dames and Moore, 1992)	Richardson (near Damascus)	November 1989	Water Chemistry.	High levels of fecal coliform and streptococcus bacteria due to failure of Safeway and Dairy Queen septic systems.
DEQ	Richardson	1998	Potential candidate for Oregon 303(d) list of degraded streams based on sediment and nutrient problems.	Insufficient data to make the 303(d) listing.

Sources: Oregon Department of Environmental Quality; Oregon Department of Fish and Wildlife; Oregon Department of Transportation; Student Watershed Research Project; United States Geological Survey

While most major point sources of pollution are known (see map in Hydrology section), non-point sources are not well documented. Richardson Creek has a high level of nutrients, which cause algae blooms in the Clackamas River. The exact sources of nutrient inputs are not

documented, but are likely to be a combination of agricultural and suburban lot applications of fertilizer. Likewise, while there is insufficient water quality monitoring data to indicate the presence of specific chemicals, herbicides and pesticides are likely to be having impacts on water quality and require further study. There are some indications, generally, that stream-borne pesticides may interfere with salmon migration.

Unexpected turbidity has been observed in Rock Creek during low water. The instances of turbidity have not been well documented, and the causes are not known.

The failure of the Safeway and Dairy Queen septic systems near Damascus is a highly visible water quality issue and has resulted in direct discharge of sewage into Richardson Creek.

Information Gaps

- No clear conclusions can be drawn from the data available.
- No trend line is apparent.
- Variability of data over time is unknown.
- The full extent of water quality problems is not known.
- The sources or causes of apparent problems have not been clearly identified.

Recommendations for the Basin Council

- Design and implement a systematic and long term monitoring program for water quality. Given the urbanization that is planned for this area, this monitoring should be the responsibility of the governing jurisdiction(s) rather than the River Basin Council. However, the Council could be a partner in this effort.
- A proactive approach to an urbanization process that protects the aquatic ecosystem should be crafted. This means a working partnership between the County, Council, landowners, and developers that employs state-of-the-art techniques (i.e. wide stream buffers, sediment ponds, detention and treatment areas, grass swales, narrow streets, development of an urban stream canopy, etc.).
- Identify logical areas to immediately protect or restore rather than waiting for additional water quality data.
- Coordinate with Clackamas County Service District #1 and Clackamas County Soils District to repair and replace failing septic systems.

HYDROLOGY AND WATER USE

Background

Rock Creek drains a watershed with a total area of close to ten square miles (6,278 acres) and is the lowest contributing subbasin to the Clackamas River. Just upstream on the Clackamas River is the Richardson Creek confluence. The Richardson Creek watershed is less than half the size of the Rock Creek watershed with a drainage area of little more than four square miles (2,709 acres). The accompanying Stream Profile map shows the general topography of both watersheds and the relative elevation profile of each mainstem.

A combination of ground water discharge and direct surface flow of water from precipitation feed Rock and Richardson Creeks and their tributaries. The volume and rate at which water flows within these streams is influenced not only by precipitation, but by the rate of local groundwater recharge and extent of poorly drained or impervious surfaces. Groundwater bodies are recharged by infiltration of precipitation during the fall, winter, and spring months. A portion of groundwater is discharged as seepage into perennial streams, providing a relatively steady rate of flow in Rock and Richardson Creeks. The survival of salmonids in these watersheds depends on these steady moderated flows.

In general, removal of the tree canopy cover and underlying organic humus layer affects rainfall runoff processes by reducing interception and infiltration rates (Dunne and Leopold, 1978). The water balance of an area is affected by altering the vegetation cover. Precipitation in the form of rainfall or snowfall is intercepted by trees and vegetated areas. Water is stored in the leaves, stems and branches of the vegetation. Water moves through the vegetated cover through stemflow and throughfall, which provides water to the soil surface at a moderated rate. The upper organic and humus layers in the soil provide temporary water storage and allow infiltration of water into the soil to take place more gradually. Without vegetation cover and organic layers to moderate the rate of infiltration, the soils become quickly over saturated, turn to mud and become overland flow.

Average annual rainfall ranges in the Rock and Richardson watersheds ranges from 53 inches in the higher elevations to about 45 inches in the lower elevations, near the confluence with the Clackamas River. December, January and February are the wettest months and July, August and September are typically the driest.

Findings

The hydrologic pattern of these two watersheds has been considerably altered from earlier natural conditions. By the late 1800s, human influences had already altered the hydrologic regime as European settlers converted forestland to agriculture, pastureland, and orchards. Logging also took place on the relatively steep slopes of the surrounding forested buttes and valley foothills. Today, the hydrologic character of these basins are impacted by current land uses such as eroded streambanks from livestock grazing (Apostol et al., 2000), fragmented riparian corridors, water quality problems and altered stream flows.

The broad pattern of development has fragmented natural vegetation and impacted the water and habitat quality of the riparian zones. Some relatively large patches of upland forest habitat and vegetated riparian corridors are still intact. The largest is approximately 1,190 acres of contiguous forest located on Scouter Mountain. This area may provide an important groundwater recharge function, augmenting flows in the lower portions of Rock Creek.

The primary significant aquifers in the Rock and Richardson area are the Troutdale Formation and the Boring Lava. The Troutdale Formation includes multiple layers of permeable and less permeable layers resulting in relatively high degree of horizontal movement of water and large amounts of natural discharge through seeps and springs. The Troutdale Formation is overlain in places by the Boring Lava, which generally sits above the regional water table (USGS, 1965). Perched groundwater within the Boring Lava may be significant as a source of flow into Rock and Richardson Creeks. If so, it will be critical for salmonid habitat protection and restoration to maintain, if not improve the rate of infiltration of precipitation into the Boring Lava. Moreover, the Troutdale Formation contacts the surface in Richardson Creek and is likely to influence water quantity and flow in that stream system. Over two-thirds of the soils in Richardson Creek are well or moderately well drained, indicated that the creation of impervious surfaces through urbanization may have significant consequences for stream flow in Richardson.

Groundwater is also withdrawn directly through wells, which may be lowering the water table and reducing flow into streams. The accompanying map shows only the major groundwater wells, along with known point sources of pollution and discharge.

The hydrologic regime of Rock Creek and Richardson Creek basins will be further altered by future urbanization. Some of the anticipated changes include an increase in the amount of impervious areas resulting from paved roads, parking lots, housing developments, shopping malls, commercial and industrial developments, etc. Without sensitive planning and development practices, increase in impervious areas will likely result in a significant increase in the volume of surface water runoff, peak flow rates, low summer flows, water storage capacity, and inputs of pollutants to nearby stream systems. These changes in hydrologic conditions would be extremely deleterious to salmonid populations.

Stream Flow Characteristics

Empirical stream flow in Rock and Richardson Creeks is currently very limited. Average annual streamflow in Rock and Richardson has been estimated to be 21 cubic feet per second for Rock Creek and seven and one half cubic feet per second for Richardson Creek, based on correlation with measured flows from nearby Johnson Creek and other regional stream flow data (Dames and Moore, 1992).

Average Annual Flow and 50-Year Flood Flows

	Rock Creek	Richardson Creek
Average Annual Flow (cfs)	21	7.5
50-year Flood	1,216	495
Watershed Area (square miles)	10	3.6

Source: Dames and Moore, 1992

The only stream gauging station installed in either Rock Creek basin or Richardson Creek basin was a US Geological Survey station near Troge Road, which recorded flow data from 1957 to 1966. The average annual peak flow for this period was 170 cubic feet per second. The chart below indicates the variation in flow during the eight-year period.

Clackamas County Water Environment Services contracted with URS Corporation to conduct a hydrologic analysis of the Rock Creek basin in order to determine peak flow characteristics and identify flooding problems. Although the results were not available to incorporate in this assessment, the URS study used a proprietary version of EPA's Stormwater and Wastewater Management Model (SWNN) to assess the surface water drainage system of the basin. In order to calibrate stream flow measurements, however, model results need to be compared with empirical stream flow measurements, which are lacking.

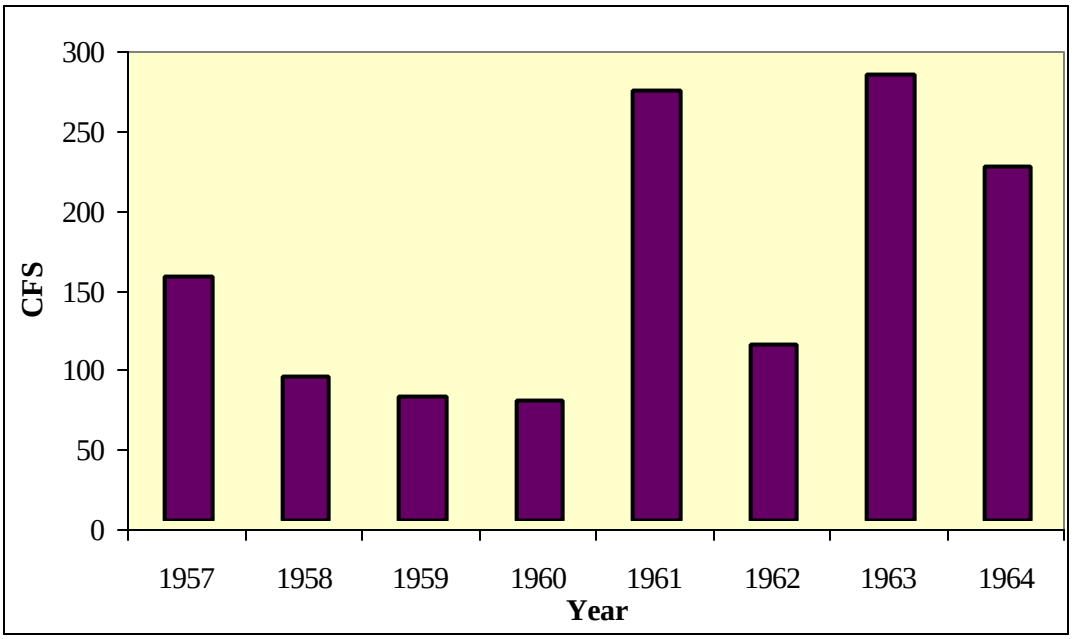
Flood Activity

Detailed knowledge of past flood activity within Rock Creek and Richardson Creek basins is also limited and requires further investigation. The most severe recorded floods within the past 100 years occurred in 1964 and 1996.

The proposed future urbanization of these two watersheds will have an effect on peak flows as well as low-flow conditions. The 2000 study by URS Corporation is designed to develop a hydraulic stormwater analysis of Rock Creek that will evaluate the implications of future development on the capacity of the existing drainage system.

As urbanization accelerates the proportion of impervious surface in the watershed will increase sharply. Without careful planning and implementation of significant mitigations, new development will result in a significant increase in the volume and peak flow rates of urban runoff.

USGS Flow Data for Rock Creek near Troge Road



Information Gaps

- The influence of the Troutdale Formation and the Boring Lava on water flow regulation in Rock and Richardson Creeks in not entirely understood.
- The extent and effect of groundwater wells on the water table and subsequently on stream flow is unknown.
- There is a lack of consistent empirical data on stream flows in both streams.
- The full extent of the floodplain has not be delineated or mapped in either watershed.
- The relative value of different areas of the watersheds for infiltration and storage of precipitation is not completely understood.

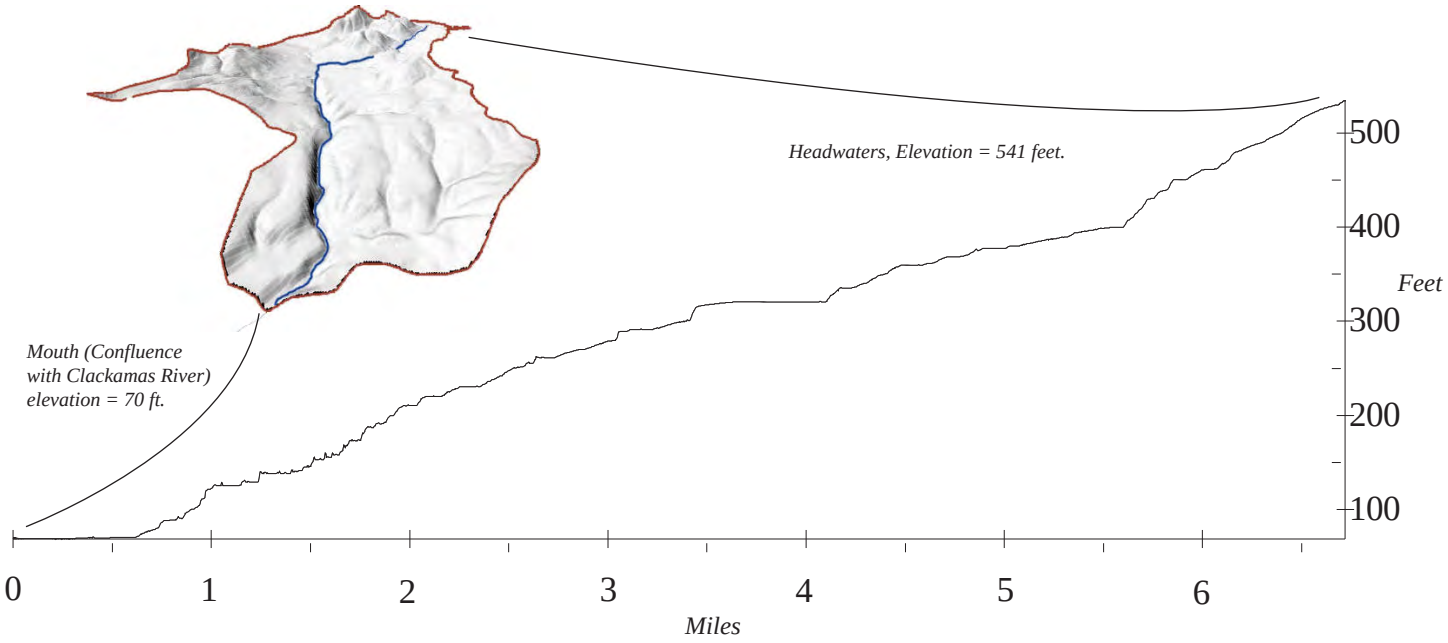
Recommendations for the Basin Council

- Work with partner agencies to design and implement a systematic and long term monitoring program that develops and empirical baseline for water flows.

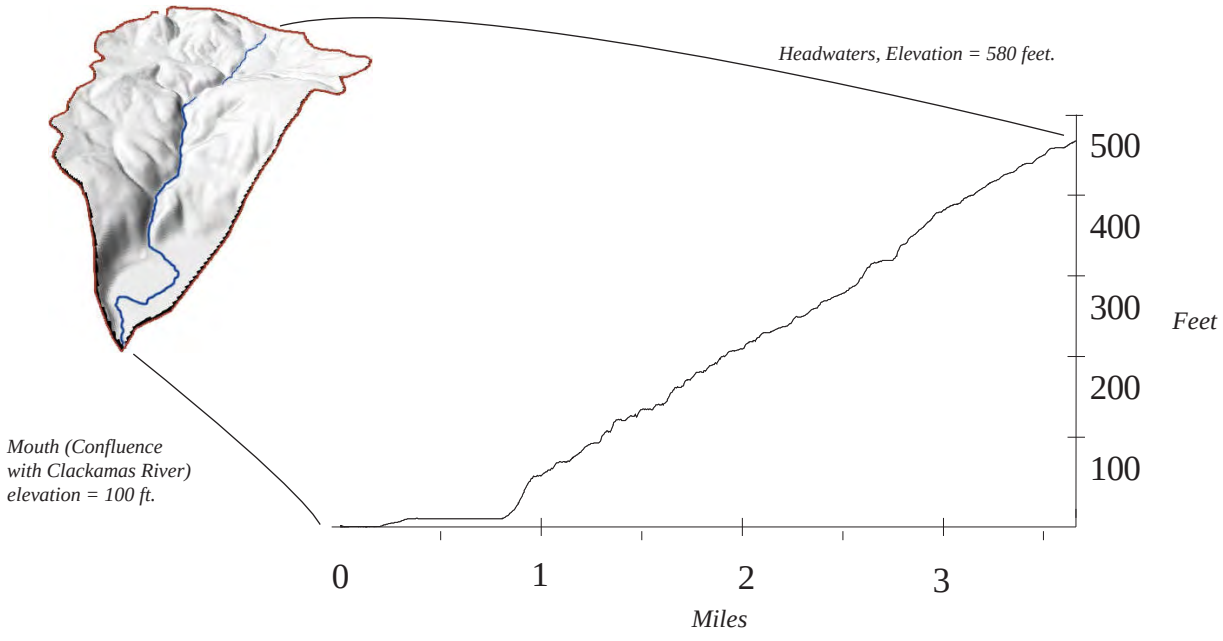
- ❖ Work with the County, Council, landowners, and developers to develop a proactive approach to stormwater runoff issues associated with urbanization process including state-of-the-art techniques that reduce impervious surfaces, delay the introduction of stormwater into streams and direct stormwater directly into groundwater recharge.
- ❖ Work with planning agencies to protect areas with high existing values for capture and infiltration of precipitation, including the Boring Hills and well and areas with moderately well drained soils.

Stream Profiles

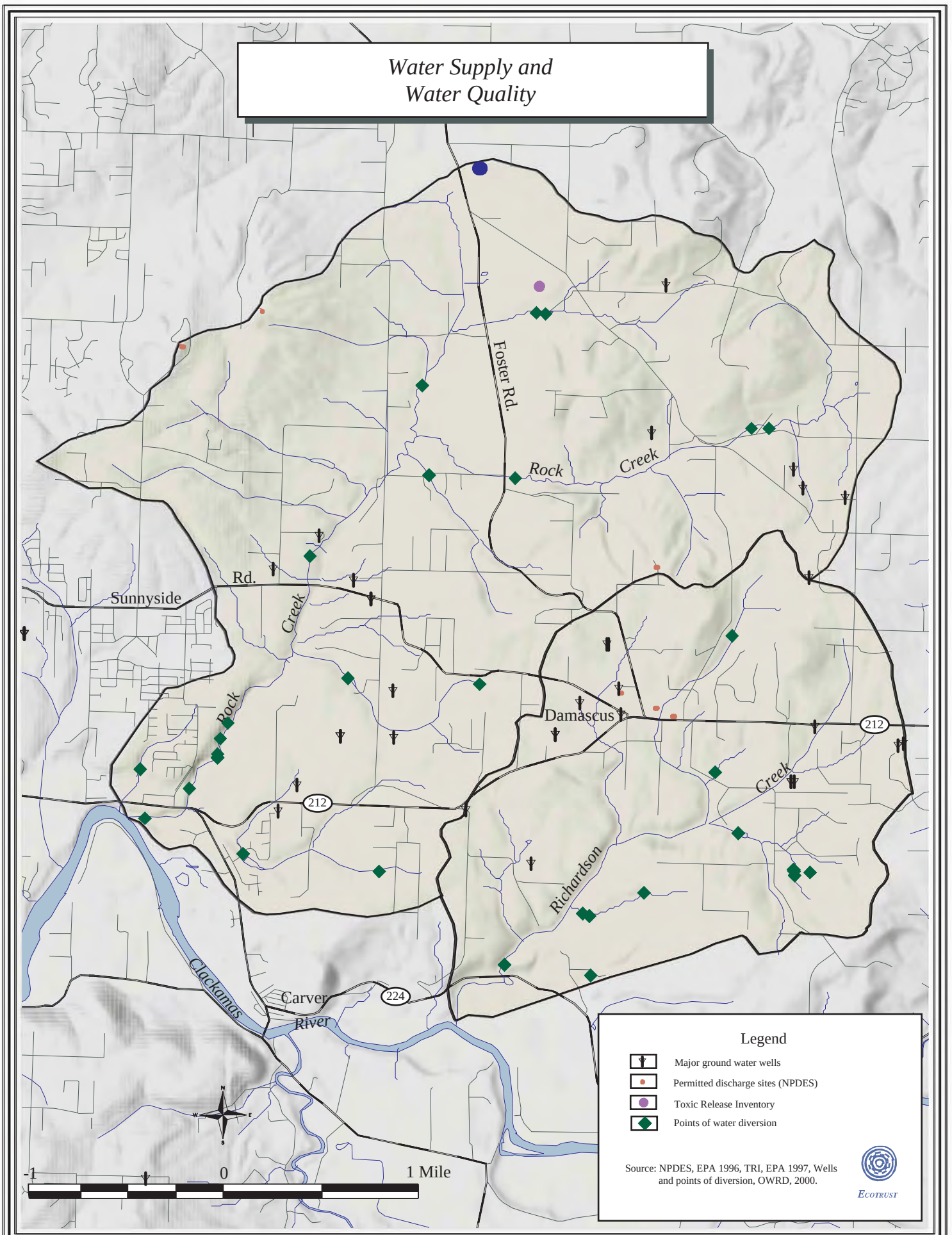
Rock Creek Watershed and Mainstem Profile



Richardson Creek Watershed and Mainstem Profile



Sources: Elevation data extracted from RLIS lite 10 foot contours, stream profiles modeled by Ecotrust, fall, 2000. X and Y axes not proportional.


Water Supply and
Water Quality
Foster Rd.
Rock
Creek
Rd.
Sunnyside
Creek
Rock
Damascus
212
212
Creek
Richardson
Clackamas
River
Carver
224
Legend
Major ground water wells
Permitted discharge sites (NPDES)
Toxic Release Inventory
Points of water diversion
Source: NPDES, EPA 1996, TRI, EPA 1997, Wells and points of diversion, OWRD, 2000.
Ecotrust
-1
0
1 Mile

WATERSHED ISSUES AND CONCERNS

Every watershed has issues unique to its location, land use pattern, history, and ecology. Rock and Richardson Creeks have been extensively studied and analyzed over the past few years, and these studies have uncovered a number of issues and concerns. The following is a list of some of the primary issues and concerns that have been identified by the Clackamas River Basin Council, community members, and individuals representing agencies and organizations that have done research in Rock or Richardson Creek basins.

Water Quality Issues

- Elevated water temperatures. Riparian areas in Upper Rock and Richardson Creek have been either reduced or completely eliminated by a combination of agriculture and infrastructure development, reducing stream shading and increasing water temperatures. This is especially evident along the Highway 212 corridor, where there is no shading of the stream corridor as a result of the lack of sufficient riparian cover.
- Pesticides and herbicides. Water quality studies have identified more than a dozen different pesticides and compounds in Rock and Richardson Creek (Carpenter, draft).
- Low dissolved oxygen in Rock Creek. Water quality studies have indicated that dissolved oxygen levels in Rock Creek are below that necessary to sustain anadromous fish (ODFW, 1999).
- Severe sedimentation problems in both Rock Creek and Richardson Creek result from erosion, channel incisions, and stormwater runoff aggravated by a lack of riparian vegetation.
- Non-point and point source pollutants. Inputs of non-point and point source pollutants are expected to increase as a result of future urbanization and development (Wu and Fowler, 2000).
- Agricultural runoff, roadside chemical applications and urban runoff all have negative effects on water quality.
- Consistent and comprehensive water quality and basic hydrologic monitoring data are lacking for both Rock and Richardson Creek watersheds.

Water Quantity Issues

- Water withdrawals (surface and groundwater).
- Low summer flow conditions unsuitable for fish have been noted in both Creeks, and have caused elevated water temperatures and low dissolved oxygen in Rock Creek.
- High winter flows are anticipated to increase as urbanization increasing impervious areas in both watersheds and stormwater becomes direct runoff instead of infiltrating into the ground as water storage. High winter flows result in limited fish refuge.
- Flood plains have not been delineated in either Rock or Richardson watersheds. Adequate flood plain mapping is crucial to balancing watershed health and human community safety with new development in both watersheds.
- Localized flood problems may result from several known undersized culverts in both Rock and Richardson Creek.

Channel Modifications

- Lack of Information on problem culverts on private land necessary to fully assess channel modification problems.
- Erosion and sedimentation problems result from a lack of riparian vegetation along large sections of stream corridors in both creeks and can lead to siltation of gravel beds critical to salmon spawning.
- Several natural and artificial stream barriers block migration of fish species in both creeks. A natural waterfall near the mouth of Rock Creek prevents fish from migrating upstream. A gravel bar at the confluence of Rock Creek and the Clackamas River may also seasonally impede fish migration. A natural debris dam inn Richardson Creek may partially block fish passage. There are numerous culverts and road crossings that may block fish passage in both basins.

Urbanization

- Perhaps the overriding issue that looms over the future of Rock and Richardson Creek Watersheds is the scheduled urbanization of approximately 50 percent of the land area over the next two to twenty years. Future development may result in several watershed impacts.
  - Traffic problems are already severe in some areas and may worsen with future growth. Moreover, new roads and road widening will increase the amount of impervious area and may affect stormwater drainage. The proposed Sunrise Corridor, which is in the final EIS stage, will likely have significant implications to watershed and ecosystem health.
  - Greater road density could result in excessive road-stream crossings and further habitat fragmentation. Title 6 of Metro's Urban Growth Management Functional Plan requires urban street densities in new urban reserves and promotes street connectivity.
  - Consistent water quality protection has been lacking and is addressed only through a complex multi-jurisdictional institutional framework. Metro and the Clackamas County Service District #1 have jurisdiction only within the UGB. Beyond the UGB streams are protected only through forest harvest rules on forested lands and largely voluntary practices on agricultural lands.
  - Urban development will require new utility lines for water, sewage, and power. The placement of these lines could have a major impact on streams and wildlife habitat. A transition away from septic to sewer systems may improve water quality in some areas, but the Clackamas County Service District #1 will likely provide sewer (and stormwater) systems when areas are formally annexed into the UGB. Prior to that sewer service will only be provided in response to a State declared health hazard.
  - The installation of new roads and parks may introduce new points of public access to creeks, with possible human health implications.
  - A proposed site for the future Damascus Town Center is located just upstream of sensitive anadromous salmonid habitat in Richardson Creek. Development will result in an increase in the amount in paved surfaces and impervious areas. Precipitation in these areas becomes direct runoff and may increase flow rates in nearby streams. Runoff from parking lots and surrounding urban areas may cause surface water and water quality problems downstream including siltation of salmon spawning gravels.

- There is a lack of comprehensive regulatory authority for these watersheds. Clackamas County can only regulate zoning and related development. It has no authority over the agricultural and forest management practices in these watersheds.

❖ Several existing plans and authorities guide future urbanization.

- Damascus Town Center planning
- Pleasant Valley master planning - Metro
- Rock Creek concept plan
- Happy Valley annexation
- Planning beginning in Fall 2000.

Fish and Aquatic Habitat

❖ Endangered Species Act affects salmon species in Rock Creek and Richardson Creek and will have significant implications for future development within these two watersheds. Rock Creek and Richardson Creek anadromous fish species are part of the Lower Columbia Evolutionary Significant Unit (ESU) as determined by the National Marine Fisheries Service (NMFS). Within the Lower Columbia ESU, steelhead (*Oncorhynchus mykiss*) were listed as a threatened species on March 19, 1998. Chinook salmon (*Oncorhynchus tshawytscha*) was listed as a threatened species on March 24, 1999. Coastal cutthroat trout (*Oncorhynchus clarki clarki*) were proposed threatened in April of 1999 for the Southwest Washington and Lower Columbia River ESU. NMFS determined that listing was not warranted for coho salmon *(Oncorhynchus kisutch*) within this ESU however, coho were designated as a "candidate" for listing due to concerns over specific risk factors. These listings will have significant implications for future development within these two watersheds.

❖ Degraded riparian and aquatic habitat. Large sections of the original riparian habitat along Rock Creek and Richardson Creek no longer exist, are fragmented or are severely degraded as a result of human impacts and natural causes. Human impacts include road building, golf courses, agriculture, grazing of livestock down to the stream channel, urbanization and housing developments. Problems associated with poor riparian vegetation cover include severe sedimentation problems, erosion, elevated water temperatures, limited streamside cover and unstable streambank conditions.

❖ A small isolated population of resident cutthroat in one of the upper reaches of Rock Creek is at a high risk of extirpation.

Wildlife Habitat and Open Space

❖ Fragmentation of wildlife habitat corridors. The habitat corridors between the forested buttes in Rock Creek and Richardson Creek basins need to be maintained and enhanced where fragmentation has occurred, and future development needs to address wildlife needs by minimizing intrusions in these natural corridors.

WATERSHED CONDITION SUMMARY

Background

Rock and Richardson Creek Watersheds are stressed, but not ruined ecosystems. Land use activities over the past 150 years have degraded conditions for anadromous fish, as well as other wildlife. This is an unfortunate result of building homes, communities, and farms among the hills and valleys without an inclusive and comprehensive plan for maintaining watershed health and function. In spite of the changes to the land that have been made, anadromous salmon and other wildlife still find suitable habitat in these watersheds. How this *habitat can be protected and improved while accommodating future urban development, is the central question.*

Summary of Findings

The following is a brief summary of what we know about the condition of these two watersheds.

- Anadromous and resident salmonids still make use of significant portions of both creeks. Three salmonid "hot spots" have been identified.
- Water quality and quantity (in summer) appear to be barely adequate for salmonids.
- Both natural and artificial barriers to fish are present.
- The historic forested character of the land has been radically altered. Only 42 percent of the land cover is presently forest, and nearly all of this is second or third growth and dominated by hardwoods.
- Riparian areas are in fairly good shape in the lower mainstem canyons, but in very poor condition on the valley floors. The lava dome uplands are a mixed picture, with areas of intact forest and other areas fragmented by fields or roads.
- Richardson Creek appears to have better fish habitat than Rock Creek.
- The channel habitat types found in these watersheds are relatively resilient and can be restored.
- Future urbanization has potentially severe implications for fish and wildlife habitat, water quality, water quantity and flow, and general watershed health.

Summary of Missing or Unavailable Information

The research to develop this assessment uncovered a number of information gaps that, if filled, could help the Clackamas River Basin Council in its efforts to protect and improve these watersheds

- Water quality testing has been sporadic and project driven. Long term measurements and monitoring are needed. There are no long term water quality monitoring programs other than high-school students collecting water quality data on Lower Rock Creek once every summer and fall through Saturday Academy and the Oregon Graduate Institute Student Watershed Research Project (SWRP).
- The hydrology of these watersheds is still not well understood. Where and how much aquifer recharge is taking place? How do the soils store and release water to the creeks? Where are springs located?
- To what extent have streams been channelized or altered?
- Do private culverts block fish passage or pose flood hazards? If so where?

- The condition of existing wetlands has not been analyzed, nor is the original role of wetlands understood. What was the former extent of wetlands? Does the presence of large areas of hydric soils, particularly in upper Pleasant Valley, indicate former wetlands? If so, were these forested or more open?
- Is the channel habitat classification by Metro accurate?
- Where do water quality problems originate?
- Field-verified and site-specific information on the delineation and condition of riparian areas is lacking, and stream shading has not been measured or analyzed. What is the structure and composition of riparian vegetation and its influence on water quality?
- What was the historic width of riparian zones for each stream segment and how does that compare to current conditions?
- To what extent is sedimentation a problem, and where does sediment originate?
- Index of biological indicator (IBI) monitoring has been short term to date, and data is inconclusive.
- What were historic anadromous salmonid population levels in these watersheds?
- Reference ecosystems to guide restorative work have not been developed.

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Appendix I

STATUTORY FRAMEWORK

The following is a list of the primary federal, state and local legislation and management plans that affect activities within the Rock Creek and Richardson Creek watersheds.

Federal Legislation

- Endangered Species Act.
  - Steelhead (Oncorhynchus mykiss): Listed as a threatened species on March 19, 1998 within the Lower Columbia ESU.
  - Chinook Salmon (Oncorhynchus tshawytscha): Listed as a threatened species on March 24, 1999 within the Lower Columbia River ESU.
  - Coastal Cutthroat Trout (Oncorhynchus clarki clarki): Proposed threatened in April of 1999 for the Southwest Washington and Lower Columbia River ESU.
  - Coho salmon (Oncorhynchus kisutch) On July 25, 1995, NMFS determined that listing was not warranted for this ESU. However, the ESU is designated as a candidate for listing due to concerns over specific risk factors.
- Clean Water Act of 1972 (US EPA) and Amendments.

State Legislation/Plans

- State of Oregon: Oregon Plan for Salmon and Watersheds, 1998.
- Oregon Department of Environmental Quality (DEQ) water Quality Conditions/DEQ 303(d) list, 1998 Water Quality Limited Streams, TMDLs.
- Oregon Water Resources Department (OWRD) water rights and water diversions.

Local Legislation/Plans:

- Metro Title 3 (also referred to as Metro's Stream and Floodplain Protection Plan) adopted in 1998.
- Metro Urban Growth Management Functional Plan.
- Metro Goal 5 buffer requirements prevents/restricts development within the 100-year floodplain.
- Clackamas County Title 6 Surface Water Regulations.
- Clackamas County stream protection ordinance (used to protect riparian vegetation).
- Three Basin Rule: the Clackamas River downstream of both Rock and Richardson Creeks is currently used for drinking water. This indicates that the Clackamas River must have acceptable water quality and brings the "Three Basin Rule" into effect.
- (OAR 340-41-470(1)). The rule states: "In order to preserve or improve the existing high quality water for municipal water supplies, recreation, and preservation of aquatic life, new or increased waste discharges shall be prohibited, except as provided by this rule."
- Pleasant Valley master planning (Metro).
- Rock Creek concept plan.
- Happy Valley annexation.

Appendix II

ANNOTATED BIBLIOGRAPHY SPECIFIC TO ROCK AND RICHARDSON WATERSHEDS

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Beyer, M.A. 1992. Clackamas River Native Fish Stock Analysis: Late Winter Steelhead and Late Run Coho Salmon. Mt Hood National Forest, Clackamas Ranger District, Estacada Ranger District.

Study focuses on species above North Fork Reservoir.

Carpenter, K.D. (Draft). Basinwide Assessment of Nutrients, Algae, and Water Quality Conditions in the Clackamas River Basin, Oregon. U.S. Geological Survey, Portland, OR. Project # OR176.

Hard copy report including text, maps, figures and tables. Contact Person: Kurt Carpenter.

Dames and Moore. 1991. Sunrise Corridor Draft Environmental Impact Statement: Geotechnical Study, Clackamas County, Oregon. Prepared for the Oregon Department of Transportation. Job No. 4117-032-020. 25 p. plus maps and tables.

Hard copy report including text, maps.

One in a series of Environmental Impact Statements (EIS) for the Sunrise Corridor highway alignment. This report examines the geotechnical/geologic-related factors related to the proposed project. The Sunrise Corridor extends from Interstate 205 (I-205) to U.S. Route 26 (Highway 26) for a distance of 13 miles. The proposed highway alignments and widening affect the lower portions of Rock Creek watershed and the middle section of Richardson Creek basin along the existing Highway 212.

Dames and Moore. 1992. Sunrise Corridor Draft Environmental Impact Statement: Water Resources and Water Quality Impacts Technical Report, Clackamas County, Oregon. Prepared for the Oregon Department of Transportation. Job No. 4117-032-020. 31 p. plus maps and tables.

Hard copy report including text, maps.

Dames and Moore. 1993.Final Technical Report on Natural Resources: Plants and Animals. sunrise Corridor Project Area, Clackamas County. Prepared for the Oregon Department of Transportation. Job No. 4117-032-020. 80 p. plus

Hard copy report including text, maps.

David Evans and Associates, Inc. 1991. Sunrise Corridor Draft Environmental Impact Statement: Final Technical Report, Surface Water Drainage Sections 4 through 6. Prepared for the Oregon Department of Transportation. 12 p. plus tables and appendices.

Hard copy report including text, maps.

Dewberry, T.C., J. R. Karr, and J.W. Adams. 1999. Evaluating Aquatic Resources in the Clackamas River Basin of Oregon. USEPA Contract # CR825041-01, Portland , OR. 57pp.

Draft report including text, graphs, and figures. Contact person: Jeff Adams, The Xerces Society, Portland, OR

The objectives of this study were to 1) document historical conditions in the Clackamas River basin and relate those to current conditions, 2) apply the benthic index of biological integrity (B-IBI), and 3) determine a river monitoring scheme that could be used by diverse local and regional community-based groups and other stakeholders. The report does not include a summary. It said “We are in the process of completing the summary, a set of numbered points that we see as the primary messages that derive from this study.” The report did stress the importance of using the B-IBI monitoring scheme and noted that the anadromous salmonids of Rock and Richardson are both severely restricted and threatened by human actions in the watershed.

Fowler, Mike, and John Davis. 2000. Memorandum to Ela Whalen and Mike Macrelli. Surface Water Management Alternatives for Rock Creek and Richardson Creek. February 22, 2000. URS Corporation. 8 p.

Technical memorandum including brief description of surface water management alternatives for Rock Creek and Richardson Creek. Contact Person: Mike Fowler, URS Corporation.

URS Corporation (URS)was hired by Clackamas County Water Environment Services to develop Surface Water Master Plans for the Rock Creek and

Richardson Creek watersheds. URS evaluated the existing natural resources of both basins, evaluated peak flow characteristics under existing and future land use scenarios, and estimated the potential increase in pollutant loads as a result of future urbanization. Based on these findings, URS identified a set of problems and opportunities related to surface water management. A draft list of these is provided in the technical memorandum and a refined list is expected to be released in the final URS report. Final report was not completed at the time the annotated bibliography was produced.

Mason, Bruce, and Girard Inc. 1997. Sunrise Corridor Highway 212/224 Final Biology Report. Prepared for the Oregon Department of Transportation. Portland, Oregon.

Hard copy report. Contact person: Nancy Munn.

Mason Bruce and Girard, Inc. 1998. Biological Assessment Addressing Impacts to Steelhead Trout, Chinook salmon, Chum Salmon, Bald Eagle and Rare Plants: East Portland Freeway at Clackamas Highway (Sunrise Corridor) I-205 to 172nd Ave. Key #05331. Prepared by Nancy Munn, Ph.D. for Oregon Department of Transportation. Portland, Oregon. 25 p. plus appendices.

Hard copy report. Contact person: Nancy Munn

Metro Regional Services. 1997. Clackamas River Watershed Atlas. Portland, OR. 40pp. (Available at: Metro, Data Resource Center, 600 NE Grand Ave., Portland, OR. 97232. ISBN 0-9662473-0-2)

Hard copy atlas including maps, figures, charts, text. Contact person: Rosemary Furfey, Metro.

This oversized atlas contains 26 large-sized colored maps, tables, charts and accompanying text that describe the natural resources and land use character of the Clackamas river basin. The purpose of the atlas was to gather information about the basin in order to help the Metro Council and other decision-makers evaluate areas for future urban growth. The atlas contains the following spatial information: 1) base map of the Clackamas River basin, 2) property ownership, 3) elevation, 4) ecoregions, 5) geology, 6) salmonid fish distribution, 7) water quality and water supply, 8) stream status based on DEQ's 303(d) designation process, 9) designated special areas, 10) land cover, 11) relative surface erosion potential, 12) relative infiltration rate, 13) slope characteristics, 14) estimated population density, 15) impervious area, 16) current zoning, 17) existing land use, 18) future land-use plans, 19) road-stream crossings, 20) road density, 21) relative susceptibility to mass wasting, and 22) information on stream gradients. An excellent source for generalized landscape characteristics of the Clackamas River basin.

Metro Regional Services. 1999. Streamside CPR: Development of measures to conserve, protect and restore riparian corridors in the Metro region. Discussion Draft.

Metro's Growth Management Services Department. Portland, Oregon. 113 p. plus appendices.

Hard copy report including text, maps, photographs. Contact persons: Rosemary Furfey, Carol Krigger, Susan Payne, or Malu Wilkinson.

Olson, S., Simpson, I., Sugnet, J., Williams, T., and A. Young. 2000. Residents Informing the Planning Process: Pleasant Valley and Its Natural Resources. Prepared for Portland State University as part of a Master's Degree Project. 51 p.

Hard copy report including text, maps, photographs. Contact Person: Steve Olson.

The purpose of this project was gather local knowledge of the natural resources and history of Pleasant Valley by conducting interviews with long term residents. Valuable information on the presence of a compacted soil layer was identified, changes in creek geomorphology, changes in stream flow characteristics, as well as notable changes in water quality and riparian areas. Residents identified environmental concerns such as dumping waste, adding fill to land, and potential problems from leaking septic tanks, oil tanks, and use of pesticides. The goal of the project was to take advantage of this valuable information and use it to guide future development plans for the area. Not only does this project provide excellent information on the history and natural resources of Pleasant Valley, it also is an excellent guide to model after for future planning processes of Rock Creek and Richardson Creek basins. There is a tremendous amount of information and insights that can be gained through interviewing long time residents of an area.

Oregon Department of Fish and Wildlife. 1999. Distribution of Fish and Crayfish and Measurement of Available Habitat in Streams of the North Clackamas County. Oregon Department of Fish and Wildlife 1997-1999 Final Report. 68 p.

Hard copy text report. Contact person: Tom Friesen.

The primary objectives were to 1) determine fish and crayfish abundance, 2) measure the quality and quantity of available aquatic habitat, and 3) assess the overall health of seven streams in North Clackamas County. These streams included Kellogg, Mt. Scott, Phillips, Dean, Cow, Seiben, and Rock creek. Habitat surveys were conducted during the summer of 1997 on Rock Creek. Fish and crayfish surveys in Rock Creek were done during each season (fall, summer, winter, spring) during 1997-98. Ratios of pool, riffle and glides were determined. Stream substrate characteristics, such as sand, gravel, cobble, boulder, etc.., were noted. Stream bank stability, stream shading, undercut banks, woody debris and fish passage barriers were noted. The index of biotic integrity (IBI) was used to determine the biological integrity of the streams. Rainbow trout, chinook, coho, and cutthroat trout were all observed in the lowest reaches of Rock Creek. The following water quality measurements were taken during the summer of 1997: average water velocity, turbidity, percent oxygen saturation, dissolved oxygen, temperature, conductivity, salinity and total dissolved solids.

Data is available for stream reaches within Rock Creek only and does not include any information on Richardson Creek.

OTAK, Inc. 1999. Rock Creek Concept Plan: Urban Reserve Areas 14 and 15, Clackamas County, Oregon. Report completed in association with Kittleson and Associates, Inc., Pacific Rim Resources, Palsa, LLC. 65 p. plus Appendices.

Hard copy report including text, maps, photographs. Contact Person: Joe Dills, Project Manager.

The purpose of the Rock Creek Plan was to 1) establish a coordinated land use, transportation, natural resource, and public facilities "concept" for the Urban Reserve Areas 14 and 15, 2) conform with Metro requirements and recommendations for urban reserve planning and 3) promote collaboration and involvement in the process by area residents, service providers, local jurisdictions, Metro and other interested parties. Rock Creek makes up the eastern boundary of the urban reserve area. The plan relates only to the proposed urban reserve areas with Rock Creek. There is nothing on Richardson Creek basin in this report.

Taylor, B. 1999. Salmon and Steelhead Runs and Related Events of the Clackamas River Basin: A Historical Perspective. Prepared for Portland General Electric, Portland, OR. 54 p.

Hard copy report including text, maps, historical timelines. Contact Person: Marty May, PGE.

University of Oregon, Department of Landscape Architecture. 1998. Designing an Open Space Network: A Framework for Habitat Preservation. School of Landscape Architecture, University of Oregon, Eugene, Oregon. 50 p.

Provides conceptual landscape designs for 3 urban reserves: Damascus, Rock Creek, and Pleasant Valley, maps, drawings, text.

Students at the University of Oregon, Department of Landscape Architecture came up with three alternative open space landscape designs for three urban reserves: Damascus, Rock Creek, and Pleasant Valley. They first identified the habitat requirements for aquatic and terrestrial wildlife and the resource and infrastructure needs of humans. Three plans were 1) an open space network of patches and corridors, 2) a linear network with modes, and 3) a large central open space with stepping stones. The purpose was to explore these three designs and their impact on the needs of humans, aquatic and terrestrial wildlife.

URS Corporation. In Process. Surface Water Master Plan for Rock and Richardson Creek Watersheds. Prepared for Clackamas County, Water Environment Services, Clackamas, Oregon. 9 p.

Technical memorandum including brief description of hydraulic analysis of Rock Creek. Contact Person: Mike Fowler, URS Corporation.

This report is currently in draft form and is expected to be completed during the fall of 2000. URS completed a hydraulic analysis of Rock Creek in order to evaluate the impact of future development on the existing surface water drainage system. Future urbanization of this area is expected to increase the amount of impervious area in the Rock Creek basin. This will likely result in a significant increase in the amount of surface water runoff will increase peak flows. The URS Corporation used the XPSWMM (a proprietary version of U.S. EPA's Stormwater and Wastewater Management Model: SWMM) to determine existing and future flood prone areas at culverted road river crossings. Since peak flow information was not available for Rock Creek, it was estimated using 3 different methods: 1) peak flow information from nearby Johnson Creek, 2) predicted peak from USGS Regression model, and 3) predicted peak from Laenen equation. Results of the analysis found one culvert deficiency under existing conditions and six under future development conditions. Detailed information on the exact location of the problem culverts and proposed corrective actions will be provided on the final report. Final report was not completed at the time the annotated bibliography was produced.

Wu, Binhong and Mike Fowler. 2000. Memorandum to Mike Nacrelli: Water Quality Modeling for Rock Creek and Richardson Creek. February 25, 2000. URS Corporation. 5 p.

Technical memorandum containing brief description of water quality modeling for Rock Creek and Richardson Creek. Contact Person: Mike Fowler, URS Corporation.

URS Corporation was hired by Clackamas County Water Environment Services to estimate the increase in pollutant loads from surface water runoff as a result of future urbanization in Rock Creek Urban Reserves 14 and 15. URS Corporation developed a simple spreadsheet pollutant load model designed to evaluate the change in three water quality parameters: total suspended solids (TSS), total phosphorous (TP), and total copper (CU) under existing and future urban land use scenarios. The results of the model simulations showed that the pollutant loads increase dramatically as future development occurs. The total suspended sediment loads increase by more than 6 times, the total phosphorous lads increase by more than 3 times, and the total copper loads increase by more than 10 times. Final report was not completed at the time the annotated bibliography was produced.

U.S. Geological Survey. 1965. Groundwater in the East Portland Area, Oregon: USGS Water Supply Paper #1793. USGS. Water Resources Division. Portland, Oregon. Prepared by G.M. Hogenson and B.L. Foxworthy. 78 p.

Water Environment Services (WES). 2000. Draft Surface Water Master Plan for Rock and Richardson Creek Watersheds.

Available from Water Environment Services, 9101 SE Sunnybrook Blvd., Suite 441, Clackamas, OR 97015.] (unpublished report).

Wolfe, Kate (URS), Lynn Sharp (URS), Todd Moses (Watershed Applications), Bob Ellis (Ellis Ecological Services). Technical Memorandum: Natural Resources Assessment of Rock Creek and Richardson Creek. December 6, 1999. 35 pages

Technical Memorandum to Diana Sharp presenting an evaluation of natural resources in Rock and Richardson Creek watersheds including conditions of riparian corridors, channel stability and fish habitat. Developed as part of the Surface Water Management Plan for both watersheds.

Woodward-Clyde Consultants. 1994. Johnson Creek Resources Management Plan: Draft July 1994. Prepared for the Johnson Creek Corridor Committee. 198 p. plus appendices.

Available from Woodward-Clyde Consultants, 111 SW Columbia, Suite 990, Portland, OR. 97201.

Other Potential Sources

Adolfson and Associates. 1998. Biological Assessment, Listed Species: Lower Columbia River Steelhead, I-205 to 172nd Avenue (Sunnyside Road), Clackamas County, Oregon.

CH_2M Hill and Adolfson & Associates. 1998. Sunnyside Road Environmental Assessment (I-205 to Southeast 172nd Avenue): Natural Resources Technical Report. Prepared for the Oregon Department of Transportation. Portland, Oregon.

Kurahashi and Associates, Inc. 1998. Hydrology, Hydraulics, and Water Quality Report: Sunnyside Road Improvement Project, I-205 to 172nd Avenue. Clackamas County, Oregon.

Leavitt, J., 1998. The Functions of Riparian Buffers in Urban Watersheds. Master's Thesis. University of Washington. Seattle, Washington.

Milwaukie High School SWRP (provided by Gordon McGhee, Clackamas River Water)

Oregon Department of Fish and Wildlife. 1998. Willamette River/Sandy River: Guide to Restoration Site Selection (Sandy, Clackamas, Molalla, Pudding, Santiam and Calapooia River Drainages).

Oregon Department of Transportation. 1998. Biological Assessment: Addressing Impacts to West Coast Steelhead Trout, Bald Eagle and Plants. East Portland Freewat at Clackamas Highway (Sunrise) Interchange (I-205 to Rock Creek, Key 05331) and Sunnyside I-205 Interchange and Sunnybrook Extension Project (Key 03346).

Oregon Department of Transportation. 1993. Draft Environmental Impact Statement: Sunrise Corridor Highway 212/224 (I-205 to US 26). Federal Highway Administration. Oregon Department of Transportation, Clackamas County, Oregon.