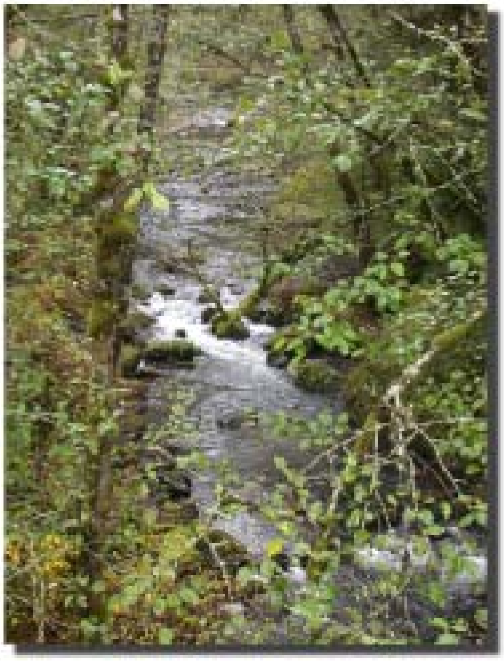
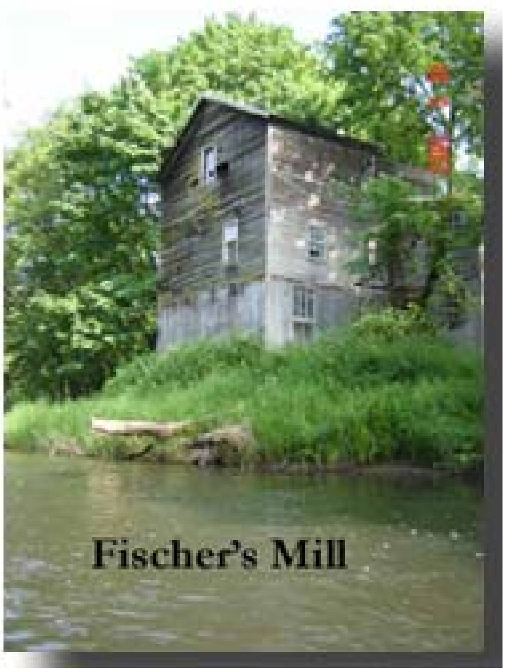


CLEAR AND FOSTER CREEK WATERSHED ASSESSMENT

September, 2002

Clackamas River Basin Council
~ Current with the Watershed ~



Prepared By

Watershed Professionals Network, LLC

CLEAR AND FOSTER CREEK WATERSHED ASSESSMENT

November 2002

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Editors Note: *The Watershed Assessment is a stand-alone document. The supporting maps and appendices are provided in electronic format on a CD Rom. Contact the Watershed Coordinator of the Clackamas River Basin Council for availability.*

CLEAR AND FOSTER CREEK WATERSHED ASSESSMENT

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LIST OF MAPS AND APPENDICES

The listed maps and appendices are provided in electronic format; they are not enclosed in this document.

Maps

Appendices

WATERSHED SUMMARY

BACKGROUND

A watershed assessment was completed in the Clear and Foster Creek watersheds to evaluate existing conditions and make recommendations to protect or enhance watershed natural resources. Clear and Foster Creek are tributaries to the Clackamas River below any major dams on the system; consequently these tributaries are positioned favorably to contribute to recovery of important anadromous fish populations. Anadromous fish species in the Clackamas basin include spring and fall chinook, coho salmon, winter steelhead, summer steelhead (non-native), migratory cutthroat trout and lamprey. Clear and Foster Creeks are utilized by fall chinook, winter steelhead and coho salmon.

The watershed, encompassing 73 square miles, was divided into five sub-watersheds for this assessment – Foster Creek, Upper Clear Creek, Middle Clear Creek, Little Clear Creek, and Lower Clear Creek (*Map 1: Base Map*). Foster Creek, the smallest watershed at 3.5 square miles, drains directly into the Clackamas River, but it is included in this assessment because of its adjacent location and similar land use patterns. Elevation in the watershed ranges from 4,226 feet on Goat Mountain to 79 feet where Clear Creek meets the Clackamas River at River Mile 8. Average annual precipitation ranges from 93 to 47 inches.

The watershed encompasses several different EPA Level IV ecoregions. The lower elevations are in the Prairie Terraces and Valley Foothills ecoregions and the higher elevations are in the Western Cascades Lowlands and Valleys ecoregions.

The entire Foster Creek watershed, and majority of the Clear Creek watershed is in private ownership. Federal land ownership includes 9% BLM and 3% USFS lands. Land use is characterized by timberlands in the upper watershed, and agricultural and rural residential in the lower reaches of the watershed. The watershed is typical of Clackamas County, which is ranked 3rd in population, 1st in number of farms, and 1st in nursery sales in Oregon.

ORGANIZATION OF THE SUMMARY

The watershed summary presents the findings of the Clear and Foster Creek Watershed Assessment in an abbreviated form. The watershed summary is organized by seven assessment components – ***Channel Habitat Types***, ***Hydrology/Water Use***, ***Riparian/Wetlands***, ***Sediment Sources***, ***Water Quality***, ***Fisheries*** and ***Wildlife***. Within each of the assessment components the critical question is answered by summarizing the ***Existing Condition***, ***Trends***, ***Data Gaps***, and ***Recommendations***.

CHANNEL HABITAT TYPES AND CHANNEL MODIFICATION *(SECTION 3)*

Question 3-1: What is the distribution of channel habitat types throughout the watershed?

Existing Condition: The largest group of channels (35%) falls into the moderate gradient class; about two-thirds of these channels are moderately confined, and valley walls confine the remaining third. Floodplain and low-gradient CHTs are more common in the lower subwatersheds. Upper Clear Creek subwatershed is dominated by moderate gradient reaches, and also has the highest proportion of steep and very steep CHT types.

Trends: Channel Habitat types do not typically change over time, however there has been conversion of some low gradient CHTs to ditches.

Data Gaps: The analysis was completed using aerial photographs with limited field verification. Classification of valley confinement was the most difficult attribute identify remotely. Several Mainstem segments were changed after the field visits. It is likely the valley confinement of other segments has been incorrectly assigned.

Recommendations: The current classification of CHTs is sufficient for the purposes of this analysis.

Question 3-2: What is the location of channel habitat types that are likely to provide specific aquatic habitat features, as well as those areas that may be the most sensitive to changes in watershed condition?

Existing Condition: Anadromous steelhead, chinook and coho are most likely to use the low gradient CHTs in Clear and Foster Creeks for spawning and rearing. In addition these CHTs have the highest sensitivity to changes in inputs of LWD, flow, sediment runoff or vegetation. These CHTs include; FP1, FP2, FP3, LM and MM, they are generally located in the lower portions of the subwatersheds along the Mainstem of Clear Creek. The exception to this are the MM CHTs, the highest proportion of this type occur in the upper Clear Creek subwatershed, indicating a high likelihood for good resident fish spawning and rearing habitat.

Trends: Not applicable.

Data Gaps: Not applicable.

Recommendations: Not applicable.

Question 3-3: What are the types and relative magnitudes of past and current channel modifications?

Question 3-4: Where were historic channel disturbances, such as dam failures, splash damming, hydraulic mining, and stream cleaning, located?

Existing Condition: Evidence of historic modifications on current channel conditions are not readily apparent. Log drives to sawmills are documented as occurring in the late 1800s. At the time sawmills were located in Viola, Metzler Park, and other areas in the watershed. It is likely that logs and at least small splash dams were located along most the main stem and large tributaries. No documentation of stream cleaning efforts was found. Although it is likely ODFW did clear LWD from main Clear and Foster Creeks as part of the region wide stream cleaning efforts in the 1970s and 1980s.

Based on the air-photo analysis and field visits, approximately 3% of the stream channel has been modified into ditches. This is most common in the Lower Clear Creek subwatershed, where 8% of the stream channel has been ditched.

There are approximately 76 ponds located on the stream network, an additional 59 ponds are located off the stream channel but in the watershed. Many of these ponds are constructed farm ponds and the ones on the stream channel provide limited or no fish passage opportunities. Other ponds are natural features created by the landforms and/ or landslide toes which capture and hold water or block the channel.

Trends: No quantitative information is available on current channel modification and additional ditching or pond creation efforts. However it is unlikely there will be any large scale changes due to current regulatory requirements.

Data Gaps: The numbers of ponds is likely an underestimate. It was difficult to align ponds observed on photos with ponds indicated on the maps.

Recommendations:

1. Ponds located on the stream channels have the potential to significantly impact water quality and impede passage of fish. In-channel ponds on fish bearing streams should be evaluated for potential impacts to water quality and fish passage.

2. Ditching of tributaries in Lower Clear Creek is a common channel-modification and should be evaluated for water quality implications.

HYDROLOGY AND WATER USE *(SECTION 4)*

Question 4-1: What land uses are present in the watershed?

Existing Condition: Current land uses within the watersheds was approximated using current zoning information available from Clackamas County. Lands zoned as Rural Commercial are found only in the Lower Clear Creek subwatershed, where they make up only 0.1% of the total subwatershed area. Rural Residential lands are found within all subwatersheds, and range from 4% of the total area in the Upper Clear Creek subwatershed to 21% of the total area in the Lower Clear Creek subwatershed. Lands designated as "Natural Resource" include "Exclusive Farm Use" (EFU), "Agricultural/Forest" (AGF), and "Timber" (TBR) lands. Natural Resource lands make up the largest proportion of watershed area in all subwatersheds, with EFU lands being the predominant designation in the lower subwatersheds, and TBR lands dominating in the headwater areas.

Trends: No quantitative information is available on changes in land use within the Clear and Foster Creek watersheds over time. However, trends most likely follow the general pattern seen in the Portland metropolitan region of full build out under current zoning regulations over the past 30 year period.

Data Gaps: Actual land use may differ from current zoning designation. Some parcels may not currently have the housing density that is allowed. Conversely, many areas zoned as rural residential may include significant areas that are forested or hobby farms.

Recommendations: Current information on zoning designation was sufficient for the purposes of this assessment. Additional data on actual land use would only be necessary if further modeling of land use impacts to watershed hydrology is desired.

Question 4-2: What is the flood history in the watershed?

Existing Condition: No data on annual peak flows are available from any location within the Clear and Foster Creek watersheds, consequently, six gages having peak flow records from adjacent watersheds were used to estimate peak flow history. The largest event that occurred in recent times was the flood of 12/21/1964 during water year 1965 (i.e., the "'64 flood"). This event was the largest annual event in water year 1965 at all five gages that had records, although the magnitude of the event varied by watershed, with smaller-magnitude flooding in the low elevation watersheds (i.e., those watersheds that most likely lacked significant snowpack). Other flood events having a recurrence interval of 10 years or greater occurred in water years 1961, 1972, 1974, and 1996. Unfortunately, all gages but one that were used in this assessment were discontinued by the time of the 1996 flood which occurred on 2/7/1996 at the Fish Creek gage (Recurrence interval estimated to = 33 years).

Trends: Regionally, the period of the early-1960's to mid-1970's contained several relatively large flood events, which were followed by a period of relatively small events up to the mid-1990's. Consequently, events such as the 1996 flood appeared to many people as unusually large events, while in fact they are within the range of recent variability.

Data Gaps: Few data are available to characterize streamflow within the Clear and Foster Creek watersheds. Stream flow records from within the Clear Creek watershed are of very short duration, and no records are available for the Foster Creek watershed. No peak flow records are available from any location within the Clear or Foster Creek watersheds.

Recommendations: Establish continuous stream flow monitoring locations within the subwatersheds. Efforts to characterize stream flow were hampered by the lack of continuous stream flow data from within the watersheds. Continuous stream flow data would improve understanding of peak flow history, allow for better estimation of natural stream flows, provide calibration data for any future modeling activity, and allow for better understanding of the effects of water use within the subwatersheds. Reinstalling gages at the locations of the four former OWRD gages that were located within the Clear Creek watershed would build upon existing data sets, and would adequately represent streamflow at the outlets of all of the Clear Creek subwatersheds. No continuous stream flow data are available for the Foster Creek subwatershed. Installation of a stream gage at or near the mouth of Foster Creek is also recommended.

Question 4-4: For what beneficial use is water primarily used in the watershed?

Existing Condition: Water is withdrawn from approximately 300 separate points of diversion within the Clear and Foster Creek watersheds (based on OWRD records). Over half of all permitted water uses are for irrigation and other agricultural uses, and the primary location of irrigated lands is in the Lower and Middle Clear Creek subwatersheds. Other significant uses include fish/recreational pond storage (approximately ¼ of total water withdrawals), and domestic use (less than 10% of total water withdrawals). Other minor beneficial uses include livestock watering, wildlife use, recreation, municipal uses, power generation, industrial use, and fire protection

Trends: The water right with the oldest priority date within the watershed is from 1922, and the most recent is from the year 2000. Few water rights existed (approximately 10% of the total withdrawal allowed today) prior to the early 1950's. The period from approximately 1950 to the early 1960's saw the sharpest increase in water rights (primarily for irrigation), with approximately 50% of the total withdrawal allowed today being permitted within this time period. Other significant increases occurred from 1974-78 and from 1989-93. Very few water rights have been permitted from 1993 to present.

Data Gaps: Rate of withdrawal given in the OWRD data is expressed either as an instantaneous rate (i.e., cubic-feet per second or gallons per minute) or as a total yearly volume (i.e., acre-feet). Some (but not all) of the water rights whose withdrawal rate is expressed in acre-feet have further restrictions that specify an instantaneous rate that water can be applied (for example, 1/40 cfs per irrigated acre) as well as the maximum volume that can be applied in a given season or over any 30-day period. It would be most convenient, when summarizing the rate of water withdrawals, to be able to express the withdrawal rate in common units of measurement for all water uses within a subwatershed. However, this type of estimate is not possible at the current time using the publicly-available information from the OWRD. The OWRD is considering changes to their Water Rights Information System (WRIS) that will allow estimation of instantaneous withdrawals. Furthermore, the OWRD database describes the quantity of water that is *permitted* to be withdrawn, however, no information is available on *actual* water use.

Recommendations: Support efforts of the OWRD to improve the Water Rights Information System (WRIS). The OWRD is considering changes to the WRIS that will allow estimation of instantaneous withdrawals associated with water rights. This information would allow a better understanding of the impacts of withdrawals on stream flows. It is recommended that the BRAG support these proposed improvements to the system. Furthermore, the BRAG should encourage and support efforts of the OWRD to improve the WRIS to identify the current status of all water rights within the watershed, and the actual amount and timing of use.

Question 4-5: Is water derived from a groundwater or surface-water source?

Existing Condition: Based on OWRD records, the majority of the volume of water withdrawn within the watersheds is from a surface water source; less than 10% of the total volume being withdrawn from groundwater sources.

Trends: Approximately 40% of the total volume derived from groundwater sources was permitted between the years 1948-1955, and the remaining 60% was permitted during the years 1989-1990. The majority (approximately 97%) of the water derived from groundwater sources is used for irrigation and other agricultural purposes, with only 2% used for industrial purposes, and 1% used for fish/recreational pond storage.

Data Gaps: Same as previous

Question 4-6: What type of storage has been constructed in the basin?

Existing Condition: There are approximately 135 ponds located within the watersheds, most of which are constructed farm ponds. No large-scale reservoirs have been constructed within the watersheds.

Trends: The time trend for water rights associated with reservoir storage follows the same general pattern as that described above for all water rights.

Data Gaps: Same as previous.

Recommendations: Same as previous.

Question 4-7: Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin?

Existing Condition: No significant interbasin transfers were identified from OWRD records

Trends: Not applicable.

Data Gaps: None.

Recommendations: None.

Question 4-8: Are there any illegal uses of water occurring in the basin?

Existing Condition: No information was available to identify if there are significant illegal uses of water occurring within the watersheds.

Trends: Not applicable.

Data Gaps: The OWRD database adequately describes the quantity of water that is legally permitted to be withdrawn, however, no information is available on illegal withdrawals.

Recommendations: Encourage and support efforts of the OWRD to identify illegal uses of water within the watershed.

Question 4-9: Do water uses in the basin have an effect on peak and/or low flows?

Existing Condition: The net effect of water withdrawals on monthly stream flows were estimated at the outlets of each of the five subwatersheds by comparing the sum of 1) consumptive uses (i.e., the portion of all water withdrawals that does not return to the stream), 2) water diverted for storage, and 3) instream water rights (if any) against the estimated monthly natural stream flows for average and dry years (represented by the 50% and 80% exceedance flow respectively). Results are as follows:

- **Foster Creek**: If all of the water is withdrawn that is allowed under the existing water rights, there would be no flow remaining in the stream during the months of July and August in average years, and none in the months of July – September in dry years. No instream water rights exist for Foster Creek.

- **Upper Clear Creek**: Even if all of the water is withdrawn that is allowed under the existing water rights, there would still be flow remaining in the stream in all months in both average and dry years. These results are due to the relatively small amount of irrigated land in the subwatershed, and the small number of other water uses. No instream water rights exist for the Upper Clear Creek subwatershed.

- **Middle Clear Creek**: Consumptive water uses plus storage does not exceed the estimated volume of natural stream flow in any month, either in average or dry years. However, when the instream water right is added, there is insufficient flow to meet all uses in the months of July – September in either average or dry years. Based on these estimates it appears unlikely that instream flow rates would be attained during these months in most years.

- **Little Clear Creek**: If all of the water is withdrawn that is allowed under the existing water rights, there would be no flow remaining in the stream during the month of August in average years, and in the months of August – October in dry years. No instream water rights exist for Little Clear Creek.

- **Lower Clear Creek**: Consumptive water use plus storage does not exceed the estimated volume of natural stream flow in any month, either in average or dry years. However, when the instream water right is added, there is insufficient flow to meet all uses in the months of July – September in either average or dry years. Based on these estimates it appears unlikely that instream flow rates would be attained during these months in most years.

Trends: No quantitative trend analysis was performed, however, in as far as the total withdrawal amount for all water rights has been increasing over time (as described above), it is likely that withdrawal effects on low flows have also been increasing over time as well. The estimates of natural stream flows available from the OWRD are based on average climatic conditions. The precipitation trend analysis (see Section 4.4.1) indicate that, regionally, we may have left a warm/dry precipitation cycle (which would result in lower than average summer stream flows) and entered a cool/wet cycle where summertime stream flows may be above average.

Data Gaps: Few data are available to characterize streamflow within the Clear and Foster Creek watersheds. Stream flow records from within the Clear Creek watershed are of very short duration, and no records are available for the Foster Creek watershed. Consequently, OWRD estimates of "natural" stream flows may not be accurate. Furthermore, the lack of information on actual vs. permitted water use (as described above) decreases our confidence in the overall results.

Recommendations:

1. Further investigate the magnitude of the effect of consumptive water uses on summertime stream flows. The lack of data characterizing stream flow conditions within the subwatersheds, and the lack of information on actual water use, result in uncertainty in the assessment of water use effects on summertime low flows. Further investigation into the magnitude of the effect will require the following:

    a. Establish continuous stream flow monitoring locations within the subwatersheds as described in the *flood history* section above.

    b. Support efforts of the OWRD to improve the Water Rights Information System; and encourage efforts by the OWRD to identify current status, actual use, and timing of all water rights within the watershed as described in the *beneficial use* section above.

2. Despite the uncertainty in the magnitude of water use effects on low stream flows the BRAG may wish to identify and implement opportunities to improve summertime stream flows through increased water use efficiency, transfer of water rights to instream uses, and other voluntary actions by water right holders. Actions should be focused on those subwatersheds where the sum of consumptive use, storage, and instream water rights exceeds the estimated volumes of natural stream flow during the certain summer months. Voluntary measures such

as an increase in the efficiency of water distribution and application to irrigated areas will help improve summertime flow conditions. Further reductions in withdrawals through voluntary transfer of water rights (either temporarily or permanently) to organizations such as the Oregon Water Trust should also be considered.

Question 4-3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?

Existing Condition: Very little data or studies are available that address land use effects on peak and/or low stream flows within the Clear and Foster Creek watersheds. Three processes that may contribute to increased peak flow magnitudes were considered in this analysis:

1. **Vegetation removal**: An assessment of possible augmentation of rain-on-snow (ROS) peak flows due to vegetation removal was provided in Section 4.4 of this report. Predicted increases due to vegetation removal were greatest in the smaller magnitude, higher frequency flood events (i.e., the peak flow having a 2-year recurrence interval) due to the greater role that snowmelt plays in these smaller events (i.e., in larger-magnitude events rainfall makes up a much larger proportion of the total water available for runoff). Predicted increases for the 2-year event range from no increase in the Foster Creek subwatershed to a 9% increase in the Upper Clear Creek subwatershed. Predicted increases for the 100-year event range from no increase in the Foster Creek subwatershed, to a 4% increase in the Upper Clear Creek subwatershed. Peak flow increases of 10% or less have a low probability of causing significant impacts to fisheries resources.

2. **Wetland loss**: Wetlands have the ability to intercept and store storm runoff, thereby reducing peak flows. Water stored in wetlands and released over time may be important to augment summertime low flows. A qualitative look at possible streamflow impacts due to wetland loss was provided in Section 4.4. The estimated area within the subwatersheds historically occupied by wetlands was compared to the present-day area occupied be wetlands. National Wetland Inventory (NWI) data was used to estimate present-day wetland area. Natural Resource Conservation Service (NRCS) data on soils classified as having hydric conditions was used to estimate historic wetland area. Present-day wetlands may occupy as little as 13% of the area that they occupied historically within the entire assessment area. Significant wetland loss may have occurred in the Foster Creek, Lower Clear Creek, and Little Clear Creek subwatersheds, where current wetland area makes up only 1%, 10%, and 21% respectively of the potential area of hydric soils. No significant loss of wetland area appears to have occurred in the Upper and Middle Clear Creek subwatersheds.

3. **Increased impervious area**: Increases in the amount of impervious area may result in increased peak flow magnitudes by eliminating or reducing infiltration of precipitation, thereby shortening the travel time to stream channels. Increases in impervious area may also reduce summer low flows by reduction of groundwater recharge. Studies from the Puget Sound area indicate that impairment begins when percent total impervious area (%TIA) in a watershed reaches 10%. An evaluation of possible peak flow increase due to impervious area was presented in Section 4.4 using a relationship between % TIA and road density.

Based on this evaluation, it appears that increases in imperious area may be adversely impacting hydrologic processes in the Upper and Lower Clear Creek subwatersheds. However, these results should not be considered conclusive – the relationship between road density and TIA was developed for urbanized areas where sources of imperviousness (i.e., parking lots, structures, etc.) are highly correlated with road density. The high density of roads in the upper Clear Creek watershed are associated with logging activities, therefore the same relationship may not be valid. Further modeling would need to be performed to determine if increases in impervious area are significant.

Trends:

1. **Vegetation removal**: Present-day peak flow increases due to vegetation removal are associated with periodic forest harvests within timberlands within the watersheds. However, the entire assessment area was historically forested, and peak flow increases associated with removal of the original forest for farming purposes were probably much greater than current increases. When current vegetation is compared to historic vegetation the predicted increases for the 2-year event range from no increase in the Foster Creek subwatershed (low elevation, low amounts of snow accumulation), to a 29% increase in the Little Clear Creek subwatershed, and predicted increases for the 100-year event range from no increase in the Foster Creek subwatershed, to an 11% increase in the Little Clear Creek subwatershed.

2. **Wetland loss and increases in impervious area**: No evaluation was performed of the trends in wetland loss and increases in impervious area. However, the majority of the wetland loss was probably associated with early land clearing and conversion to farmland in the late 1800's – early 1900's. Current rates of wetland loss are probably low given current regulations on wetland protection. Conversely, the proportion of impervious area within the subwatersheds has probably increased at a steady rate since settlement of the area, as the area occupied by roads and structures increased with increasing population size.

Data Gaps:

1. **Vegetation Loss**: The data used to describe "current" vegetation conditions within the watersheds was based on 1993 imagery; consequently it is representative of conditions nine years ago.

2. **Wetlands**: The NWI data used to describe current conditions is based on imagery from the mid to late 1980's, consequently it is representative of conditions approximately 15-20 years ago. In addition, the NWI most likely fails to identify many wetlands that currently exist within the watersheds, particularly in forested areas. The estimation of historic wetland area using mapped hydric soils is coarse in scale, and may not accurately represent true historic conditions.

3. **Impervious area**: The estimation of TIA is based on a relationship to road density. The relationship between road density and TIA was developed for urbanized areas where sources of imperviousness (i.e., parking lots, structures, etc.) are highly correlated with road density.

The high density of roads in the upper Clear Creek watershed are associated with logging activities, therefore the same relationship may not be valid.

Recommendations:

1. **Vegetation Loss**: Result from this analysis indicate that augmentation of rain-on-snow (ROS) peak flows due to vegetation removal is a minor concern in the assessment area, and no further assessment or actions are recommended.

2. **Wetlands**:

    a. Investigate historical extent of wetlands within the watershed. A comparison of current wetland area to watershed area containing hydric soils indicates that wetlands may have historically occupied a much greater portion of the watershed than they currently do. Further analysis is needed to define the historic extent of wetland area within the watershed.

    b. Perform functional assessment of wetlands within the watershed. More information on wetland condition and function is needed in order to identify and prioritize any wetland enhancement efforts

3. **Wetland Loss / Impervious area**: Model possible impacts to watershed hydrology associated with wetland loss and increase in impervious area. It is recommended that a modeling tool such as the Distributed Hydrology-Soil-Vegetation Model (DHSVM) developed by the University of Washington and Battelle Pacific Northwest Research Labs be used in any further hydrologic modeling. Such a modeling effort should include an evaluation of all items included in Figure 4-12 (Generalized diagram of the primary interactions between land uses and changes in stream flows) of this report.

RIPARIAN/WETLAND HABITAT CONDITIONS *(SECTION 5)*

Question 5-1: What are the current conditions of riparian areas in the watershed?

Existing Condition: Vegetation was mapped using aerial photo interpretation techniques within a 100’ wide riparian corridor (on either side of the stream), along 142 miles of stream within the Clear and Foster Creek watersheds. In addition, riparian shading was estimated from aerial photographs along the same streams.

- **Current riparian vegetation**: The percentage of riparian area dominated by non-tree vegetation (i.e., shrubs, grass-like plants, or non-riparian vegetation such as pasture and crops) ranged from 9% in Upper Clear Creek to 39% in Lower Clear Creek. Forested riparian areas were generally dominated by stands of mixed conifer/hardwood species. Greater than 80% of the forested riparian areas were in the small (4- to 12-inch average DBH), and medium (>12- to 24-inch average DBH) tree size classes. From 57% (Foster

Creek) to 83% (Little Clear Creek) of the forested riparian areas had dense forest canopies; the remainder rated as having sparse canopies.

- **Shade**: Streams are in general well-shaded, with current shade levels proportional to basin position (i.e., the headwater areas are generally more well-shaded then areas near the mouth of the basin). It is difficult to assess if current shade levels are below potential levels, and if so, to what extent. The degree to which riparian areas within the watershed are deficient in terms of recruitment potential, are not necessarily reflected in riparian shade levels, because small trees, shrubs, and even dense non-woody vegetation can provide high levels of shade.

Trends: Characterization of riparian vegetation and shade was based on a single year's (1998) imagery, and as such no trends in conditions could be assessed. However, given the greatly reduced harvest rate over the past ten years on federal lands in the watershed, and the implementation of more stringent forest practice regulations, it is reasonable to assume that riparian tree size classes and shade have been increasing at least over the past ten-year period.

Data Gaps: The photographs used to describe current riparian vegetation and shade levels were taken in 1998; consequently these results are representative of conditions four years ago.

Recommendations: Riparian conditions should be reassessed periodically (~ every five years) to assess changes due to management and enhancement activities.

Question 5-2: How do the current conditions compare to those potentially present for this ecoregion?

Question 5-3: How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/ enhancement opportunities might be?

Existing Condition: Current riparian recruitment potential was organized by six riparian recruitment situations:

- **Satisfactory**: Riparian recruitment potential in these areas is currently satisfactory as compared with potential conditions for the ecoregion, and no enhancement is needed to achieve potential conditions. Only a very small proportion (1% - 4%) of the total length of stream is estimated to currently have satisfactory recruitment potential.

- **Approaching satisfactory**: Riparian trees within these stands are smaller than the potential size for the ecoregion, however, the trees are of an adequate size to currently provide adequate LWM recruitment and shade. These stands are not as productive (in terms of riparian function) as they can be. However, if protected, these stands will attain potential conditions over time. Current riparian recruitment potential is rated as approaching satisfactory along approximately 20% of the total stream length in all subwatersheds with the exception of the Little Clear Creek subwatershed, where approximately 30% of the total stream length is rated as approaching satisfactory.

- **Hardwood**: Hardwood stands are generally approaching a size that is large enough to provide satisfactory recruitment potential, but are dominated by hardwoods where the potential vegetation is conifer or mixed stands. The hardwood category makes up a very small proportion of total stream length. The hardwood category is not present at all in the Foster Creek subwatershed, and comprises from 1%-2% of the total length within the remaining subwatersheds.

- **Narrow buffers**: These stands have trees in the near-stream area that are of a size (generally medium, with a few areas of large-sized trees) and species (conifer or mixed conifer/hardwood) approaching satisfactory relative to potential conditions, however, these areas are very narrow. This category makes up only a very small proportion of total stream length (1% – 3%). The source of limitation is split approximately evenly between agricultural operations, residential development, infrastructure (roads, power lines, etc.), and past logging. The outer (farthest from the stream) portions of these stands consist of a variety of vegetation types and sizes. Within areas of forestry land use the stands generally consist of regeneration-and small-sized conifers and mixed conifer/hardwoods. Tree and shrub vegetation is absent in many areas of agricultural and residential land use.

- **Small-sparse**: This grouping includes both stands of small- or regeneration-sized trees and sparse stands of medium- and large-sized trees. In both cases current recruitment potential is far removed from potential conditions, however (unlike the following grouping), these stands are forested. Percent of total riparian length within the "small-sparse" category ranges from 44% in the Lower Clear Creek subwatershed to 73% in the Upper Clear Creek subwatershed.

- **Absent**: This grouping includes stands that are devoid of riparian tree vegetation. Current vegetation consists primarily of riparian grass species, brush species, and non-riparian vegetation (cropland, pasture, and some areas of non-native vegetation). This grouping makes up a significant proportion of the total riparian length in most subwatersheds; 4% of total riparian length within the Upper Clear Creek subwatershed, 16% and 17% in the Middle and Little Clear Creek subwatersheds respectively, and 25% and 29% in the Foster Creek and Lower Clear Creek subwatersheds.

Trends: Same as previous

Data Gaps: Same as previous

Recommendations: The following protection/enhancement recommendations are grouped by the six riparian recruitment situations described above. Prioritization of protection/enhancement actions should favor 1) those streams that currently have (or have the potential for) fish usage, 2) those streams having channel characteristics that are most responsive to inputs of large woody material, and 3) are limited with respect to stream shading:

- **Satisfactory**: Protect current conditions. No enhancement necessary.

- **Approaching satisfactory**: Protect current conditions. No active enhancement actions are needed for the majority of these stands (i.e., just let them grow).

- **Hardwood:** Appropriate enhancement techniques may include conversion of some of these areas over time to conifer stands. However, many of these stands have some recruitment potential at present, and any conversion should be considered in light of other considerations (e.g., wildlife and aesthetic concerns). Among the hardwood-dominated stands, only areas that consist primarily of alder (which is short-lived and usually converts to salmonberry over time) should be considered for active restoration. The hardwood dominated stands should be the lowest priority for active enhancement activities.

- **Narrow buffers**: The inner (closest to the stream) portions of many of the stands will, if protected, provide more desirable conditions over time. The outer (farthest from the stream) portions of many of these stands would benefit from active enhancement techniques such as releasing the conifer component (if present) in hardwood-dominated portions of the stands, converting hardwood-dominated stands to conifer, under-planting sparse stands, or density management (commercial thinning) to accelerate structural development in conifer stands.

- **Small-sparse**: Active enhancement would greatly benefit many of these stands. Appropriate enhancement techniques may include releasing the conifer component in small mixed-species stands, converting the hardwood-dominated stands to conifer, under-planting sparse stands, or density management (commercial thinning) to accelerate structural development in conifer stands.

- **Absent**: In most cases these would be the highest priority areas for enhancement. Appropriate restoration/enhancement techniques would include riparian plantings.

Question 5-4: Where are the wetlands in this watershed?

Existing Condition: The National Wetland Inventory (NWI) was used to identify the locations of all wetlands within the watershed. A total of 157 wetlands covering 188 acres were identified by the NWI. Wetland density (area occupied by wetlands/area of subbasin) ranged from 0.1% of the Upper Clear Creek subwatershed to 0.7% of the Foster Creek subwatershed, and was 0.4% of the assessment area overall.

Trends: No evaluation was performed on the changes in wetland area and location over time. However, as described in the response to *Question 4-3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?*, a comparison of current wetland area to area of hydric soils (an indicator of areas that may have contained wetlands historically) suggests that present-day wetlands may occupy as little as 13% of the area that they occupied historically within the entire assessment area. Significant wetland loss may have occurred in the Foster Creek, Lower Clear Creek, and Little Clear Creek subwatersheds, where current wetland area makes up only 1%, 10%, and 21% respectively of the potential area of hydric soils. No significant loss of wetland area appears to have occurred in the Upper and Middle Clear Creek subwatersheds. The majority of the wetland loss was probably associated with early land clearing and conversion to farmland in the late 1800's – early 1900's. Current rates of wetland loss are probably low given current regulations on wetland protection.

Data Gaps: The NWI data used to describe current conditions is based on imagery from the mid to late 1980's, consequently it is representative of conditions approximately 15-20 years ago. In addition, the NWI most likely fails to identify many wetlands that currently exist within the watersheds, particularly in forested areas. The estimation of historic wetland area using mapped hydric soils is coarse in scale, and may not accurately represent true historic conditions.

Recommendations: Same as described in the hydrology land use effects section above.

Question 5-5: What are the general characteristics of wetlands within the watershed?

Existing Condition: Wetland characteristics are summarized by 1) wetland type, and 2) wetland modifications:

1. **Wetland types**: Palustrine emergent wetlands (wetlands dominated by rooted herbaceous plants, such as cattails and grass) are found within all subwatersheds, and range from <1% (Little Clear Creek) to 17% (Upper Clear Creek) of the total wetland area. Palustrine forested wetlands (dominated by trees taller than 20 feet) make up the largest single grouping of wetlands in all subwatersheds (43% - 74% of total wetland area) with the exception of Upper Clear Creek (11% of total wetland area). Palustrine open water wetlands (lakes and ponds) are found in all subwatersheds with the exception of Upper Clear Creek, and make up from 26% (Little Clear Creek subwatershed) to 33% (Lower Clear Creek subwatershed) of the total wetland area. Palustrine scrub-shrub wetlands (wetlands dominated by shrubs and saplings less than 20 feet tall) are only found in the Lower Clear Creek subwatershed (14% of the total wetland area). Palustrine unconsolidated bottom wetlands (substrate is primarily mud or exposed soils, and have <30% vegetative cover) are only found in the Middle (4% of total wetland area) and Upper Clear Creek (72%) subwatersheds.

2. **Wetland modifications**: Excavated wetlands lie within a basin or channel excavated by humans. Wetland modified by excavation were identified in all subwatersheds, and ranged from 1% (Middle Clear Creek) to 24% (Foster Creek) of the total wetland area. Diked/Impounded wetlands are created or modified by a human-made barriers designed to obstruct the inflow of water, and were identified in all subwatersheds, ranging from 3% (Foster Creek) to 64% (Upper Clear Creek) of the total wetland area. The water level in Partially drained/ditched wetlands has been artificially lowered, but soil moisture is still sufficient to support wetland vegetation. Partially drained/ditched conditions were only noted in one wetland in the Middle Clear Creek subwatershed (3% of the total wetland area), and in 3 wetlands in the Lower Clear Creek subwatershed (1% of the total wetland area).

Trends: No information is available to quantitatively evaluate trends in wetland types and modifications, the assessment being based solely on NWI data acquired from 1980's imagery. However, current rates of wetland modification are probably low given current regulations on wetland protection.

Data Gaps: Same as previous

Recommendations: Same as described in the hydrology land use effects section above.

Question 5-6: What opportunities exist to restore wetlands in the watershed?

Existing Condition: Current wetland information is insufficient to identify wetland enhancement opportunities.

Trends: The trend in opportunities to restore wetlands is improving: Interest in wetland protection is widespread as the importance of these areas to watershed function becomes better understood, and funding sources exist to pay for wetland protection and restoration efforts.

Data Gaps: Insufficient information exists to identify the amount and location of wetland loss, the wetland disturbances that limit wetland function, and the functions of specific wetlands that could be used to prioritize enhancement activities.

Recommendations: Same as response to *Question 4-3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?*.

SEDIMENT SOURCES *(SECTION 6)*

Question 6-1: At present, what are the important sediment sources in the watershed?

Question 6-2: In the future, what will be the important sources of sediment in the basin?

Existing Condition: Long-term downcutting by the Clackamas River, Clear Creek and other streams has created steep and unstable landforms stretching the length of the Clear and Foster basins. Most large landslides are located in a few terrain types: along the valley walls of Clear Creek and its major tributaries; in the deep ravines cut into upland slopes; along terrace scarps; and in a few bedrock slides on Goat Mountain.

Most of the large landslides are prehistoric, and due chiefly to natural forces. However, even old natural landslides can affect human structures and land uses, or be partly reactivated by significant changes in slope geometry or drainage patterns.

Soil-erosion index values for most of the study area are low. The areas most susceptible are along the terrace scarps and valley walls, especially where vegetation has been cleared for farming, houses, or timber harvest. The Lower Clear and Foster subwatersheds contain the highest proportion of relatively erosion-susceptible ground; the other subbasins have smaller proportions.

At this level of analysis, it is not possible to identify the specific local sources of erosion in the basin, or to quantitatively determine the relative magnitudes of sediment delivery from mass wasting and surface erosion. Our preliminary appraisal is that surface erosion (and other chronic processes such as soil creep) is a greater source of sediment than landsliding in most years. But in extremely wet and stormy winters such as 1995-96 and 1996-97, even a few significant landslides can provide many years' worth of sediment flux to streams, as well as damage to structures and roads.

In summary, we find that current conditions of erosion and sediment transport in the Clear and Foster Creek basins are mostly fair to good. This status is probably due mainly to the current low population density and land-use intensity in these basins.

Trends: Erosion depends on local combinations of natural susceptibility and human activities, combined with triggering events (usually storms). The steeper landforms and terrain types, distributed across all of the subwatersheds, are naturally susceptible to erosion processes and storms. Some landslides and surface erosion will occur, regardless of human activities.

Erosion problems associated with suburban and rural-residential development are more likely in the Lower Clear Creek basin, along with other scattered areas. Agriculture (chiefly Christmas trees) and forestry are practiced in all of the subwatersheds, so all have the potential for the processes related to land-management activities.

Future sediment supply will depend on the land uses that are allowed or encouraged, and especially where and how they take place. More intensive residential development, changes in cropping, or increased logging could cause increases in the amount of sediment reaching the streams, if conducted in unsuitable places (erodible landforms), in an improper manner (without regard to erosion processes), and when inevitably struck by wet winters and big storms. If the erodible areas are avoided to the extent possible, and good management and development practices employed everywhere, the Clear and Foster basins could continue to enjoy low erosion and sedimentation rates.

Data Gaps: Mapping of sediment sources and deposits from air-photos is a useful but imperfect technique. Photos show a biased sample of the larger, well-exposed, recent features. Field checking is required to fully confirm the existence, dimensions, causes, activity levels, etc. of features recognized on air-photos, and to find those not revealed by the photos.

From the limited amount of fieldwork that has been done so far we cannot determine the extent to which human activities contribute to mass movement and surface erosion in this area. Although we can draw many inferences from similar situations in the region, further work would be necessary to suggest the major ways that erosion can be aggravated in this particular study area.

The working maps produced in this project constitute a continuation of a process of information-gathering and interpretation. More extensive future effort is necessary to confirm the information generated here. In particular, surveys of landslides and erosion damage would be most useful immediately after major storms and very wet winters.

Recommendations: As the state of erosion in the study basins is generally fair to good, we do not make any radical recommendations to deal with sediment sources. Most of the actions listed below utilize existing rules and procedures, well-known management practices, and voluntary cooperative measures to address specific problems. Various combinations of these actions can be applied throughout all of the subwatersheds.

1. Information/assessment: In cooperation with Oregon DOGAMI and Clackamas County Project Impact, continue studies of mass movement in the Clear and Foster Creek basins (and neighboring rural Clackamas County), with field work devoted to confirming, measuring, and determining the contributory causes of slides in the region.

2. Avoidance (regulatory and zoning measures): Utilize existing land-use planning tools to ensure proper consideration of potential stability problems in the siting and construction of new structures and roads. Most of these are already in place, such as and rules regarding earth-movement hazard areas and development standards for protection of natural features (including hillsides and stream corridors; see Clackamas County Zoning and Development Ordinance).

3. Prevention/protection: Ensure better geotechnical evaluation of proposed structures, roads, forest practices, etc. in slide-susceptible areas (mainly by enforcement of existing rules).

Question 6-3: Where are severe erosion problems that are manageable, so as to be assigned a high priority for remediation techniques or projects?

Existing Condition: Human activities have probably had a role in some landslides, but we are unable to assign specific causes for most cases based on this limited survey.

The screening could not pick out most small, local cases of surface erosion in the basin. In general, agricultural, forestry and development practices have been appropriate and properly applied; the condition of the streams is fairly good, as indicated by satisfactory turbidity levels. Air-photos do not show many obvious surface-erosion features, but most of those are too small to show up.

In the photos and/or in the field, we did see places where preventable surface erosion is occurring or could happen: bare vehicle and animal paths on sloping rural-residential and hobby-farm lots; a few areas where ground had been scarified after recent logging; unpaved roads showing signs of erosion, commonly due to neglect of drainage control (culverts, water-bars).

Trends: Same as previous.

Data Gaps:

1. Same as previous.

2. In addition, information regarding the extent of road-related erosion problems could be generated by road surveys that inventory the state of the running surfaces (particularly for unpaved roads), cuts, fill slopes, and drainage structures.

Recommendations:

1) ***Information/assessment***:

   a) In cooperation with Oregon DOGAMI and Clackamas County Project Impact, continue studies of mass movement in Clear and Foster Creek basins (and nearby rural Clackamas County), with field work devoted to confirming, measuring, and determining the contributory causes of slides in the region. (Such investigations can inform all other steps.)

   b) In cooperation with the County, Soil and Water Conservation District, and local land-owners, conduct an inventory of unpaved roads (location, condition, drainage, etc), to evaluate the need for erosion control and remediation. This would especially involve forest roads in the Upper, Middle, and Little Clear Creek subwatersheds; and multi-home private roads in all subwatersheds.

2) ***Avoidance (regulatory and zoning measures):*** Utilize existing land-use planning tools to ensure proper consideration of potential stability problems in the siting and construction of new structures and roads. Most of these are already in place, such as and rules regarding earth movement hazard areas and development standards for protection of natural features (including hillsides and stream corridors; see Clackamas County Zoning and Development Ordinance).

3) ***Prevention/protection***:

   a) Ensure better geotechnical evaluation of proposed structures, roads, forest practices, etc. in slide-susceptible areas (mainly by enforcement of existing rules).

   b) Employ erosion-prevention measures in cultivated fields, pastures, hobby farms, and rural-residential lots to avoid exposure of bare soil to running water, especially on slopes and before/during the wet season.

4) ***Restoration:*** Encourage voluntary measures to carry out prevention and remediation projects. In particular, organize appropriate neighborhood and land-owner groups to provide adequate surfacing and surface-erosion control of private rural roads; and planting, fencing, or other means of protecting waterways from compaction and erosion by livestock, off-road vehicles, etc.

WATER QUALITY *(SECTION 7)*

Question 7-1: What are the designated beneficial uses for streams in the watershed?

Beneficial Uses: Clackamas River Basin (OAR 340-41-442)	
Public Domestic Water Supply*	Salmonid Fish Spawning
Private Domestic Water Supply*	Resident Fish & Aquatic Life
Industrial Water Supply	Wildlife & Hunting
Irrigation	Fishing
Livestock Watering	Boating
Anadromous Fish Passage	Water Contact Recreation
Salmonid Fish Rearing	Aesthetic Quality
	Hydro Power
* With adequate pretreatment (filtration and disinfection) and natural quality that meets drinking water standards. (ODEQ 2001b).	

Question 7-2: What are the water quality criteria that apply to streams in the watershed?

Water quality criteria that apply to Clear Creek are identified in the Oregon water quality standards for the Clackamas River Basin. The criteria that were used to assess water quality data for this report are shown below. A more comprehensive list is shown in the Water Quality Section of the report.

Parameter (Beneficial Use)	Criteria Type/ Measurement	Criteria *
Dissolved Oxygen (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric Criteria Dissolved oxygen (mg/L)	Salmonid Spawning: Greater than 11.0 mg/L Cold Water Aquatic Life: Greater than 8.0 mg/L. (Several conditions apply, refer to State standards for details.)
pH and TDS (Resident fish and aquatic life, water contact recreation)	Numeric Criteria (pH) (Total Dissolved Solids)	pH: 6.5 – 8.5 TDS: 100 mg/L
Nutrients (Aesthetics)	Narrative Criteria (phosphorus, nitrates)	No State numeric criteria. Recommended criteria (EPA 2001) Total Phosphorus 0.04 mg/L Nitrates 0.15 mg/L
Temperature (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric Criteria (temperature)	Salmonid fish rearing: 64 ° F (17.8° C) Salmonid spawning, egg incubation, and fry emergence: 55 ° F.
Turbidity (Resident fish and aquatic life, water supply, aesthetics)	Narrative Criteria (turbidity (NTU))	Not greater than 10% increase over natural stream turbidity (ODEQ 2001b). Screening criteria for aquatic life– 50 NTU (WPN 1999) Screening criteria for slow sand filter (National Drinking Water Clearinghouse 2000)
Bacteria (Water contact recreation)	Numeric Criteria *Escherichia coli*	126 colonies/100 ml. (30 day log mean) 406/100 ml. (Single sample)
* This description of criteria is abbreviated. Most criteria have associated conditions and exceptions that apply. The full text of the regulations should be used for a specific application (ODEQ 2001b).		

Question 7-3: Are there stream reaches identified as water quality limited on the State's 303(d) list?

Existing Condition: Clear Creek is not specifically listed on the 303(d) list. The lower Clackamas River, from River Mill Dam to the mouth, is listed in the 1998 303(d) list for temperature.

Trends: The State periodically updates the 303(d) list pending on new information. Given the data summarized in this report, the State may consider adding sections of Clear Creek to the 303(d) list.

Data Gaps: See below, *Question 7-5: What are the key data/information gaps in water quality information?*

Recommendations: Data summarized in this report indicates that lower Clear Creek, from the mouth to Viola, at RM 12, should be listed for violations of the 64 degree F. temperature criteria. Nutrients are excessive in the small tributaries to Lower Clear Creek, but generally do not exceed recommended criteria (EPA Ecoregional criteria) in Clear Creek itself. Listing these small tributaries is a judgement call that ODEQ would need to make.

Question 7-4: What do water quality studies, existing data sets, or other summary documents indicate about water quality conditions?

Existing Condition: Overall, water quality is fairly high in Clear Creek where it has been sampled. The one major exception is temperature in lower Clear Creek. Several tributaries in Lower Clear Creek show the effects of increased urbanization and rural development, which is threatening water quality.

1) ***Nutrients, Bacteria and associated indicators:*** Two tributaries, Bargfeld Creek, at RM 7.5, and Hattan Fork, at RM 4.3, on lower Clear Creek show elevated concentrations of total phosphorus, nitrates and bacteria that exceed water quality criteria. The most likely explanation for elevated nutrients and bacteria are the cumulative effects of septic systems, livestock wastes, and chemical application of fertilizers that occur within the subwatershed. Recovery of nutrients to near background levels occurs at the mouth of Clear Creek. Upper Clear Creek (at RM 20) provides a contrast of low nutrients and bacteria associated with a predominantly forested landscape. There were no sample locations in Middle, Little Clear Creek, and Foster Creek subwatersheds.

2) ***Turbidity***: Turbidity shows a similar pattern to nutrients. Slightly elevated in Bargfeld and Hattan Fork Creek, but otherwise quite low (less than 10 ntu) at other stations in Clear Creek.

3) ***Temperature:*** Water temperature monitoring shows a similar pattern in Clear Creek as that observed for nutrients. Water temperature was observed to be in good condition at Highway 211, but then warmed along the lower 12 miles of stream. Monitoring at Viola (RM 12) and at Fisher's Mill Road (RM 8.0) indicate violations of the Oregon water quality criteria for protection of salmonid rearing. Some warming in temperature may be associated with natural processes, such as the increase in air temperature at lower elevations, the natural increase in stream channel width in a downstream direction or possibly in relation to groundwater inflows.

4) ***Pesticides:*** Information on contaminants in Clear Creek is fairly minimal although there are numerous studies on contaminants at the Willamette River Basin scale. The limited sampling in Clear Creek detected five commonly used herbicides: atrazine and desethylatrazine (a metabolic breakdown product of atrazine), metolachlor, pendimethalin, and triclopyr. The detection of these pesticides does not indicate an immediate threat to beneficial uses of water. The detections do indicate that Clear Creek is likely similar to other locations in the Willamette Basin, where a diversity of other pesticides have been detected.

Trends: There is no long-term data to evaluate the trend in water quality from a statistical approach. One can speculate that increased urbanization (and associated rural development) will continue to degrade water quality as was evident from the two small tributaries that were monitored.

Data Gaps: See below, *Question 7-5: What are the key data/information gaps in water quality information?*

Recommendations:

1 ***Prevention/Protection***:

a) Passive restoration refers to activities that prevent or avoid degradation. Since Clear Creek is generally in good condition the CRBC may be effective in protecting water quality in the long term by coordinating with other governmental entities. Prevention may invlove such activities as Planning and Zoning that minimizes the effect of increasing population density on sensitive areas. Generally, streams, riparian areas, and wetland areas are sensitive areas where clearing, increased impermeable areas, livestock/pet wastes, and chemical application will have the greatest negative impact. Buffering these areas from increased urbanization and lower densities will help maintain the high water quality that is generally observed in Clear Creek.

b) A second aspect of prevention/protection is to maintain those landscapes/land uses that currently provide higher water quality. Although monitoring in the forested zone was minimal, it is apparent that the forested land use curently provides higher water quality (nutrients, bacteria and temperature) than the mixed agricultural/urban areas. Use of BMPs in forestry that protect and maintain water quality and current actions to improve riparian stands for LWD recruitment and shade should be encouraged.

2 ***Advocacy and Coordination:***

a) There are numerous agencies that are interested in assisting the CRBC in protecting and enhancing watersheds; for example, Metro, OWEB, DEQ, ODFW, ODF,USDA NRCS, OSU Extension, and the Clackamas County SWCD. The Clackamas SWCD is a particularly suited to assist the CRBC in working with local landowners on the small acreages and hobby farms that occur in Clear Creek. The Clackamas County utilizes a "Micro Watershed" based approach to work with private landowners.

b) The SWCD Micro Watershed approach may be particlurly applicable to the small watersheds with current nutrient and bacteria problems:

i) Bargfeld Creek (confirmed problem)

ii) Hattan Fork Creek (confirmed problem)

iii) Lower Clear Creek (suspected – any concentrated rural/urban population area).

3 ***Education:*** Education activities can also be closely coordinated with other agencies such as OSU – Extension and the Clackamas County SWCD. Education activities specific to water quality protection may include:

a) Livestock, manure, and nutrient management

b) Pesticide and fertilizer application

c) Backyard conservation practices to protect streamside zones and wetlands.

d) Crop, pasture and forest practices

4 ***Restoration Activities:*** Restoration refers to active management activities. Restoration activities for water quality should be prioritized in the denser population zones in the Lower Clear Creek subwatershed. Restoration activities may include:

a) Riparian planting programs (associated with education to maintain riparian zones).

b) Riparian fencing and livestock management to enhance vegetative coverage.

c) Livestock manure management.

d) Pond management to decrease the impact of in channel ponds on water quantity and temperature.

e) Water management to decrease flow diversions and restore/enhance wetlands.

Question 7-5: What are the key data/information gaps in water quality information?

Existing Condition and Data Gaps: Water quality data collected by the Clackamas County SWCD (Clackamas County SWCD 2001) and Pacific Gas and Electric (PGE, 2002) provided useful information to characterize water quality conditions in Clear Creek. This water quality information combined with the results of the other watershed assessment components leads to general recommended actions that the CRBC and community can take to protect and restore water quality. As with any study, it also leads to further questions that the CRBC and community may wish to answer.

Nutrient Sources and Effects

Although nutrients are high in some tributaries, there is little information on the specific sources of nutrients or the effects of these nutrients in Clear Creek. Excessive algal growth stimulated by nutrients can lead to depression of dissolved oxygen and shifts in the macroinvertebrate community. These changes can have direct effects on reducing growth and survival of juvenile salmon and trout. These potential effects can best evaluated by measuring dissolved oxygen over 24-hour periods (diel monitoring) during critical periods and biological monitoring of algal and macroinvertebrate communities. Diel dissolved oxygen monitoring is fairly straightforward given access to the right monitoring equipment. Monitoring biological communities is not as straight forward. Although, samples may be easy to collect, properly analyzing and interpreting results requires professional expertise.

Identifying specific sources of nutrients through monitoring may not be necessary to recommend further action. Clean-up activities may be better addressed through programs/projects that provide information, technical assistance, and cost-sharing to homeowners and landowners. Further identifying specific sources may disenfranchise the target groups rather than gain their cooperation.

Water Temperature Monitoring

Monitoring to date indicates that water temperature exceeds recommended criteria for salmonid spawning and rearing along the lower reach (12 miles) of Clear Creek. Since the CRBC has been involved in tree-planting projects and water temperature may be a limiting factor for salmonid species it would be useful to establish a long-term water temperature monitoring program. A comparable multi-year data set would be necessary to detect any long-term changes in water temperature attributed to these projects since temperature varies over longer term periods due to climatic variation.

Pesticides

There is limited data on pesticide residues in the Clear Creek watershed. The limited data indicates the occurrence of some commonly used herbicides. Detection of herbicides is likely to increase with further monitoring.

Recommendations:

The following list describes some information needs and approaches to monitoring for CRBC consideration.

1. Septic Systems. The data obtained in the two small tributaries, Bargfeld and Hattan Fork Creek, indicate a high potential for contamination from septic systems. This issue may be worth investigating in more detail to determine: a) if the pollutant source is indeed septic systems, b) if so, is this due to poorly designed, undersized, or failing systems, c) and whether some alternative to septic systems are called for. The CRBC should coordinate with the local health district to determine a course of action.

2. Filling in Spatial Coverage: Data on other streams and sub-watersheds, specifically Middle, Little, and Foster Sub-watersheds is entirely lacking. The CRBC should consider whether further monitoring in these areas is needed, or whether applying conclusions from monitoring in similar land use areas is sufficient to move forward with restoration activities.

3. Hot Spots & Volunteer Monitoring: As identified in this assessment, there are tributaries that appear to be pollutant hot spots. Continuing to monitor these locations over time may assist in understanding cause and effect as well as whether the results are an anomaly associated with a low water year.

4. Volunteer Monitoring: Volunteer monitoring is a good way to involve local landowners and promote ownership in the program. Volunteer monitors may be paired up with the "Micro Watershed" approach for watershed restoration described by the Clackamas County SWCD. Volunteer monitoring should be viewed as primarily an educational exercise, and not a substitute for professional level assessment.

5. Coordinated Monitoring and Trend Data: As with many watersheds, monitoring in Clear Creek lacks a Monitoring Program Plan. A comprehensive monitoring program plan would assure that data is collected with sufficient rigor to answer questions in a scientifically valid manner. Currently a number of entities collect data, but the value of that data is compromised by the lack of an objective based monitoring plan that outlines minimum sample frequency, standard protocols, and quality assurance/quality control procedures.

   Trend data at a small number of selected stations will provide the most useful information over time to determine if water quality is getting better or worse in Clear Creek. Trend analysis requires a high sample frequency (number of samples/time period) over a long period of time to be effective. Monitoring programs also require continuous flow data at an associated gaging station to be effective in interpreting the data.

FISHERIES *(SECTION 8)*

Question 8-1: What salmonid species are documented in the watershed, are any of these currently ESA or candidate species?

Question 8-2: What is the distribution, relative abundance and population status of salmonid species in the watershed?

Existing Condition: Anadromous fish occurring in the Clackamas basin include: spring and fall chinook, coho salmon, winter steelhead, summer steelhead (non-native), migratory cutthroat trout and lamprey). Clear and Foster Creeks are utilized by fall chinook, winter steelhead and coho salmon. The distribution of anadromous fish is limited by 15' to 20' falls on Upper Clear Creek and the North Fork of Clear Creek (*Map 7: Fish Distribution*). Access to several tributaries is blocked by high falls at the confluence with the main Clear Creek.

Resident fish potentially occurring in Clear and Foster Creeks include, cutthroat trout, rainbow trout and mountain whitefish. The last confirmed sighting of a bull trout in the Clackamas River was in the early 1970's, bull trout are thought to have been eliminated from the basin (Cramer xx).

Fall Chinook are federally listed as Threatened. Winter Steelhead stocks in the Clackamas basin are federally ESA listed as Threatened. The wild coho salmon stocks in the Clackamas basin are candidate species for federal ESA listing and are state-listed as Endangered.

Trends: There is limited information on the historic and current distribution and abundance of the listed anadromous fish in Clear and Foster Creeks. Little is known about fall chinook. There have been recent increases in hatchery returns and declines in wild steelhead. The wild coho stock is considered the last remaining population with a substantial run in the entire Columbia River Basin.

Data Gaps: There is very little specific information on fish distribution and habitat utilization in Clear and Foster Creeks. Information on trends and status is largely inferred from data from the Clackmas system.

Recommendations: There is no central collection point for data that is collected making it difficult to track down and compile any information that has been collected. Creating a central collection point for all data collected including ODFW, Angler Groups (Gil mentioned spawning surveys had been done on his property). Also, to better document the extent and areas of concentrated fish use try engaging volunteer groups to do annual spawner surveys.

Question 8-3: Which salmonid species are native to the watershed, and which have been introduced to the watershed?

Question 8-4: What are the species interactions?

Existing Conditions: Between 1949 and 1995 brook trout, chinook salmon, coho salmon, cutthroat, rainbow trout and steelhead have all been stocked in Clear and Foster Creeks. Brook trout are the only non-native species and there are no references to brook trout currently occurring in either Clear or Foster Creeks. It is likely these stocking efforts were unsuccessful.

The only identified species interaction is increases in hatchery returns of winter steelhead and declines in wild steelhead returns have raised concerns hatchery fish may be mixing with wild fish (Cramer xx).

Trends: Stocking and enhancement efforts were discontinued in 1995-1997.

Data Gaps: **N**one.

Recommendations: None.

Question 8-5: What is the condition of fish habitat in the watershed (by sub-basin) where habitat data has been collected?

Existing Condition: Key parameters of the quantitative habitat data were compared to the NMFS PFC matrix values. Substrate conditions were properly functioning at all sites and in general most sites visited in Clear and Foster Creeks had good quality spawning gravels with only localized areas of high fines and embedded conditions. Stream channel segments that had floodplains were in properly functioning condition which means there were frequent active off channel areas and margin side channels. Large woody debris numbers were low at almost all sites visited which can directly influence pool formation and bank stability. At most sites all three parameters were rated as not properly functioning. In addition, most of the large wood that was observed was very old and decadent, it will probably not last in the channel much longer.

The observations made during the qualitative surveys were similar to the quantitative data. In several locations along main Clear Creek large wood was stacked adjacent to the channel after apparently having been removed from the gravel bars in front of private property. In many locations landscaping extended to the edge of the stream creating smooth mowed grassy banks this did not function to provide much cover. Specific locations of problem areas in both Clear and Foster Creeks are identified in *Appendix 1: CHT and Aquatic Field Report*.

Trends: No long term data is available on habitat conditions. Although as development in the watersheds continue landscaping, wood removal and rip rapping are likely to increase.

Data Gaps: This was a limited data collection effort. Due to limited access no sampling was completed in the Little Clear Creek subwatershed.

Recommendations: Continue qualitative sampling of main Clear Creek. Continue riparian planting for long term supply of large wood. Investigate opportunities to introduce large wood to the channel. Educate landowners about benefits of large wood.

Question 8-6: Where are there potential barriers to fish migration?

Existing Condition: There are multiple natural fish passage barriers in the Clear Creek watershed. The ones which are primarily limiting anadromous fish distributions are located at the confluence of main Clear Creek and the north fork of Clear Creek in the upper Clear Creek subwatershed. These are 15 to 20’ falls blocking both forks of the river. There is also an approximately 10’ tall falls on Swagger Creek below Highland Rd. Several of the tributaries have partial or complete barriers preventing anadromous fish from utilizing the tributaries. The limited access to tributary streams increases the importance of the main channel habitat for fish.

In Foster Creek there are no known natural fish passage barriers. There is a small dam above Gerber Road that appears to be seasonally installed and removed. Depending on the timing and use of the dam it may be a fish passage barrier or possibly have a negative impact on downstream habitat.

There is currently an assessment of all road crossings ongoing. This assessment will provide a comprehensive review of all fish passage barriers associated with roads in the Clear and Foster Creek watersheds.

Trends: The increased awareness of the need for fish passage and ongoing surveys are likely to result in a decrease in man-made barriers.

Data Gaps: There is limited data on road crossings and in-channel ponds.

Recommendations: Incorporate results of ongoing road survey and upstream extent of fish into assessment.

WILDLIFE AND UPLAND VEGETATION *(SECTION 9)*

Uplands and Wildlife Summary

Question 9-1: Are vegetation maps current, do they cover the entire watershed and are they mapped at a scale appropriate for wildlife and Species of Special Concern impact analysis?

The vegetation maps available for the study area were good places to initiate an investigation on available habitat for the watershed. However, using these maps for on the ground planning on expenditure of funds for action is problematic. A revised vegetation map is needed for the watershed that reflect the current vegetation. All habitat fragmentation, patch analysis, and wildlife habitat assessment is based in large part on this vegetation layer to define suitable habitat.

Much of this watershed lies between the Metro Analysis Area in the Willamette Valley and the Upper Cascades where federal land managers, particularly the Forest Service has developed vegetation classifications. Because most of the watershed is private, there has been little incentive to update the classification and delineation in this watershed until now. The actions developed from this Watershed Assessment and other Basin wide decisions are based on vegetation data that lack accuracy and precision. Tools and additional information are readily available to revise this map. Jimmy Kagan, Director, ONHIC, indicated that the Forest Service developed a Potential Natural Vegetation map for Northwestern Oregon. This used Plant Associations, a finer resolution of mapping than Alliance. They used Ecoplot and other forest data plots for their initial delineation. This first approximation map was verified using belt transects to determine ecological gradient to refine the delineation. This information along with the Metro data, and Northwest Habitat Insititue, and other classification efforts in the vicinity could be used to readily update the current vegetation map in this watershed.

Question 9-2: What species of concern (plants or animals), including any disjunct populations, are present within the watershed? What function does the habitat and conditions within the watershed have on these species conservation?

For this document, plant species of concern comprises those plant protected by the Oregon State Wildlife Law (OSWL). To protect native plants, the OSWL provides that bulbs, rhizomes, seeds, roots, or native plants shall not be exported from Oregon through sale, offered for sale, or collected without a permit. This law protects native plants in the following family or genera of plants: *Lilium, Calochortus, Frittillaria, Erythronium, Cypripedium, Calypso, Lewsii, Douglasia*, *Rhododendron* or *Azalea*. Collection is gained through a permitting process with the State Department of Agriculture.

For this document, wildlife species of concern are those species that do not have ESA, BLM, USFS or State of Oregon status (protection) but are of local concern or regional importance. Big game (e.g., deer, elk, bear, and cougar), upland game birds (e.g., turkeys and ring-necked pheasants) and non-game species (e.g., most songbirds) are included under this heading.

Specific information on plant or wildlife species of concern is lacking throughout the watershed.

Question 9-3: What special status (plants or animals) are known to occur or is there potential habitat for these species within the watershed? What function does the habitat and conditions within the watershed have on these species long-term viability?

Three such plant species are known to occur in the watershed: *Latherus holochlorus* (Thin-leaved peavine), *Cimcifuga elata* (tall bugbane), and *Delphinium leucophaeum* (white rock larkspur). *Montia howellii* (Howell's montia) has a high potential to occur in the watershed but to date has not been found here. *Sowerbyella rhenana* and *Ramaria araiospora* are two rare fungi, which have been found on BLM lands. Rare plants and fungi have been surveyed for on BLM lands only. These plants and fungi are not afforded legal protection on private lands and have not been surveyed for on private lands in the watershed.

Survey for rare animal species has been conducted on BLM lands. Spotted owl is the only species listed under the ESA known to occur in the vicinity of the watershed. There are eight Sensitive species known to occur in the watershed. Most of these species are affiliated with mature or late successional forests. Nine other Sensitive species may occur in the watershed. In all cases, fragmentation and decreased patch size compromises the species habitat use within the watershed. Corridors and remnants of mature or late successional forests can provide a dispersal mechanism.

Surveys for the sensitive species which may occur in the watershed should be carried out on public lands and willing private landowner parcels. Potential habitat for red-legged frog and two very rare grassland birds was modeled. The areas with the highest potential for these species should be surveyed for to confirm presence / absence and information on habitat quality and the ability to provide protection for long-term viability.

Question 9-4: What are the noxious weed species and what is their distribution within the watershed?

Although weeds have invaded many parts of the watershed, large tracts remain weed free. Weeds are found throughout the watershed with some elevational and habitat distinction by species (Refer to *Map 9: Current Vegetation and Noxious Weeds*). Few surveys for weeds have been conducted within the watershed. The challenge is to protect the weed free areas from invasion, while reducing the impact to areas where weeds have been established. As with tackling weeds in backyards and gardens, vigilance and persistence do count in controlling weeds.

A windshield survey should be conducted of all roads within the watershed using a GPS to identify areas where weeds are located. The list of the weeds by location and a ranking of the invasion should be noted. Public education on the devastating effects of weeds and potential control measure should be considered. An interagency approach to this problem is needed to control weed spread.

Question 9-5: What wildlife species and habitats found on the Upper Clear Creek are found in the Lower Clear Creek Watershed? Are there wildlife species found in the Upper Clear Creek Watershed, which are important indicator species for the Lower Clear Creek Watershed?

Agricultural development, home site development, weed encroachment, and human and domestic animal disturbance have created habitat fragmentation within the watershed. There is no information on the presence / absence of wildlife species that occur in the Upper Clear Creek Watershed that may occur in the Lower Clear Creek Watershed because no surveys have been conducted in the lower watershed. In addition, few surveys have been conducted in the Upper Clear Creek Watershed. Surveys for Spotted Owl are the only studies completed in the watershed. Because of elevational differences, there are likely few species that would act as good indicators for both the upper and lower elevations.

To address the question of ecosystem integrity and subsequently wildlife habitat, a focal species approach was used to evaluate habitat continuity or corridor needs. “Focal species” refers to individual species selected for monitoring in ecosystem-level management programs. Three analyses were performed to address the issue of habitat fragmentation and habitat types across the watershed: grassland birds, red-legged frog, and Douglas-fir forest. Distributions of the potential habitat for these species and community type are presented.

Surveys to confirm the presence of potential habitat or confirmation of the maps’ predictions is needed. In addition, photo point monitoring of habitat condition and trend across habitat within the watershed. Another useful measure is the use of Neotropical migrant bird species in select habitats to determine habitat quality.

Question 9-6: What are the key data/information gaps for wildlife, rare species, species of concern, and upland vegetation components?

The highest priority for this component of the Watershed assessment is to develop an accurate map of the current vegetation in the watershed. Information on the weed species and distribution within the watershed is needed. Selected species surveys including Neotropical migrant bird species plots should be developed. At these locations, photo-point monitoring is needed to establish a baseline for current condition and trend.

1.0 INTRODUCTION

The Clackamas River Basin Council (CRBC) contracted with Watershed Professionals Network to complete a watershed assessment and provide assistance in developing a watershed action plan. Clear Creek and Foster Creek are tributaries to the lower Clackamas River located below any major dams on the system, and therefore potentially important to restoration of anadromous fish species in the river. Foster Creek drains directly into the Clackamas River, but it is included in this assessment because of its adjacent location and similar land use patterns. A general reference to Clear Creek watershed in this document therefore usually refers to both watersheds.

The CRBC will complete a separate Watershed Action Plan based on the findings and recommendations in this watershed assessment. In addition, the CRBC is completing a fish barrier assessment to identify and prioritize fish passage projects.

1.1 PURPOSE AND SCOPE

The purpose of the assessment is to characterize current and historic watershed conditions in the Clear Creek watershed and to make recommendations to protect/enhance watershed natural resources, with particular reference to the aquatic environment. The assessment will aid the CRBC in identifying opportunities and setting priorities for watershed restoration actions.

1.1.1 Approach

The assessment generally followed the framework described in the *Oregon Watershed Enhancement Board's Watershed Assessment Manual* (WPN, 1999). The assessment focused on the following components: Channel habitat classification and modification; hydrology and water use; riparian/wetlands; sediment sources; water quality; fisheries; and wildlife and upland vegetation. Generally the approach builds on existing information, and enhances this information with aerial photo interpretation and limited field checking. Additional fieldwork was used to verify channel habitat types and to characterize fish habitat condition. GIS was used as a critical assessment tool and method of displaying results.

1.1.2 Organization of Document

This document follows the overall organization of the assessment itself. A historical summary and seven resource component assessments were completed. These included the following:

- Review of the historical conditions in the watershed (***Section 2.0: Historical Conditions***);
- Classification of channel habitat types, and an assessment of channel modifications (***Section 3.0: Channel Habitat Type Classification and Channel Modification***);
- Assessment of hydrology and water use (***Section 4.0: Hydrology and Water Use***);

- Assessment of riparian and wetland habitat conditions (***Section 1.0: Riparian / Wetland Habitat Conditions***):

- Assessment of sediment sources in the watershed (***Section 6.0: Sediment Sources***);

- Assessment of water quality in the watershed (***Section 7.0: Water Quality***);

- Assessment of fish and fish habitat (***Section 8.0: Fisheries***);

- Assessment of Wildlife and Upland Vegetation (***Section 9.0: Wildlife and Upland Vegetation***).

The ***Watershed Summary*** at the beginning of this document provides the findings and recommendations from these sections in an abbreviated format.

Supporting ***Appendices*** and ***Maps*** are provided as separate hard copies and as electronic files on CD-ROM. The Clackamas Basin Watershed Coordinator should be contacted for copies.

1.2 STUDY AREA OVERVIEW

1.2.1 Study Area Location and Assessment Subwatersheds

The study area includes the Clear and Foster Creek watersheds, located in Clackamas County, Oregon (Figure 1-1, *Map 1: Base Map*). Elevations in the watershed range from 4,226 feet on Goat Mountain to 79 feet where Clear Creek joins the Clackamas River at river mile (RM) eight. No incorporated cities are located within the watersheds. Cities surrounding the watershed include Estacada and Sandy to the east, and Oregon City and Gladstone to the west of the watersheds. Downtown Portland is approximately 25 miles from the center of the Clear Creek watershed to the northwest. State highway 224 is adjacent to the watersheds to the northeast, and State highway 211 passes through the watershed. No railroads are located within the watersheds. For the purposes of this assessment the watersheds have been subdivided into five subwatersheds. Subwatershed characteristics are given in Table 1-1.

One of the most basic parameters affecting watershed hydrology is basin topography. The elevational range found within a subwatershed determines, to a large extent the hydrologic regime (i.e., rain-, rain-on-snow, or snowmelt-dominated runoff patterns) of the area. Similarly, basin relief determines the potential energy available to move water through the system. The topography of the Clear and Foster Creek watersheds is typical of areas within the Willamette Valley and adjacent foothills, with the downstream areas occurring within fluvial deposits from the Missoula floods, while higher elevational areas are dominated by volcanic geology (basalts and lava flows) (WPN, 2001). Mean subwatershed elevation and slope generally increase moving upstream throughout the subwatersheds (Table 1-1). With the exception of Upper Clear Creek, all subwatersheds are low-elevation (less than 1,500 feet) and of low relief. The low relief of all subwatersheds with the exception of Upper Clear Creek limit the potential energy available to move water through the system, resulting in relatively low stream velocities and erosion potential.

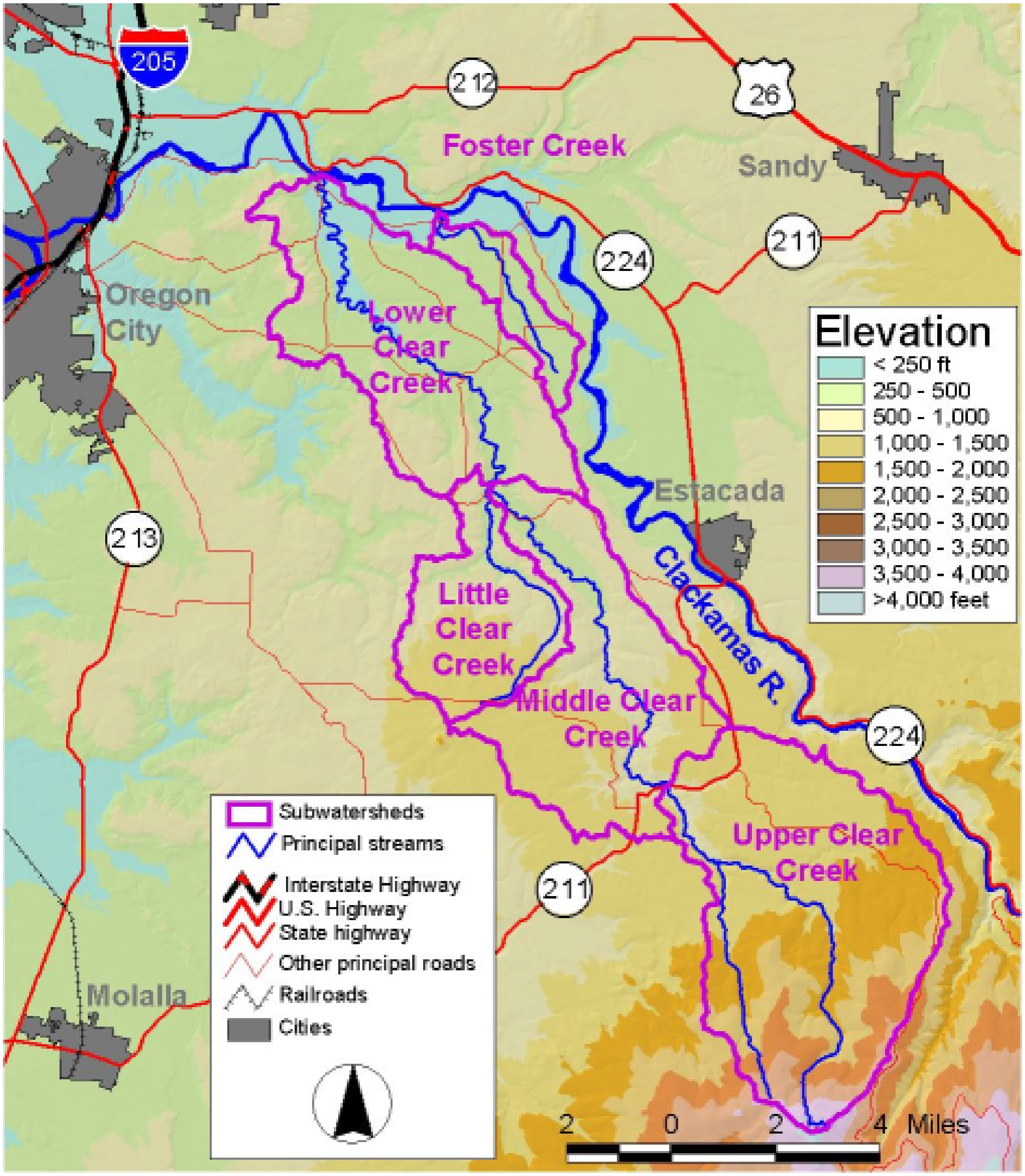

Figure 1-1. Shaded-relief map of the Clear and Foster Creek watersheds. Data sources: BLM (2002a, 2001a), OGDC (2000a, 1998a), USGS (2001).

Table 1-1. Characteristics of subwatersheds within the Clear and Foster Creek watersheds. Data sources: USGS (2001).

Subwatershed	Area (mi^2)	Elevation (feet)			Slope (%)		
		Mean	Minimum	Maximum	Mean	Minimum	Maximum
Foster Creek	3.5	350	128	554	2	0	24
Upper Clear Creek	27.1	1,809	696	4,226	6	0	64
Middle Clear Creek	17.2	892	328	1,529	4	0	36
Little Clear Creek	9.1	882	328	1,486	4	0	38
Lower Clear Creek	19.3	433	79	886	3	0	43
Entire Clear Creek	72.7	1,111	79	4,226	5	0	64

1.2.2 Water Features

The Clear Creek watershed contains a diversity of stream channel types with floodplain and moderate gradient channels predominating in the lower watershed and moderate gradient to steep confined valleys predominating in the upper watershed (Table 1-2). Ditches are a significant feature in the Lower Clear Creek subwatershed that contribute to decreased streamflows during the summer. See additional details in *Section 3: Channel Habitat Type Classification and Channel Modification.*

Channel characteristics in the Clear and Foster Creek basins reflect the geologic and geomorphic processes that have been active in the region. The channels in the basin can be sorted into a small number of landform types based on their combinations of geologic materials, terrain, and history.

In the mountainous parts of the basins, mostly small streams are eroding into resistant volcanic and volcaniclastic rocks, on moderate to steep slopes. On Goat Mountain—Green Mountain and the higher parts of the Boring Lava hills (such as Highland Butte and Outlook), most of the streams are small, and flow in relatively steep, narrow channels cut into bedrock. A few ponds and wetlands are associated with landslides or past glacial processes (Clear Lake). The larger streams have eroded deep gorges, such as those along the main stem of Clear Creek and (southern) Little Clear Creek near Dodge and Elwood.

The terrain in about two-thirds of the Clear-Foster area is dominated by a series of plateaus and terraces, built up by a combination of local volcanic eruptions. Where the streams flow over the terrace edges into the deeper canyons, these streams have eroded ravines of varying lengths and depths. The channels in these ravines are typically narrow and steep, and local gradients are controlled by the rocks' resistance to incision. In many places, hard layers of basalt, conglomerate, sandstone, or mudstone form ledges, waterfalls, and step-pools (such as on Swagger Creek); in others, stream incision has left narrow slices into bedrock (as at the mouth of Foster Creek).

Table 1-2: Summary of miles of stream in each CHT by subwatershed.

Subwatershed	FP1 (<1%)	FP2 (<1%)	FP3 (<1%)	LC (<2%)	LM (<2%)	MM (2-4%)	MC (2-4%)	MH (1-6%)	MV (4-8%)	SV (8-16%)	VH (>16%)	Ditch	Total Miles
Foster Creek	0.00	1.53	1.19	0.62	0.86	0.00	0.23	0.00	0.00	0.00	0.00	0.33	4.75
Little Clear Creek	1.98	1.05	0.36	0.30	0.48	7.32	2.07	0.36	3.94	1.74	0.93	0.00	20.53
Lower Clear Creek	8.62	0.40	2.81	1.13	3.92	7.21	3.22	1.55	3.86	0.57	0.00	3.06	36.36
Middle Clear Creek	4.39	0.79	0.29	0.36	5.38	5.59	1.23	0.74	5.53	3.47	0.25	0.32	28.33
Upper Clear Creek	0.00	0.00	1.04	0.40	3.12	12.98	9.88	1.26	7.49	7.95	8.12	0.00	52.22
Total Miles	14.99	3.77	5.68	2.82	13.76	33.10	16.64	3.90	20.83	13.72	9.29	3.70	142.20
Gradient Class Subtotals			24.44 (17%)		16.58 (12%)		49.74 (35%)		24.17 (17%)		23.01 (16%)	3.70 (3%)	

FP1= Large Floodplain CHT (<1% gradient, unconfined)
FP2= Medium Floodplain CHT (<2% gradient, unconfined)
FP3= Small Floodplain CHT (<2% gradient, unconfined)
LC= Low Gradient Confined CHT (<2% gradient, confined)
LM= Low Gradient Moderately Confined CHT (<2% gradient, moderately confined)
MM= Moderate Gradient Moderately Confined CHT 2-4 % gradient, moderately confined)
MH= Moderate Gradient Headwater CHT (1-6 %, confined)
MV= Moderately Steep Narrow Valley CHT (3-10% gradient, confined)
SV= Steep Narrow Valley (8-16% gradient, confined)
VH= Very Steep Headwater (>16%, Confined)

Along Clear Creek (especially from Dodge-Elwood to Fischer's Mill) and the major tributaries (Mosier, Little Clear, Little Cedar, and Bargfeld Creeks, etc.), the combination of stream incision and landsliding has produced deep, complex ravines. The smaller tributaries that cross or originate on the irregular surfaces of the large landslide bodies typically have gentle gradients, commonly interrupted by small ponds and wetlands. The landslides are major contributors to the supplies of coarse sediment (including boulders and cobbles, locally) and large woody debris to the streams.

Downstream of Springwater, Clear Creek flows dominantly on alluvium (as opposed to bedrock) in a generally wider valley bottom where, low-gradient streams meander across their valley bottoms, occasionally abandon channel segments, and inundate their floodplains and low terraces during high flows. The younger/lower terraces of the north end of the area (including most of the Foster Creek basin) are typically flatter than the rolling higher surfaces in the south. Consequently, the tributaries flowing on them tend to have very gentle gradients, except where they have eroded ravines into the terrace scarps, as near the mouth of Foster Creek.

1.2.3 Climate

The Clear and Foster Creek watersheds experience climatic conditions typical of the Willamette Valley and Cascade Mountain foothills. Climate data from several climate stations in and around the watershed (Figure 1-2, Table 1-3) was used to characterize conditions in the area.

Air temperatures vary throughout the area with elevation (Figure 1-3). Mean minimum air temperatures occur in the months of December and January, and range from 27-35^{0}F. Mean maximum air temperatures occur in the months of July and August, and range from the mid 70's to the low 80's.

The Oregon Climate Service (1998) has published digital maps of mean annual and monthly precipitation for the State of Oregon, based on available precipitation records for the period 1961-1990. The Oregon Climate Service (OCS) maps were produced using techniques developed by Daly and others (1994)[1], which use an analytical model that combines point precipitation data and digital elevation model (DEM) data to generate spatial estimates of annual and monthly precipitation. As such, the precipitation maps available from the OCS incorporate precipitation data from the local stations shown in Figure 1-2 and Table 1-3. Average annual precipitation within the watershed generally increases as elevation increases (Figure 1-4). Average annual precipitation ranges from approximately 47 inches near the mouth of the Clear and Foster Creek subwatersheds, to approximately 93 inches in the headwaters of the Upper Clear Creek subwatershed.

[1] For further information on how these maps are produced the reader is referred to Daly and others (1994), or the on-line overview available at http://www.ocs.orst.edu/prism/overview.html.

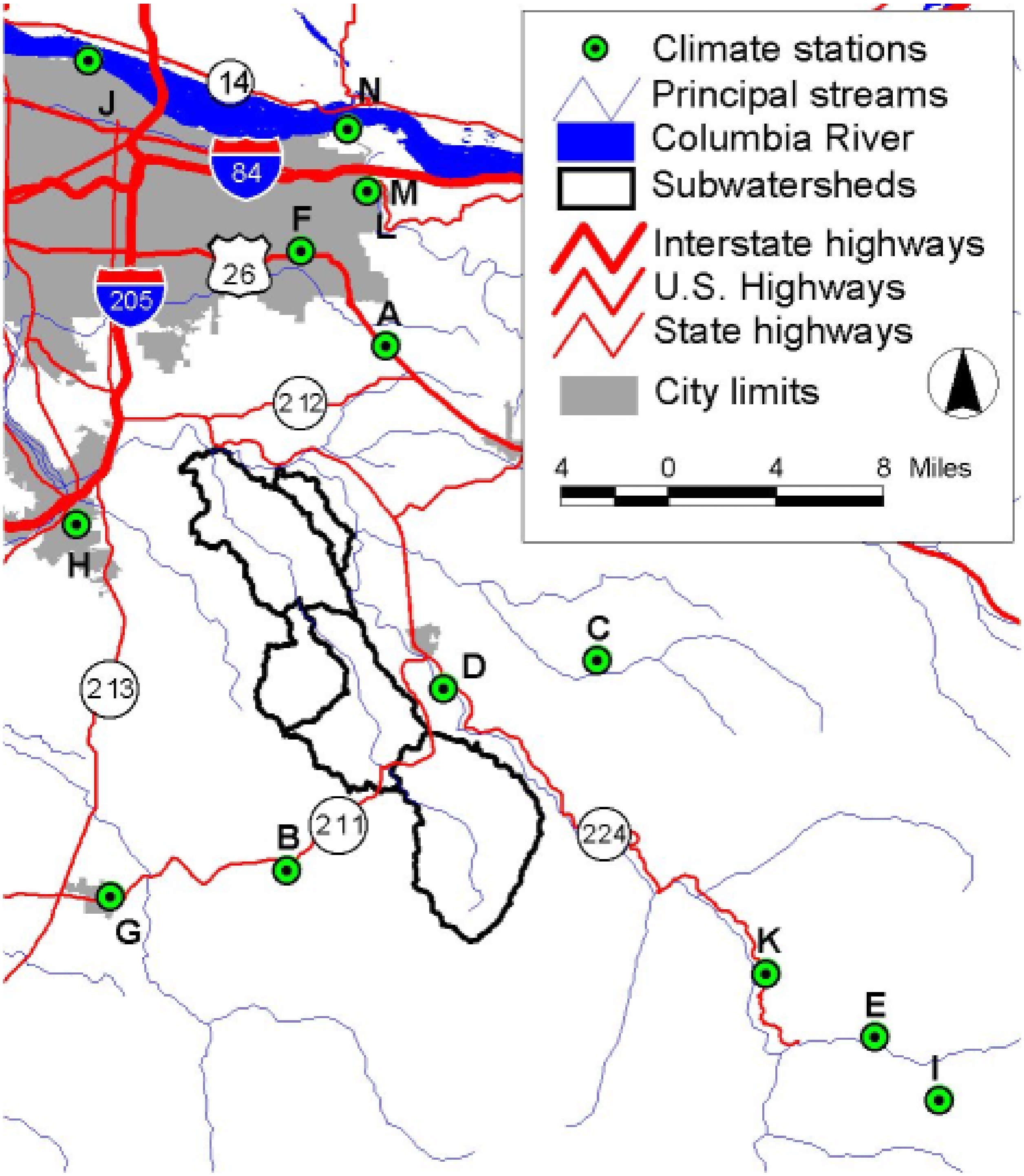

Figure 1-2: Climate stations in the vicinity of the Clear and Foster Creek watersheds. Data sources: BLM (2002a), EarthInfo (1996), OGDC (1998a, 1998b), NRCS (2001a), WDOE (2000), WDOT (2000).

Table 1-3: Station information for climate stations in the vicinity of the Clear and Foster Creek watersheds. Data sources: EarthInfo (1996), NRCS (2001a).

Map code	Station Name	Elevation (ft)	Parameter	Period of record			% Coverage
A	Boring 2 N	141	Hourly precipitation	11/16/1956	to	5/31/1960	99
B	Colton	680	Daily precipitation	2/1/1950	to	9/30/1951	99
			Hourly precipitation	7/6/1948	to	12/31/1995	97
C	Eagle Creek 9 SE	926	Daily precipitation	11/1/1972	to	12/31/1995	100
			Daily snowfall	11/1/1972	to	12/31/1995	97
			Temperature	10/1/1973	to	7/31/1979	25
D	Estacada 2 SE	410	Daily precipitation	1/1/1948	to	12/31/1995	98
			Daily snowfall	1/1/1948	to	12/31/1995	98
			Hourly precipitation	8/19/1948	to	12/31/1948	100
			Monthly precipitation	1/1913	to	Present	
			Temperature	1/1/1948	to	12/31/1995	98
E	Estacada 24 SE	2,200	Daily precipitation	2/1/1950	to	9/30/1951	100
			Daily snowfall	9/1/1951	to	9/30/1951	100
			Hourly precipitation	9/14/1948	to	12/31/1995	91
F	Gresham	310	Daily precipitation	2/1/1950	to	9/30/1951	100
			Daily snowfall	11/28/1950	to	11/28/1950	100
			Hourly precipitation	7/1/1948	to	12/30/1995	87
G	Molalla	400	Daily precipitation	7/1/1948	to	12/31/1976	100
			Daily snowfall	7/1/1948	to	12/31/1976	100
			Temperature	12/1/1948	to	12/31/1976	100
H	Oregon City	171	Daily precipitation	7/1/1948	to	12/31/1995	99
			Daily snowfall	7/1/1948	to	12/31/1995	98
			Monthly precipitation	1/1925	to	Present	
			Temperature	7/1/1948	to	12/31/1995	99
I	Peavine Ridge	3,500	Daily precipitation	10/1/1981	to	9/30/2001	
			Daily snowpack	10/1/1982	to	9/30/2001	
			Temperature	2/8/1989	to	9/30/2001	
			1st-of-month snowpack	3/1/1938	to	9/30/2001	
J	Portland Intl Airport	21	Daily precipitation	11/1/1941	to	12/31/1995	92
			Daily snowfall	12/1/1941	to	12/31/1995	92
			Hourly precipitation	11/3/1948	to	12/31/1995	100
			Temperature	11/1/1941	to	12/31/1995	92
			Windspeed	1/1/1948	to	12/31/1995	
K	Three Lynx	1,120	Daily precipitation	1/1/1931	to	12/31/1995	100
			Daily snowfall	1/1/1931	to	12/31/1995	98
			Hourly precipitation	2/1/1971	to	12/31/1995	87
			Temperature	1/1/1931	to	12/31/1995	100
L	Troutdale	89	Daily precipitation	1/1/1954	to	9/30/1955	100
			Daily snowfall	1/1/1954	to	9/30/1955	98
			Temperature	1/1/1954	to	9/30/1955	100
M	Troutdale 2	141	Daily precipitation	1/7/1956	to	7/31/1959	76
			Daily snowfall	1/7/1956	to	7/31/1959	77
			Temperature	1/7/1956	to	7/31/1959	63
N	Troutman Substation	29	Daily precipitation	7/1/1948	to	12/31/1995	85
			Daily snowfall	7/1/1948	to	12/31/1995	85
			Hourly precipitation	7/5/1948	to	3/31/1953	98
			Temperature	7/1/1948	to	12/28/1995	85

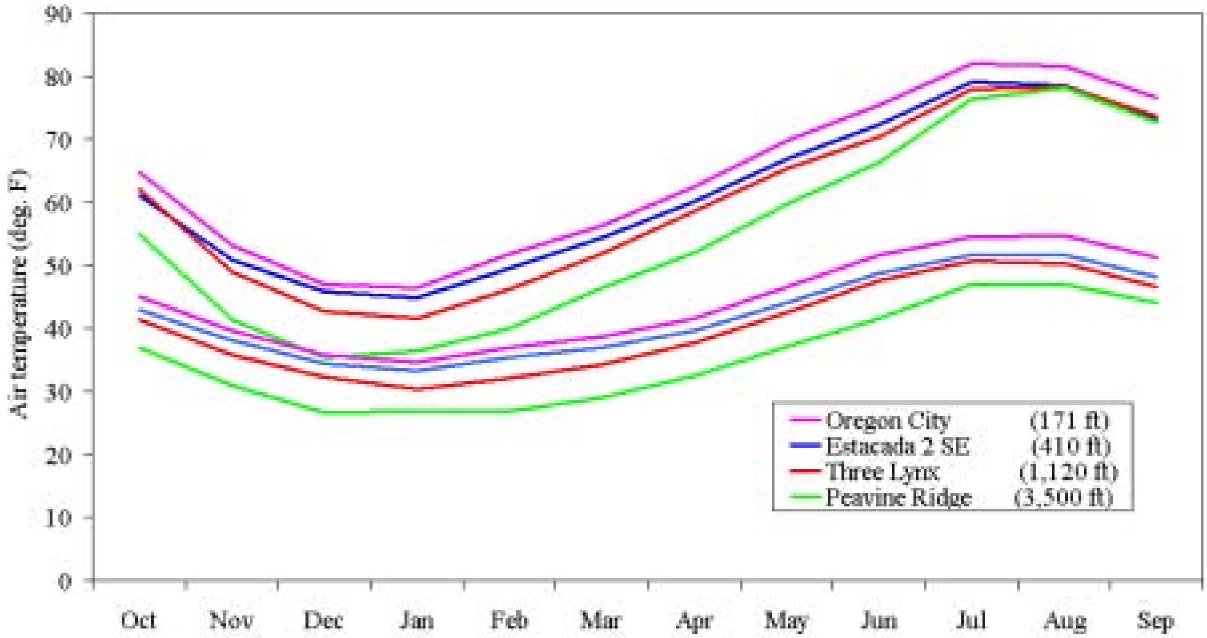

Figure 1-3. Mean minimum and maximum air temperatures for climate stations in the vicinity of the Clear and Foster Creek watersheds. Refer to Figure 1-2 and Table 1-3 for station location and data availability.

Mean monthly precipitation was also estimated for each subwatershed using data available from the Oregon Climate Service (1998) (Figure 1-5). Variation in mean monthly precipitation values are reflected in elevational differences among the subbasins. Mean monthly precipitation is lowest in the month of July for all subbasins; ranging from 0.8 inches in the Foster and Lower Clear Creek subwatersheds to 1.3 inches in the Upper Clear Creek subwatershed. December has the highest values of mean monthly precipitation in all subbasins, ranging from 7.4 inches in the Foster Creek subwatershed to 10.7 inches in the Upper Clear Creek watershed.

Year-to-year variability in precipitation was assessed using long-term precipitation records from the Estacada 2 SE climate station (Figure 1-6, Table 1-3.). Total monthly precipitation data available from the Oregon Climate Service (2002) was used to calculate total precipitation by water year[2] (Figure 1-6). Missing data for four months were estimated using data from the Oregon City climate station data (Figure 1-2, Table 1-3) that correlated well with the Estacada 2 SE station data[3].

[2] Water year is defined as October 1 through September 30. The water year number comes from the calendar year for the January 1 to September 30 period. For example, Water Year 1990 would begin on October 1, 1989, and continue through September 30, 1990. This definition of water year is recognized by most water resource agencies

[3] Monthly precip. @ Estacada 2 SE = 1.10976 * monthly precip. @ Oregon City + 0.56562; $r^2 = 0.92$

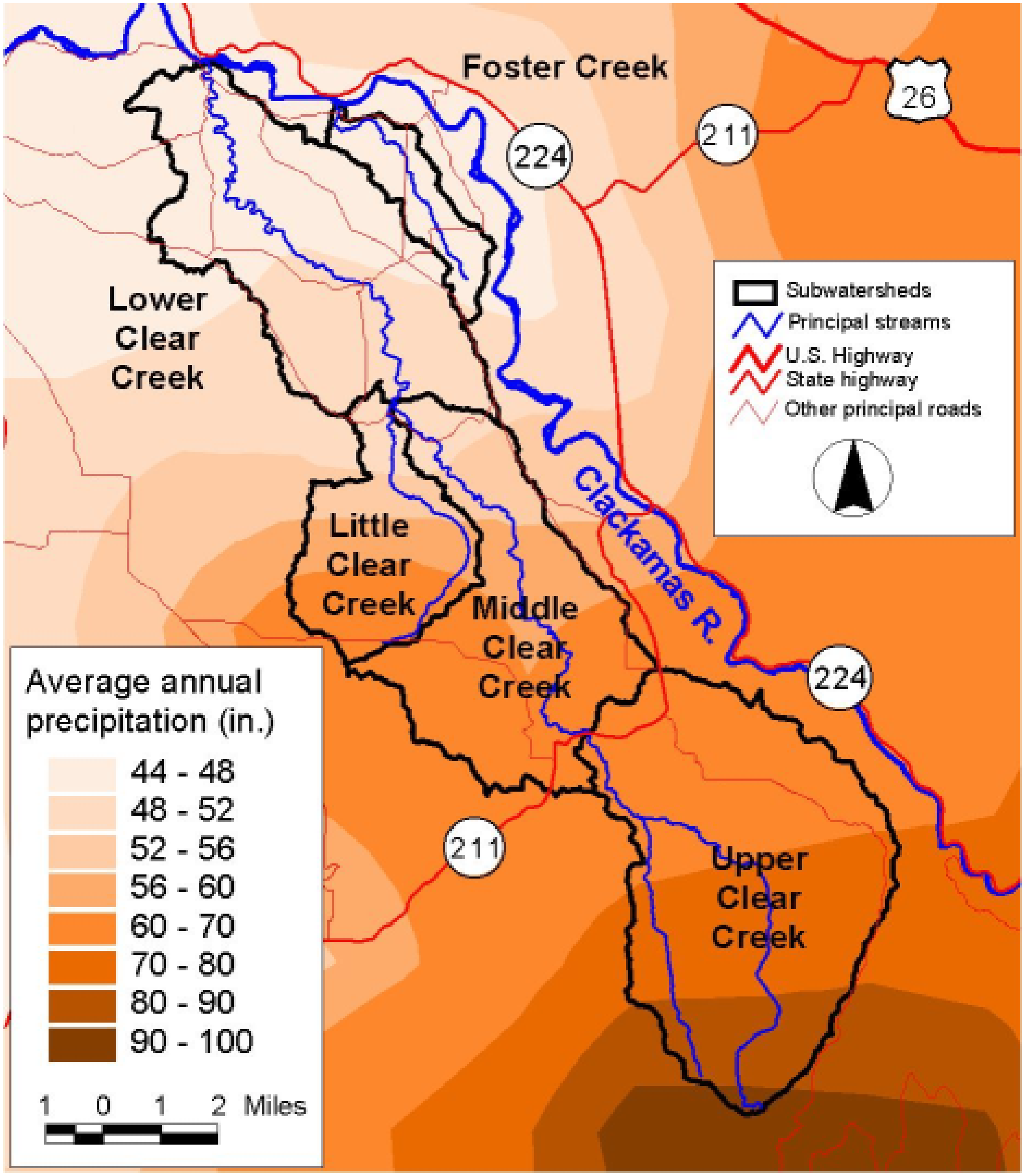

Figure 1-4: Average annual precipitation in the Clear and Foster Creek watersheds. Data sources: BLM (2002a, 2001a), Oregon Climate Service (1998).

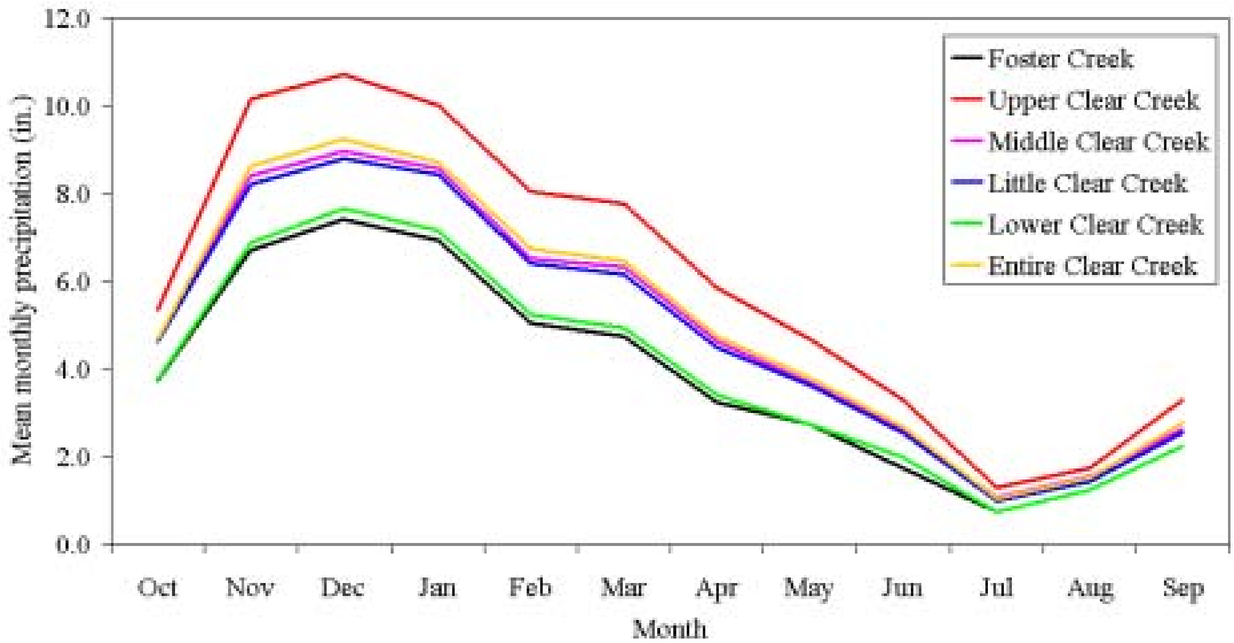

Figure 1-5: Mean monthly precipitation by subwatershed within the Clear and Foster Creek watersheds. Data sources: Oregon Climate Service (1998).

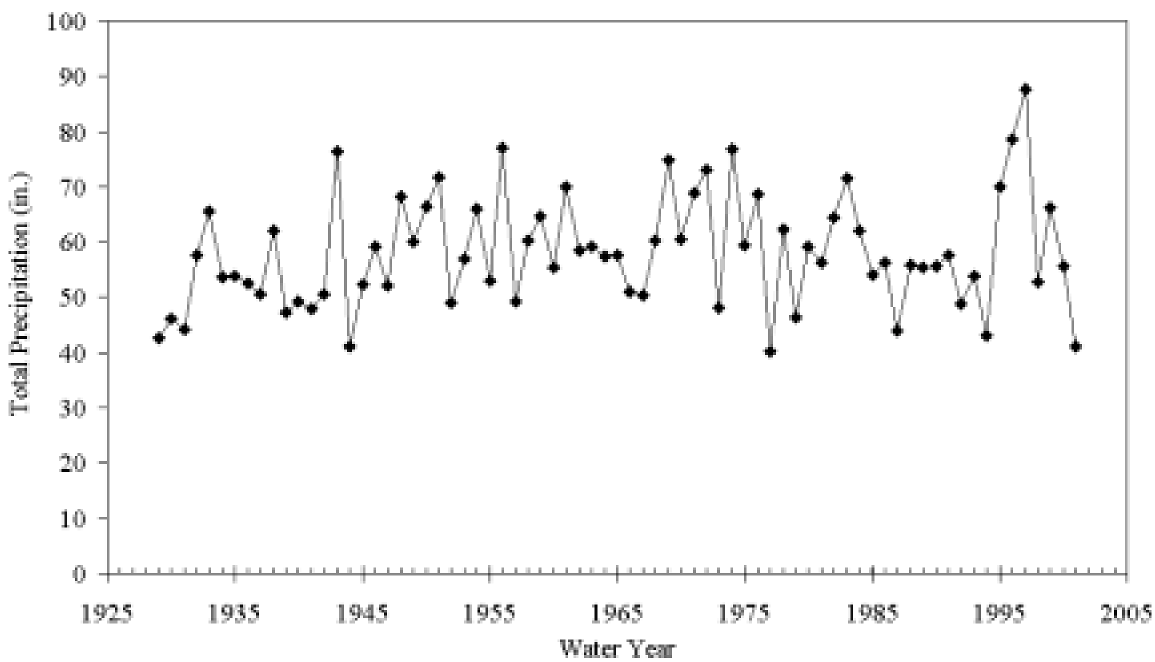

Figure 1-6: Annual precipitation at the Estacada 2 SE weather station. Data source: Oregon Climate Service (2002).

The two primary patterns of climatic variability that occur in the Pacific Northwest are the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The two climate oscillations have similar spatial climate fingerprints, but very different temporal behavior (Mantua, 2001). One of the primary characteristics distinguishing these trends are that PDO events persist for 20-to-30 year periods, while ENSO events typically persist for 6 to 18 months (Mantua, 2001). Several studies (Mantua et al., 1997; Minobe, 1997; and Mote et al., 1999) suggest that five distinct PDO cycles have occurred since the late 1800's (Table 1-4). Changes in Pacific Northeast marine ecosystems have been correlated with PDO phase changes. Warm/dry phases have been correlated with enhanced coastal ocean productivity in Alaska and decreased productivity off the west coast of the lower 48 states, while cold/wet phases have resulted in opposite patterns of ocean productivity (Mantua, 2001).

Table 1-4: Recent Pacific Decadal Oscillation (PDO) cycles in the Pacific Northwest (source: Mantua et al. 1997; Minobe 1997; Mote et al, 1999).

PDO cycle	Time period
Cool/wet	1890-1924
Warm/dry	1925-1946
Cool/wet	1947-1976
Warm/dry	1977 –1995
Cool/wet	1995 – present (estimated)

Statistical techniques used by Envirovision Corporation (2000) were applied to the annual precipitation record available from the Estacada 2 SE climate station to understand whether local trends follow the documented PDO cycles. Data from this station was processed in the following manner:

1. The mean and standard deviation was calculated for the annual precipitation at the Estacada 2 SE station over the period of record

2. A standardized departure from normal was calculated for each year by subtracting the mean annual precipitation from the annual precipitation for a given year, and dividing by the standard deviation

3. A cumulative standardized departure from normal was then calculated by adding the standardized departure from normal for a given year to the cumulative standardized departure from the previous year (the cumulative standardized departure from normal for the first year in a station record was set to zero).

This approach of using the cumulative standardized departure from normal provides a way to better-illustrate patterns of increasing or decreasing precipitation over time by reducing year-to-year variations in precipitation, thus compensating for the irregular nature of the data set. Values for the cumulative standardized departure from normal increase during wet periods and decrease during dry periods. Results for the Estacada 2 SE station are given in Figure 1-7.

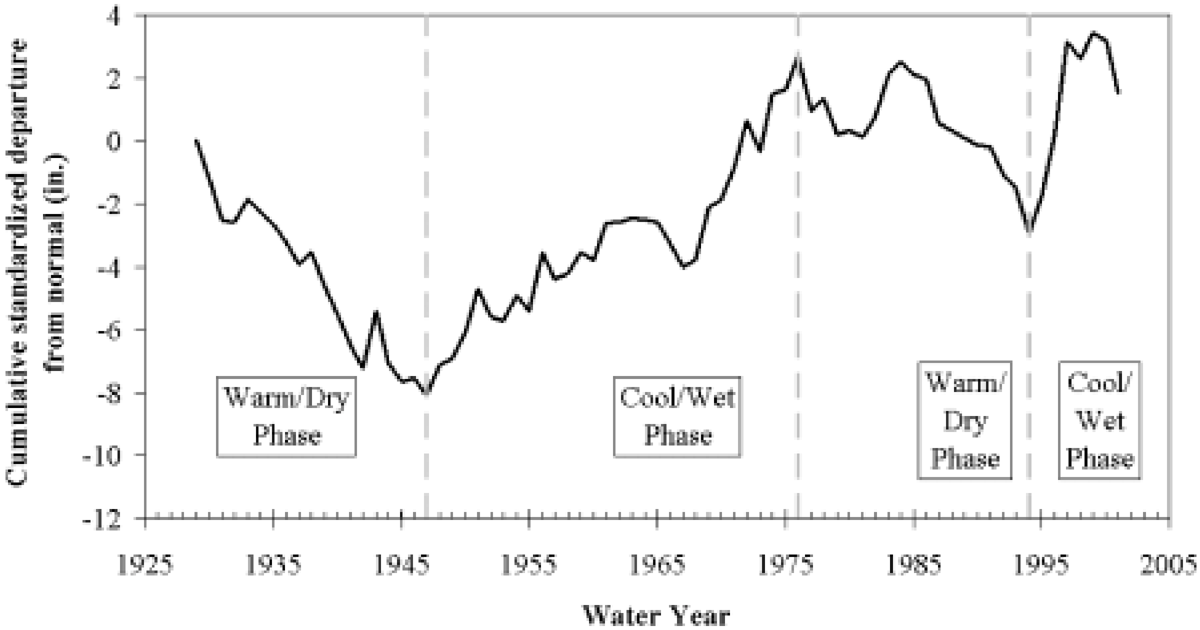

Figure 1-7: Cumulative standardized departure from normal of annual precipitation for the Estacada 2 SE weather station. Local PDO cycles are shown as vertical dashed lines

Precipitation patterns from the Estacada 2 SE station follow the documented regional trends (Table 1-3). The warm/dry phase that is regionally reported to have lasted until 1946 appears to have ended in 1947, and the following cool/wet phase appears to have lasted until 1976. A short-warm/dry phase appears to have occurred from approximately 1977 - 1994, and we currently appear to be in a cool/wet phase, however, data are not conclusive.

Data on snowfall (i.e., depth of snow independent of snow density) and snowpack (i.e., depth of snow on the ground, expressed in terms of snow water equivalent or SWE) are available from several stations in the vicinity of the Clear and Foster Creek watersheds (Figure 1-2, Table 1-3). Mean monthly snowfall is shown in Figure 1-8, and snowpack is shown in Figure 1-9.

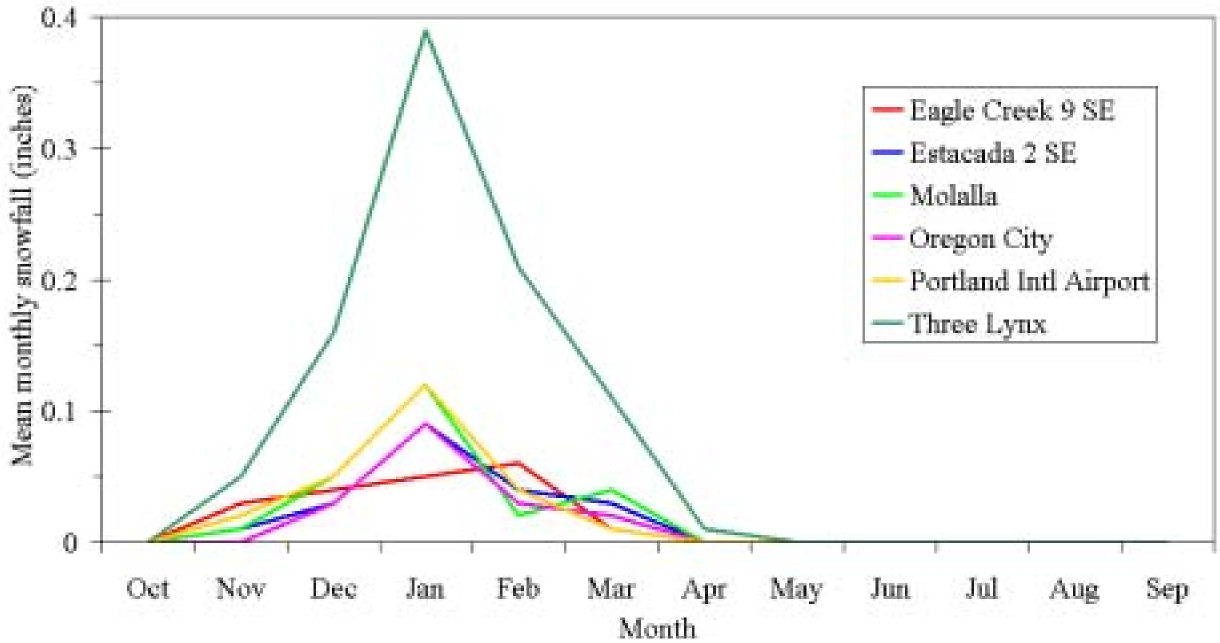

Figure 1-8. Mean monthly snowfall at climate stations in the vicinity of the Clear and Foster Creek watersheds.

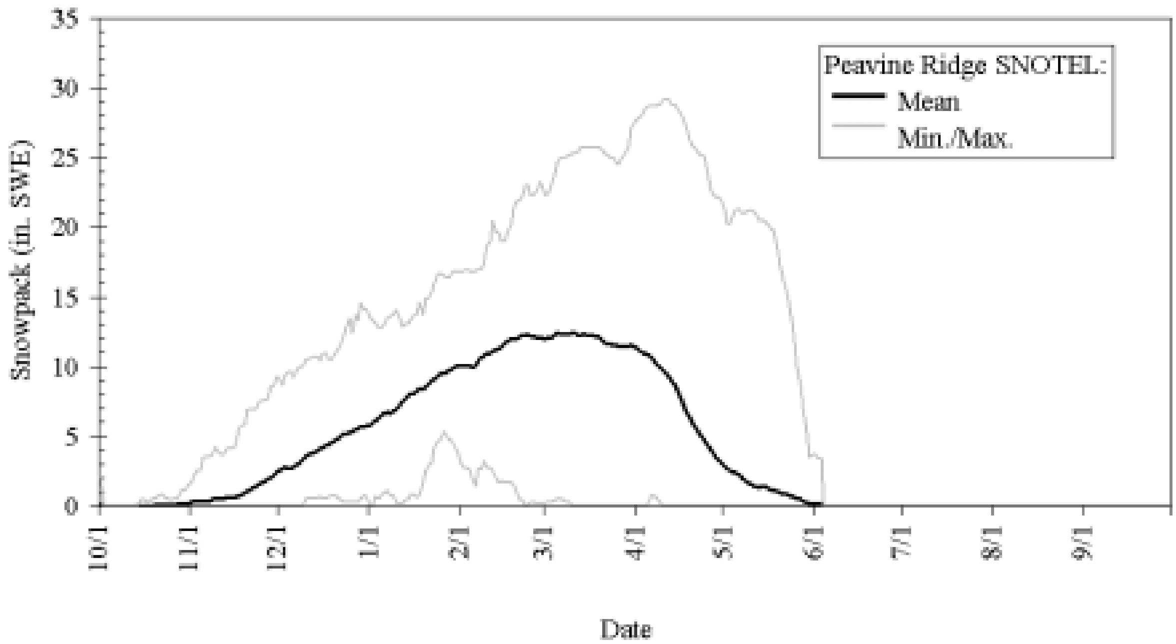

Figure 1-9. Snowpack (in inches of snow-water equivalent) at the Peavine Ridge SNOTEL station.

Unfortunately, snowfall data are not available for the higher elevation areas, and snowpack data are unavailable for lower elevation areas. Consequently, a direct comparison of the two data sources is not possible. However, several points can be made based on the data presented in Figure 1-8 and Figure 1-9: The amount of snowfall is proportional to elevation, and occurs from the month of October to April, with the highest snowfall occurring in the month of January. On average, snowpack increases through the winter months, reaching maximum values during the month of March, after which snowpack decreases. Snowpack is generally gone by the beginning of June.

1.2.4 Geology: Rocks and Landforms

The geologic history of the lower Clackamas region, spanning about 15 million years (15 Ma), has been characterized by the interaction of volcanic and depositional processes along the border between the Cascade Range and the Portland Basin (part of the Willamette structural trough). The materials include volcanic and sedimentary rocks, poorly-indurated to unconsolidated fluvial and mudflow deposits, and the soils formed on them.

Four major geologic units include the Sardine Formation, the Troutdale Formation, the Boring Lava, and Alluvial Deposits: Terraces and Floodplains. These units are briefly described below, and in greater detail in the Sediment Sources Section.

Sardine (Rhododendron) Formation

The Goat Mountain highlands are built of the oldest rocks in the study region, Western Cascade volcanic rocks named the Sardine Formation or Rhododendron Formation by various workers. Andesitic lava flows erupted from vents at Goat Mountain, Soosap Peak, and other sites east and south of the study area, about 15-5 Ma. Along with associated flow breccias, the lavas built thick volcanic piles around the vents; mudflows carried some of the material north and west, where it was deposited in the lowlands (and is exposed in the bottom of Clear Creek almost to Viola). All of these rocks are now well cemented.

Troutdale Formation, Sandy River Mudstone

As the Cascade Range rose (after about 4 Ma), the ancestral Columbia River and streams flowing off the growing mountains deposited sediments in the trough to the west. These fluvial conglomerates, sandstones, and siltstones form one of the thickest layers of materials in the Portland Basin. In the study area, they lap onto the Goat Mountain highlands near Dodge and Elwood, and thicken northwestward; as much as 500 ft is exposed in the canyon of Clear Creek.

Boring Lava

High Cascade-like volcanic activity extended across the Portland Basin in the late Pliocene and Pleistocene (about 3.2-0.5 Ma). Named for the Boring Hills, these basaltic flows and associated agglomerates and tuff-breccias erupted intermittently from dozens of vents in the region, forming cinder cones, shield volcanoes, and some extensive lava plateaus. In the Clear-Foster area, the main sources were in the Outlook buttes (3.15 Ma, among the oldest Boring Lavas yet dated), in the hills between Redland and Four Corners, and at Highland Butte. The Clackamas River, Clear Creek, and their tributaries later eroded into and broke up the nearly continuous surface of Boring Lavas and cones that probably once stretched from Oregon City to the Cascade foothills.

Alluvial Deposits: Terraces and Floodplains

Erosion and deposition processes continued throughout occasional eruption of the Boring Lavas. There are some breccias that were probably formed by mudflows coming off the volcanoes; meanwhile, streams continued to bring sediment down from the Cascades. The highest surface in the study area, called the Springwater surface, is mantled with fluvial conglomerate (with lesser sands, silts, and debris flows), deposited over Troutdale sediments and interbedded with Boring Lavas. The Springwater is thickest next to the Cascades near Dodge, and thins westward toward Logan, where it laps against the Boring volcanic plateau; it probably once formed a near-continuous piedmont or bajada surface at the foot of the Cascades. Now about 2 Ma old, it is commonly highly weathered to about 75 ft depth.

1.2.5 Soils

The properties of soils found within a watershed influence to a large extent the movement of water through and within the soil layers. Information on soils in the Clear and Foster Creek watersheds is available from the soil survey of the Clackamas area (NRCS, 1985; 1998) published by the USDA Natural Resources Conservation Service (NRCS; formerly the Soil Conservation Service). The NRCS has classified soils into hydrologic soil groups (HSGs) to indicate the rates of infiltration and transmission (rate at which the water moves within the soil) (Table 1-5). Hydrologic soil groups found within the Clear and Foster Creek watersheds are shown in Figure 1-10, and summarized in Table 1-6.

Table 1-5. Descriptions of hydrologic soil group properties (NRCS, 1986).

Group	Typical soil textures	Infiltration/Transmission Properties
A	Deep, well drained to excessively drained gravel, sand, loamy sand, or sandy loam	High infiltration rates. High rate of water transmission (greater than 0.30 in/hr).
B	Deep to moderately deep, moderately well to well drained soils with moderately fine to moderately coarse textures (silt loam or loam)	Moderate infiltration rates. Moderate rate of water transmission (0.15-0.30 in/hr).
C	Soils with layers impeding downward movement of water, or soils with moderately fine or fine textures (sandy clay loam)	Slow infiltration rates. Low rate of water transmission (0.05-0.15 in/hr).
D	Soils are clayey, have a high water table, or are shallow to an impervious layer (clay loam, silty clay loam, sandy clay, silty clay, or clay)	Very slow infiltration rates. Very low rate of water transmission (0-0.05 in/hr).

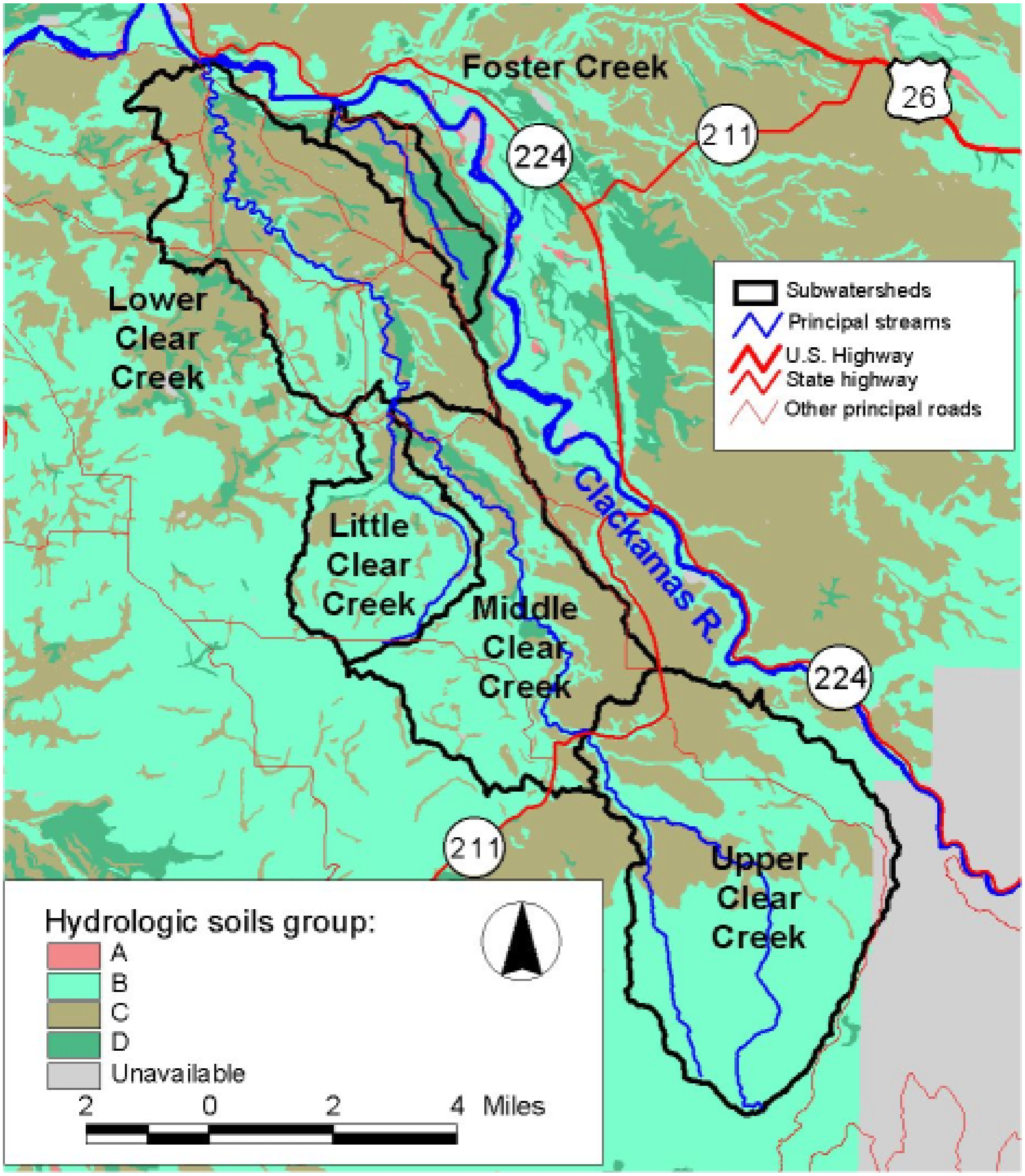

Figure 1-10. Hydrologic soil groups found in the Clear and Foster Creek watersheds. Data Sources: BLM (2002a, 2001a), NRCS (1998).

Table 1-6. Summary of percent subwatershed area by Hydrologic Soil Group. Data source: NRCS (1998).

Subwatershed	A	B	C	D	Unavailable
Foster Creek		3%	47%	49%	
Upper Clear Creek		69%	29%		2%
Middle Clear Creek	0.4%	55%	41%	4%	
Little Clear Creek		76%	20%	4%	
Lower Clear Creek		30%	60%	10%	
Entire Clear Creek	0.1%	56%	39%	4%	1%

Hydrologic soils group information is available for 99% of the project area (Table 1-6). Soils that are part of HSG group "A" (i.e., soils that have the highest rates of infiltration and water transmission) make up only a small proportion (i.e., 0.4% of the Middle Clear Creek subwatershed) of the soils found in the watersheds. Soils in the Little and Upper Clear Creek subwatersheds have the highest infiltration and transmission rates found in the project area; approximately 76% and 69% of the soils falling in HSG B respectively, and an additional 20% and 29% in HSG B (Table 1-6). Conversely, the Foster Creek subwatershed has the slowest rates of infiltration and transmission, with 47% of the soils being classified as HSG type "C" and an additional 49% as HSG type "D".

1.2.6 Hydrology

Few data are available to characterize streamflow within the Clear and Foster Creek watersheds. Continuous stream flow records[4] from within the Clear Creek watershed are of very short duration, and no records are available for the Foster Creek watershed. The locations of available stream flow data from within and around the watershed are shown in Figure 1-11 and summarized in Table 1-7. Stations included in Figure 1-11 and Table 1-7 are not significantly affected by regulation or diversion (Moffatt et al., 1990; USGS, 2002a). Only one of the gages included here is currently active (gage #14209700 - Fish Creek near Three Lynx).

The four stream gages within the Clear Creek watershed that were maintained by the Oregon Water Resources Department (OWRD) provide the only continuous record of mean daily stream flow conditions within the watershed. The entire period of record for these gages is shown in Figure 1-12. Figure 1-13 shows the same record normalized for drainage area. Also shown in Figure 1-13 is the mean daily stream flow for USGS gage #14198500 (Molalla River above Pine Creek near Wilhoit). Regression analysis was used to determine if gage #14198500 adequately represents flow conditions within the Clear Creek watershed. Although mean daily stream flows at all four of the Clear Creek gages correlated well with flows at gage #14198500 (r^2 values

[4] Approximately 100 grab-sample flow measurements are available along the mainstem of Clear Creek for the period 1913-2001 (M. McCord, OWRD, pers. comm., 8/8/2002). These data were not used in this analysis because of the discontinuous nature of the data set.

ranged from 0.75 to 0.91), inspection of the values in Figure 1-13 indicates that several high flow events that occurred at gage #14198500 did not occur at the Clear Creek gages.

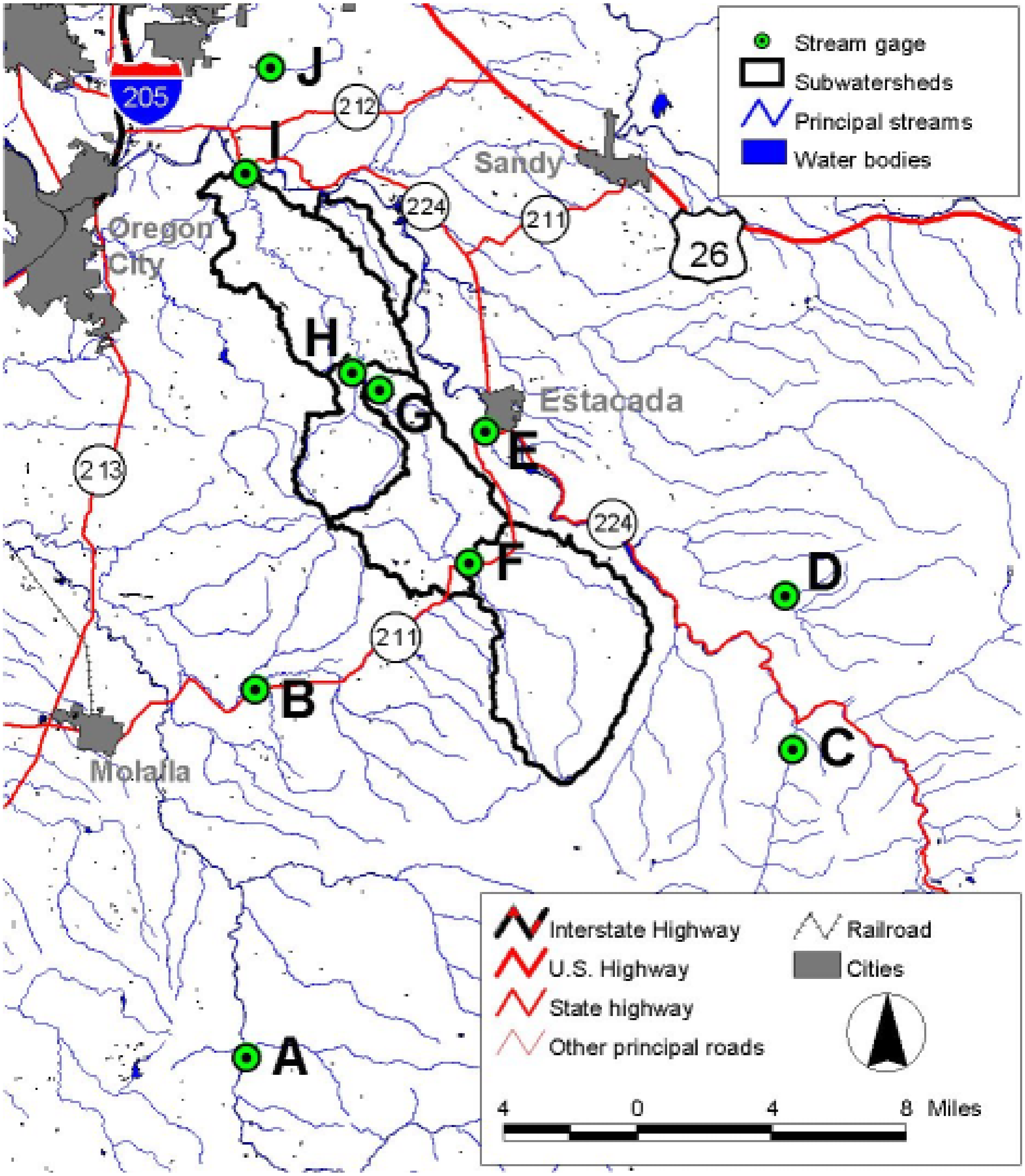

Figure 1-11. Stream gages within and around the Clear and Foster Creek watersheds. Refer to Table 1-7 for gage information. Data sources: OWRD (2002a), USGS (2002a).

Table 1-7. Stream gages within and around the Clear and Foster Creek watersheds. Refer to Figure 1-11 for gage locations. Data sources: OWRD (2001a), USGS (2002a).

Map ID	Gage number: name	Drainage area (mi^2)	Gage elev. (ft)	Period of record: Mean daily flow	Period of record: Peak flows (Water Year)	Current status / responsible agency
A	14198500: Molalla River above Pine Ck near Wilhoit	97	791	10/1/1935 - 9/30/1993	1936 - 1993	Inactive / USGS
B	14199700: Bull Ck near Colton	4	425	n/a	1953 - 1968	Inactive / USGS
C	14209700: Fish Ck near Three Lynx	45	940	8/18/1989 - 9/30/2000	1990 - Present	Active / USGS
D	14209750: Whisky Ck near Estacada	1	2,030	n/a	1965 - 1977	Inactive / USGS
E	14209900: Dubois Ck at Estacada	3	490	n/a	1957 - 1977	Inactive / USGS
F	14210600: Clear Ck near Springwater	21.7	700	1/21/1936 - 2/9/1937	n/a	Inactive / OWRD
G	14210650: Clear Ck at Viola	43.6	345	1/22/1936 - 2/9/1937	n/a	Inactive / OWRD
H	14210676: Little Clear Ck near Viola	9.0	340	1/22/1936 - 2/9/1937	n/a	Inactive / OWRD
I	14210750: Clear Ck at Carver	72.6	90	1/22/1936 - 1/21/1937	n/a	Inactive / OWRD
J	14210800: Rock Ck near Boring	2	300	n/a	1957 - 1966	Inactive / USGS

Figure 1-14 shows the average, minimum, and maximum mean daily discharge at USGS gage #14198500 (Molalla River above Pine Creek near Wilhoit) for the entire period of record of the gage. Also shown in Figure 1-14 are mean daily discharge values that correspond to the period of record (1/22 – 12/18/1936) at the four OWRD stream gages that were located within the Clear Creek watershed. Figure 1-14 indicates that mean daily stream flows for the months of January – August 1936 approximated average conditions, while the September – December flows were at or close to the minimum conditions observed. Given the reasonably-good correlation between mean daily flow at gage #14198500 and the four OWRD gages that were located within the Clear Creek watershed, it seems reasonable to conclude that mean daily stream flows shown in Figure 1-12 and Figure 1-13 are a valid representation of average conditions within the Clear and Foster Creek watersheds for the months of January – August, and underestimates for the months of September – December.

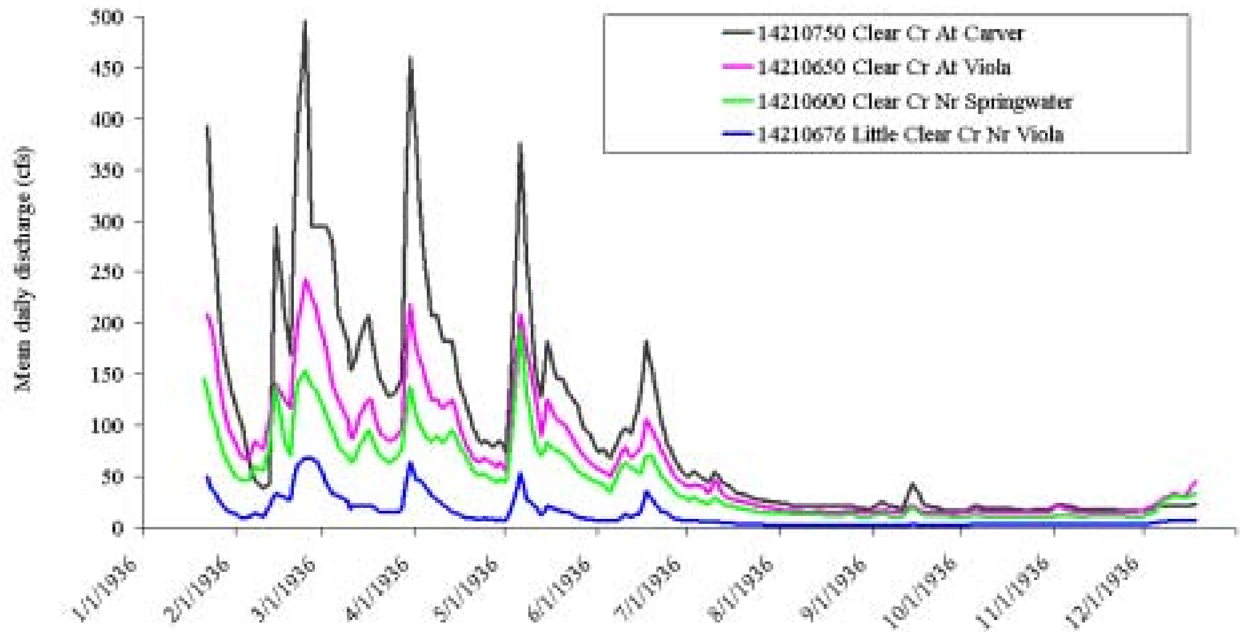

Figure 1-12. Mean daily discharge at four OWRD stream gages that were located within the Clear Creek watershed. Data source: OWRD (2002a).

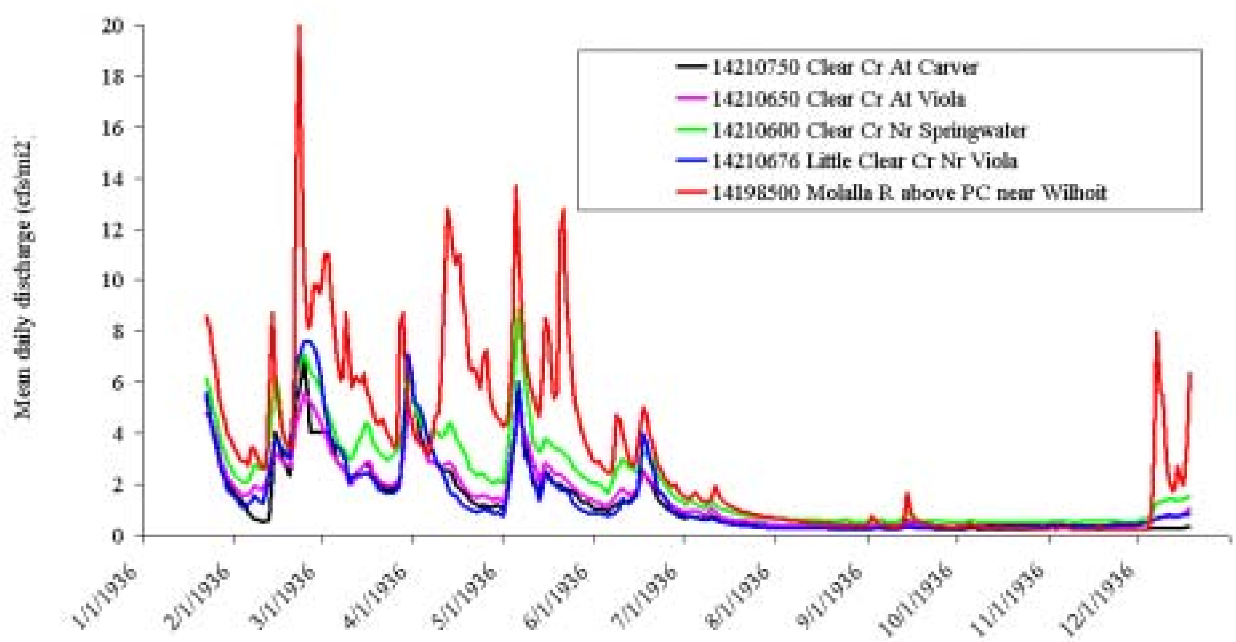

Figure 1-13. Mean daily discharge normalized by drainage area at four OWRD stream gages that were located within the Clear Creek watershed, and for USGS gage #14198500 (Molalla R. above Pine Ck near Wilhoit). Data sources: OWRD (2002a), USGS (2002a).

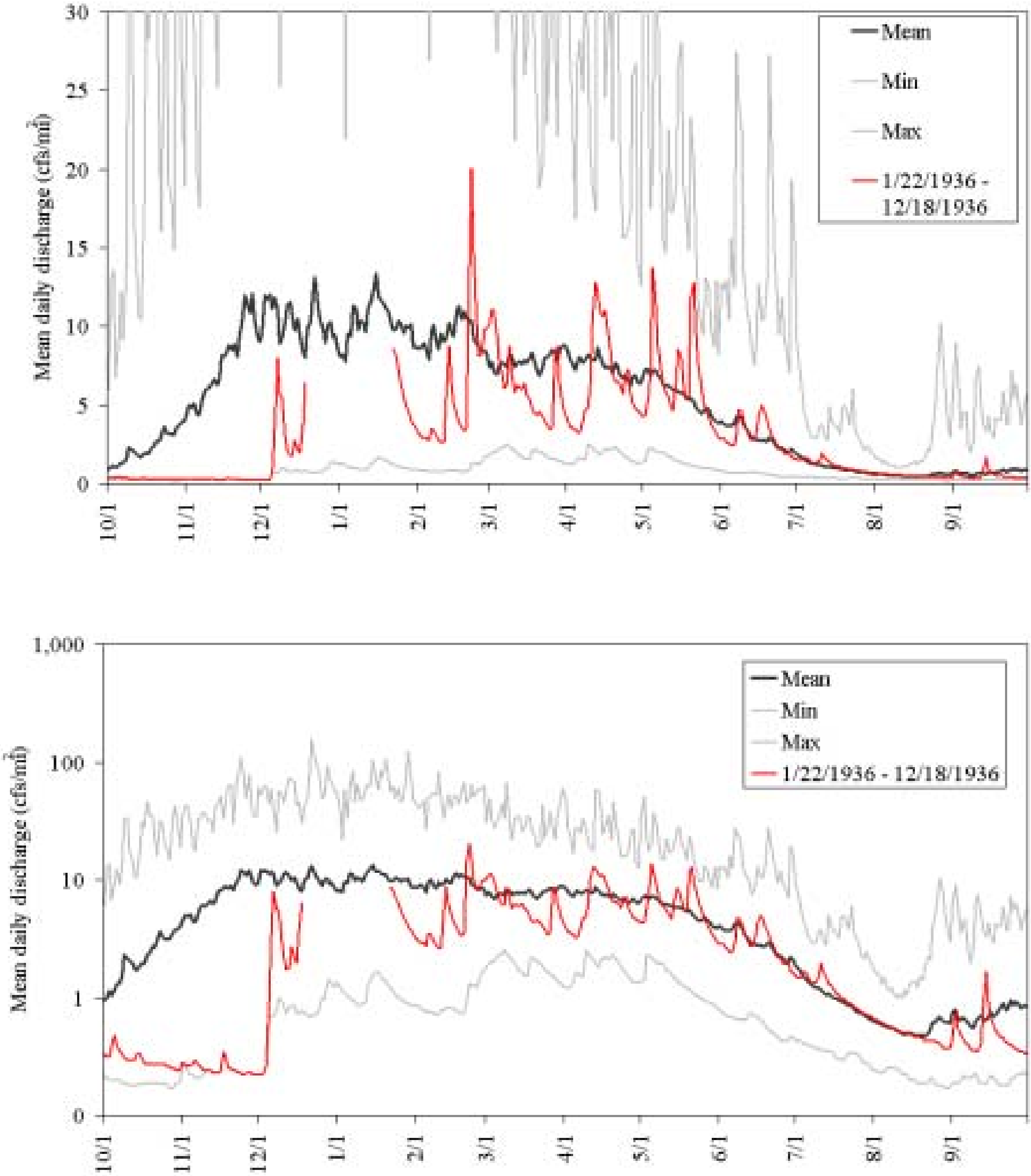

Figure 1-14. Average, minimum, and maximum mean daily discharge normalized by drainage area at USGS gage #14198500 (Molalla R. above Pine Ck near Wilhoit). Also shown are mean daily discharge values that correspond to the period of record (1/22 – 12/18/1936) at the four OWRD stream gages that were located within the Clear Creek watershed. Discharge on the bottom graph is plotted on a logarithmic scale. Data sources: OWRD (2002a), USGS (2002a).

1.2.7 Ecoregions

Information on level IV ecoregions found within the Clear and Foster Creek watersheds was available from the US Environmental Protection Agency (EPA, 2001). Level IV ecoregions are shown in Figure 1-15 and summarized in Table 1-8. Ecoregions denote areas of general similarity in the type, quality, and quantity of environmental resources, and can serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components (Pater et al., 1998). Level IV ecoregion characteristics affecting watershed hydrology are summarized in Table 1-9 (WPN, 2001).

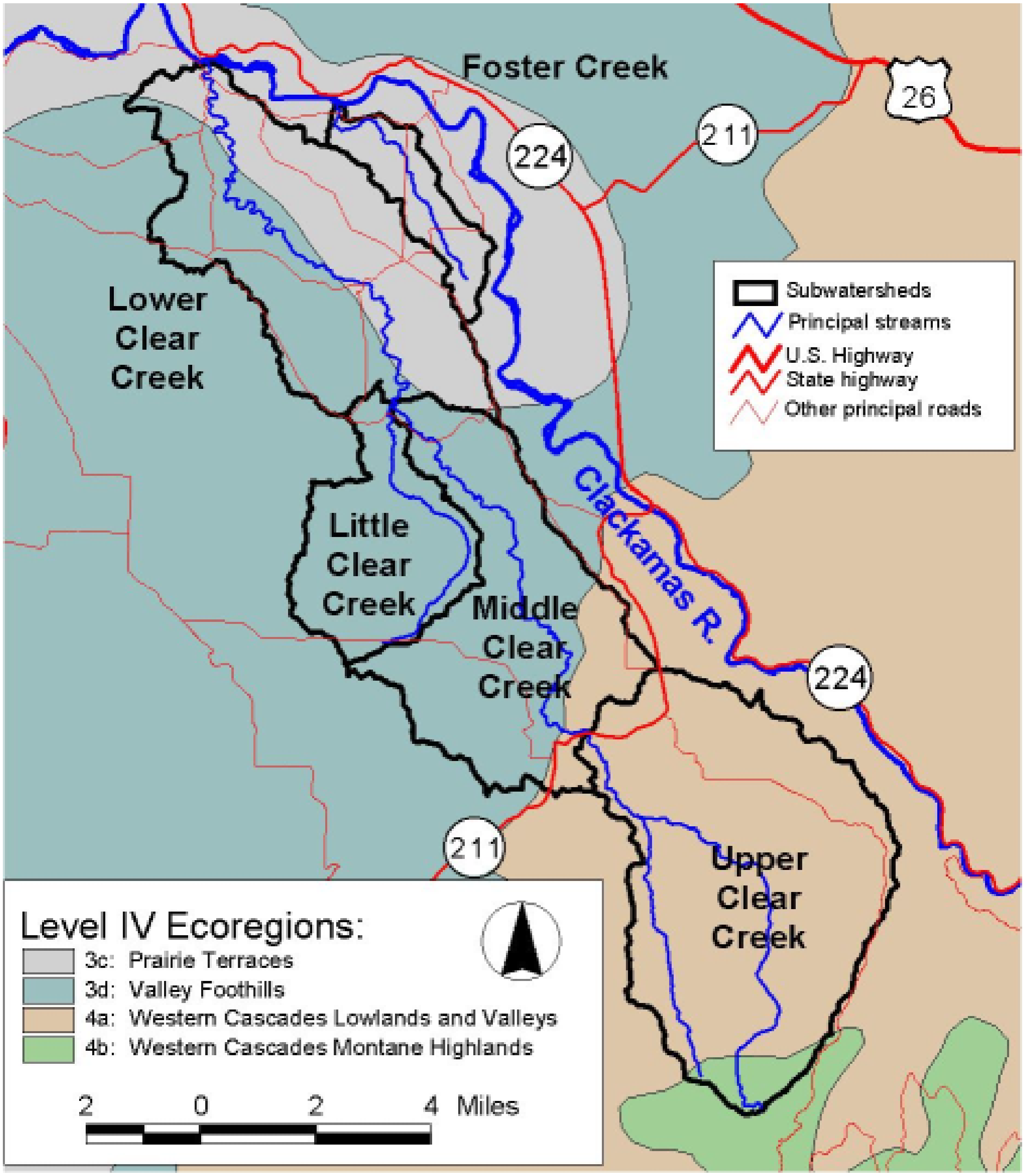

Figure 1-15. EPA Level IV ecoregions within the Clear and Foster Creek watersheds. Refer to Table 1-8 for summary. Data sources: BLM (2002a, 2001a), EPA (2001).

Table 1-8. Summary of percent subwatershed area by EPA Level IV ecoregion within the Clear and Foster Creek watersheds. Data source: EPA (2001).

Subwatershed	3c: Prairie Terraces	3d: Valley Foothills	4a: Western Cascades Lowlands and Valleys	4b: Western Cascades Montane Highlands
Foster Creek	100%			
Upper Clear Creek			95%	5%
Middle Clear Creek	0.1%	83%	17%	
Little Clear Creek		100%		
Lower Clear Creek	53%	47%		
Entire Clear Creek	18%	43%	38%	2%

Table 1-9. EPA level IV characteristics affecting watershed hydrology (WPN, 2001).

	Potential upland vegetation	Historic Crown Closure	Natural Disturbances
3c	Oregon white oak savanna, and prairies, with Oregon ash, Douglas-fir, grand fir and other wetland vegetation in wetter areas.	Areas other than floodplains were dominated by prairies and oak savannas with less than 30% crown closure. Fire suppression has replaced oak savannas with oak woodlands or Douglas fir forests with crown closures > 50%.	Periodic burning by Native Americans in the past maintained prairie vegetation and occasionally encroached on streamside vegetation. Frequent low-intensity fires may have been much more common within oak woodlands in the past. Fires are no longer a part of the ecosystem.
3d	Oregon white oak, madrone; some Douglas-fir and western red cedar.	Dense forests were historically found in this ecoregion, greater than 30% crown closure.	Periodic burning by native Americans in the past maintained prairie vegetation and occasionally encroached on streamside vegetation. Fires are no longer a part of the ecosystem.
4a	Douglas-fir, western hemlock, western red cedar, vine maple and western red alder forests.	Crown closure can be as low as 50% on drier sites. In general, historic crown closure is greater than 70%. Due to the absence of large wildfires, stand densities are greater than in the past.	Douglas-fir/western hemlock forests experience fire more frequently than neighboring silver fir/red fir forests, although the fire return interval is variable. While wildfires during late summer and fall once burned large areas within the lower western Cascade Mountains, streamside areas sometimes escaped the fires. Fire suppression has now eliminated most of these wildfires.
4b	Pacific silver fir, western hemlock, Douglas-fir, mountain hemlock, noble fir, subalpine fir, and white fir forests.	Historic crown closure typically greater than 30%. Repeated fire can create semi-permanent big huckleberry communities in mountain hemlock forest areas.	Silver fir forests experience less-frequent fires than neighboring Douglas-fir forests, but burn more frequently than subalpine forests at higher elevations. Fires are infrequent but severe in this forest type.

1.2.8 Vegetation

The watershed assessment developed classification and maps of the ***potential***, ***historic*** and ***current vegetation*** as the basis for the wildlife habitat assessment. See Section 9 for further description of the vegetation classification and delineations.

There are five cover types used to describe *potential vegetation* within the study area: open water (38 ac); agriculture (24,238 ac); Douglas-fir, western hemlock, western red cedar (21,628 ac); grass, shrub, sapling or regenerating young forest (8 ac); and mixed conifer-mixed deciduous forest (2,883 ac). These types are not evenly distributed across the subwatersheds (See *Map 8: Predicted Vegetation GAP2).* Open water and agriculture is limited by terrain in the upper elevations within the study area.

The Oregon Biodiversity Project classified historic (circa 1850) vegetation. Three vegetation types dominated the landscape: Western Douglas-fir – Mixed Conifer, Mountain Hemlock, and Ponderosa pine – White oak. Western Douglas-fir – Mixed Conifer dominated the watershed with over 43,000 acres or 89 % of the watershed. This type dominates all of the subwatersheds and the only type found in Foster and Lower Clear Creek. Mountain Hemlock was found in Upper Clear Creek comprising less than one percent of this subwatershed. The map also shows that Ponderosa pine – White oak was found on south-facing slopes and other drier sites. (However, a Forest Consultant and long time resident of the watershed believes that this vegetation community has been misidentified in the upper third of the watershed and should be indicated as Douglas-fir white oak instead.) (See *Map 10: Historic Vegetation*.)

Current Vegetation is characterized by the ONHIC Best Approximation Map, which incorporates the most up-to-date vegetation classification and mapping information. This Best Approximation Map synthesizes classification and mapping efforts from GAP and Plant Association Groups (PAG) (*Map 9: Current Vegetation and Noxious Weeds*). Today the map has errors or omissions, which requires caution when using this for analysis. Classification for this watershed is poor relative to areas around it because it is outside the Metro analysis area and outside the classification efforts conducted in the upper elevations in the Cascades on Federal lands.

1.2.9 Land Ownership / Land Use

Information on land ownership was available from the Bureau of Land Management (BLM, 2002b). Land ownership within the watershed is shown in Figure 1-16, and summarized in Table 1-10. The entire Foster Creek watershed, and 89% of the Clear Creek watershed is in private ownership (Table 1-10). Private timber company lands are found within all subwatersheds with the exception of Foster Creek. The proportion of subwatershed area owned by private timber companies ranges from 46% in Upper Clear Creek to 1% in Lower Clear Creek, and is 22% of the entire Clear Creek watershed overall. City, county, and state lands make up less than 1% of the total area within the entire Clear Creek watershed. Lands managed by the BLM are found within all subwatersheds with the exception of Foster Creek. The proportion of subwatershed area managed by the BLM ranges from 15% in Upper Clear Creek to 2% in Lower Clear Creek, and is 9% of the entire Clear Creek watershed overall. Lands managed by the U.S. Forest Service (Mt. Hood National Forest) are found only in the Upper Clear Creek subwatershed, where they make up 9% of the total subwatershed area (3% of entire Clear Creek watershed).

Information on current land zoning within the Clear and Foster Creek watersheds was available from Clackamas County (2001a, 2002) (Table 1-11, Figure 1-17). Lands zoned as Rural Commercial are found only in the Lower Clear Creek subwatershed, where they make up only make up only 0.1% of the total subwatershed area (Table 1-11). These areas include the community of Redlands, and a portion of the community of Carver. Rural Commercial zoning is intended for commercial uses such as food stores, auto repair, banks, feed stores and doctors' clinics (Clackamas County, 2002).

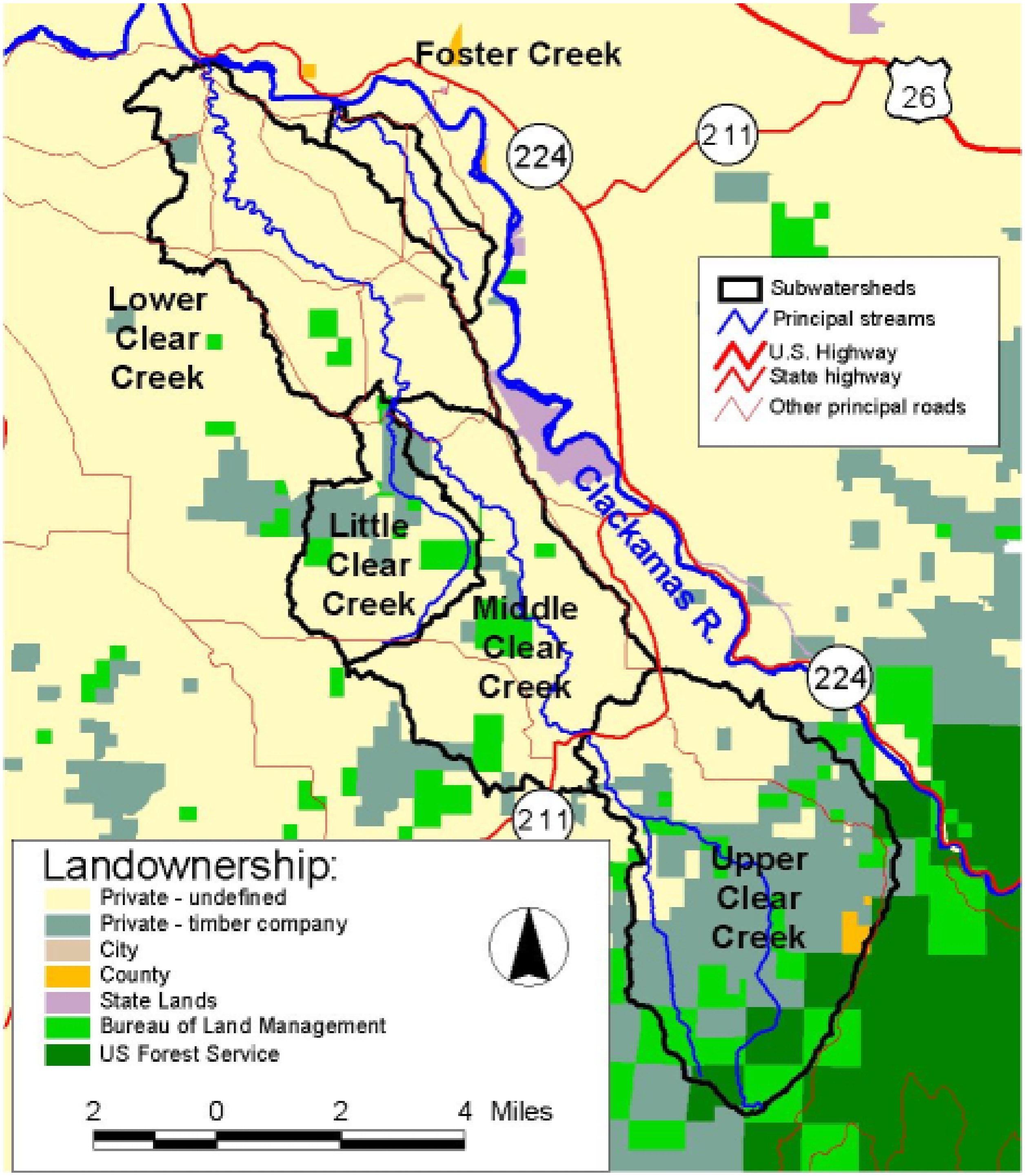

Figure 1-16. Land ownership within the Clear and Foster Creek watersheds. Refer to Table 1-10 for ownership summary. Data sources: BLM (2002a, 2002b, 2001a).

Table 1-10. Summary of land ownership within the Clear and Foster Creek watersheds. Shown are % subwatershed area, and square miles (in parentheses). Data source: BLM (2002b).

Subwatershed	Private-Undefined	Private Timber Co.	City of Estacada	Clackamas County	State Park	BLM	USFS
Foster Creek	100% (3.5)						
Upper Clear Creek	29% (7.8)	46% (12.4)		1% (0.3)		15% (4.1)	9% (2.5)
Middle Clear Creek	86% (14.8)	6% (1.0)			0.05% (0.01)	8% (1.4)	
Little Clear Creek	67% (6.0)	23% (2.1)				11% (1.0)	
Lower Clear Creek	96% (18.6)	1% (0.2)	0.4% (0.1)		0.001% (0.0002)	2% (0.4)	
Entire Clear Creek	65% (47.3)	22% (15.6)	0.1% (0.1)	0.4% (0.3)	0.01% (0.01)	9% (6.9)	3% (2.5)

Table 1-11. Summary of current zoning within the Clear and Foster Creek watersheds. Shown are % of subwatershed area by zoning category. Data sources: Clackamas County (2001a).

	Rural Center	Rural Residential				Natural Resource		
subwatershed	**RC**: Rural Commercial	**RA1**: Rural Area Single Family Residential 1 acre	**RA2**: Rural Area Single Family Residential 2 acres	**RRFF5**: Rural Residential Farm/Forest 5 acres	**FF10**: Farm/Forest 10 acres	**EFU**: Exclusive Farm Use	**AGF**: Agricultural/ Forest	**TBR**: Timber
Foster Creek				13%		54%	3%	31%
Upper Clear Creek				2%	2%	2%	1%	93%
Middle Clear Creek				5%	3%	25%	30%	37%
Little Clear Creek				10%		0.01%	30%	60%
Lower Clear Creek	0.1%	2%	2%	13%	4%	59%	2%	18%
Entire Clear Creek	0.03%	1%	0.4%	7%	3%	22%	12%	56%

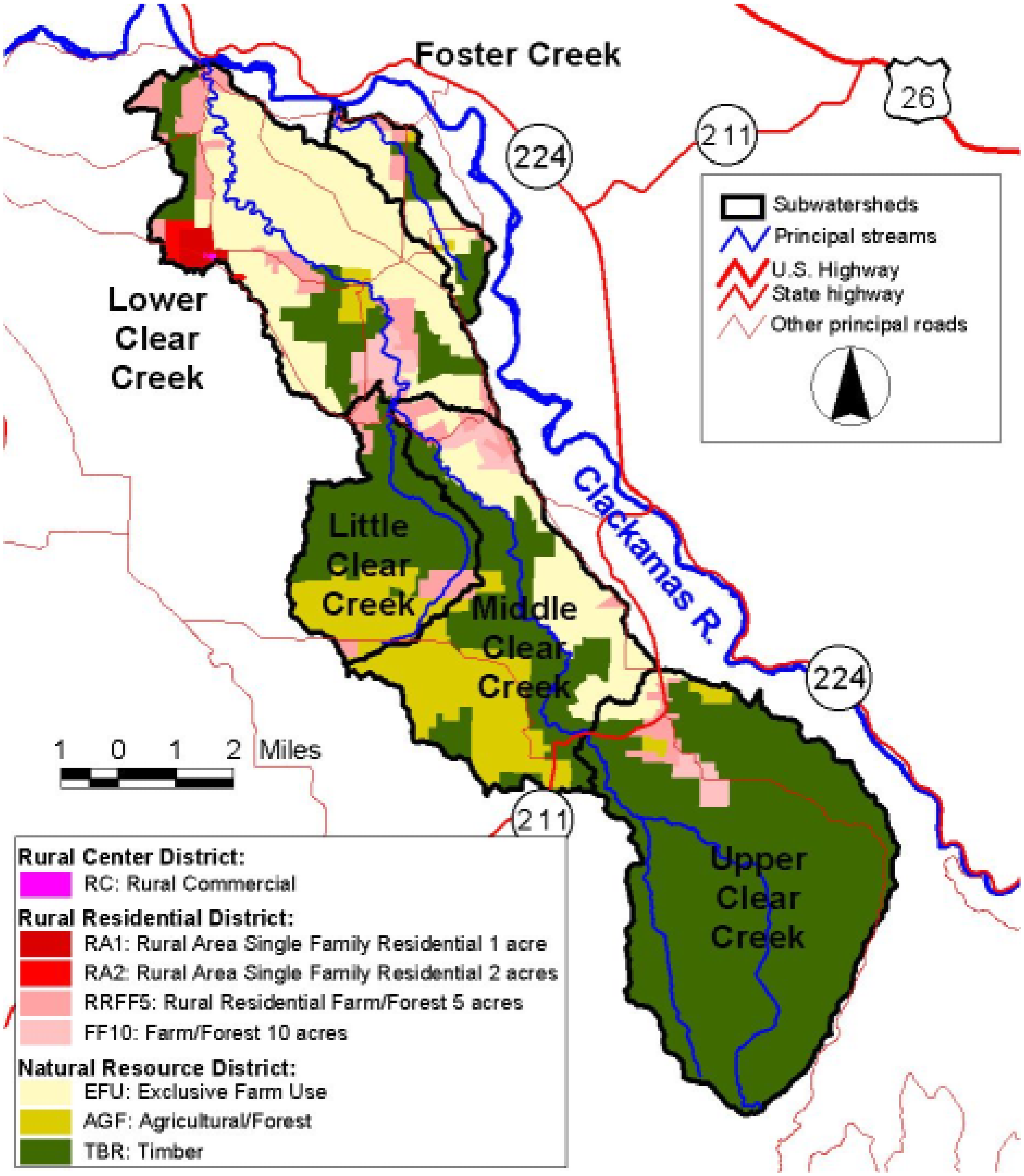

Figure 1-17. Current zoning within the Clear and Foster Creek watersheds. Data sources: BLM (2002a, 2001a), Clackamas County (2001a).

Rural Residential lands within the watersheds include areas zoned as “Rural Area Single Family Residential - 1 acre lot size” (RA1), “Rural Area Single Family Residential - 2 acre lot size” (RA2), “Rural Residential Farm/Forest - 5 acre lot size” (RRFF5), and “Farm/Forest - 10 acre lot size” (FF10). Lands zoned RA1 and RA2 are only found in the Lower Clear Creek subwatershed in the vicinity of Redland (Figure 1-17) where each category makes up 2% of the total subwatershed area (Table 1-11). Lands zoned RRFF5 are found in all subwatersheds; the proportion of subwatershed ranging from 2% in Upper Clear Creek to 13% in both the Foster Creek and Lower Clear Creek subwatersheds (Table 1-11). Lands zoned FF10 are found in Upper Clear Creek (2% of subwatershed area), Middle Clear Creek (3% of subwatershed area), and Lower Clear Creek (4% of subwatershed area).

Lands designated as “Natural Resource” make up the largest proportion of watershed area in all subwatersheds (Table 1-11, Figure 1-17). Lands zoned as “Exclusive Farm Use” (EFU) are zoned for primarily farm and forest activities, and have a minimum new parcel size of 80 acres (Clackamas County, 2002). EFU lands make up the greatest proportion of subwatershed area in the Lower Clear Creek and Foster Creek subwatersheds (59% and 54% of subwatershed area), while Little Clear Creek has less than 1% EFU lands. The “Agricultural/Forest” (AGF) designation differs from the EFU lands in that these areas are characterized primarily by a mixture of agricultural and timber uses (Clackamas County, 2002). The minimum new parcel size for AGF lands is also 80 acres. Lands zoned AGF make up 30% of the subwatershed area in both Middle Clear Creek and Little Clear Creek, and 3% or less of the total area in all other subwatersheds. Lands zoned as “Timber” (TBR) include areas that are primarily used for forest production. Minimum new parcel size for TBR lands is also 80 acres. Proportion of subwatershed area zoned TBR ranges from 93% of the Upper Clear Creek subwatershed to 18% of the Lower Clear Creek subwatershed (Table 1-11).

1.3 SOCIO-ECONOMIC CONDITIONS

What makes this watershed important to people? What are primary human uses in the Clear and Foster Creek Watersheds? What are the current conditions of human uses in the watershed? Where do they generally occur? Trends- where will growth occur in the future? What type of growth will this be?

1.3.1 Historical

Before and during the 18th century Native Americans used the Clear and Foster Creek watersheds for an economy based on a seasonal harvest of plants and animals. The Clackamas River Basin and associated lowlands were frequented by several tribal groups coming to catch salmon at the Willamette Falls. As summer approached, camps would move into the highlands for hunting and gathering. With mid - 19th century settlement of the basin by Euro-Americans began to harvest natural resources at a far higher level than before. Key factors in European settlement patterns were the growth of Oregon City and the building of the Barlow Road. As people moved into the watershed they gradually filtered up the basin, using the land for subsistence hunting and fishing, agriculture, timber harvest and later for recreation and rural residence.

Fishing, hunting and picnicking were popular recreational pastimes as early as the mid-nineteenth century. Early journals chronicle fishing expeditions from Portland to Viola to fish and net trout and salmon. By the 1870's salmon and steelhead populations in the Clackamas watershed had declined, however the fishing was still famous in the region. Long-time residents along Clear and Foster Creek recall pitchforking Chinook salmon out of the creeks as late as the 1940's. (personal interviews)

1.3.2 Recreation

Currently the most concentrated public recreation in the Clear and Foster Creek sub-watershed involves fishing, camping and picnicking at Metzler County Park (Clear Creek) and day use at the Carver public boat ramp at the mouth of Clear Creek. Some undeveloped fishing access is available at county crossings at locations like Fischer's Mill and Viola. Bicyclists and auto tourists from the Metro area use some of the roads in the basin for scenic day tours. From personal observation it is noted that many landowners along the creeks enjoy their riparian areas for recreation; there are many family swimming holes, rope swings, picnic areas and barbecues amidst park-like grassy settings. Some of these settings may present opportunities for streamside riparian enhancement with willing landowners. Public recreation potential along Clear and Foster Creek is limited by access to the creeks; all of Foster Creek and most of Clear Creek run through private property. These creeks presently don't contribute a great deal to regional tourism or recreational opportunities. They contribute to scenic and visual values in that the public enjoys the rural scenery.

The sub-watersheds of Clear and Foster Creek may hold potential for wayside interpretation of Oregon Trail and early settlement history and the history of fisheries. The second fish hatchery in the U.S. was established above the mouth of Clear Creek in 1877.

Metro owns 492 acres in Clear Creek Canyon two miles south of Carver. The site, formerly a ranch, is now managed as a natural area. Metro is conducting ongoing restoration of the riparian habitat - planting riparian forest, removing exotics and maintaining wetlands at this site. This site may become a Regional Park in the future.

Recreation opportunities on BLM lands are relatively limited by the land ownership pattern in the watershed. The BLM manages only nine percent of the watershed, made up of relative small isolated tracts of land (often under 640 acres). Most of these lands are characterized by a forested setting with obvious evidence of human modifications both on BLM lands and adjacent lands. These modifications are associated with timber harvest, roads, utility corridors, agriculture and residential development.

There are no developed recreation sites on BLM lands. Most of the recreation use on BLM lands in the watershed is by people living adjacent to or near the parcels. Clear Lake (T. 5 S., R. 4 E., Section 14) is an undeveloped area managed by the BLM that has historically received recreation use. Problems with resource damage and garbage dumping made it necessary to block and close motorized access to the lake, however non-motorized uses are still allowed. During a field review for the 1997 Clear Down Timber Sale a non-motorized trail was identified on BLM lands in T. 5 S., R 4 E., Sections 5 and 9. The trail also extended onto to private land. No information on who trail or used the trail could be found, but the source of both was most likely local residents. Part of the trail was obliterated as a result of timber harvest project. It is likely that other motorized and non-motorized user-established trails exist on BLM lands and other ownership in the watershed. Use by full sized and other off-road motorized vehicles also occurs in several areas on BLM lands in the watershed where access is not physically restricted. Other activities that most likely occur are hunting, target shooting, fishing, hiking, and equestrian use.

Visuals: Visual modifications to the landscape are evident throughout most of the Clear Creek watershed. As stated above, most of these modifications are associated with timber harvest, roads, utility corridors, agriculture and residential development. In an effort to address visual resources on BLM-administered lands, a Visual Resource Management (VRM) classification system was developed and used to inventory all BLM-administered lands in the Salem District. There are four classes of scenic values within the VRM system. The classes range from Class I lands having the highest scenic values and receiving the greatest protection down to Class IV lands having the lowest scenic values and fewer modification restrictions.

Clear Lake is the only area in the watershed with a VRM Class II rating. Several small BLM parcels in the watershed have a Class VRM III rating. Most of these lands are areas that may be more visible by residences or other occupied areas. Early notification and working with adjacent and nearby landowners on any projects affecting visual resources in these areas would be important.

Most of the BLM lands in the watershed are classified as VRM IV. Class IV lands generally have a low visual sensitivity and fall into the “seldom seen” category. While sensitivity on Class IV lands is generally low, the impacts of proposed projects to visual resources should still be evaluated and mitigation measures considered.

1.3.3 Economy/Economic Values

The entire Foster Creek watershed is privately owned. Eighty-nine percent of the Clear Creek watershed is in private ownership. These two watersheds provide homesites, timber, agricultural, water, wildlife and recreational resources.

Timber and Agriculture

Early use of the Clear Creek watershed had an emphasis on timber. In the mid -1800’s there were several mills in the area and the creek was used for log transport. Farmland expanded as the thick timber was cleared. Forest and agricultural products continue to be important to the local economy. Much of the watershed is zoned for natural resources; timber, farm and agricultural/forest uses. In Upper Clear Creek 46% of the watershed is managed as private timberlands. In general the main forest products are Christmas trees and small woodlot production.

Table 1-12. Timber, Farm and Agricultural/Forest Zoned Land within the Clear and Foster Creek Watersheds.

	Exclusive Farm Use	Agricultural/ Forest	Timber	Total Land Zoned Natural Resources
Foster Creek	54%	3%	31%	88%
Upper Clear Creek	2%	1%	93%	96%
Middle Clear Creek	25%	30%	37%	92%
Little Clear Creek	.01%	30%	60%	90%
Lower Clear Creek	59%	2%	18%	79%

Land owned and managed by private timber companies is found within all of the watershed except for Foster Ck. Twenty-two percent of the overall Clear Creek Watershed is owned by private timber companies. Public lands managed by the Bureau of Land Management and the Forest Service comprise 18% of the Clear Creek Watershed. The Mount Hood National Forest manages nine percent of the land in Upper Clear Creek. The BLM has holdings in all zones of the Clear Creek Watershed, with a total of nine percent of the watershed.

Timber management activities on BLM-administered lands are tied to the Land Use Allocations specified in the Salem District Resource Management Plan (RMP, May 1995). All of the BLM lands in the watershed have a General Forest Management Area (GFMA) Land Use Allocation. Riparian Reserves are a second Land Use Allocation that occurs adjacent to streams that run throughout GFMA lands. Under the Salem District RMP, regeneration and thinning timber harvest is expected in GFMA and some habitat management activities may also occur in Riparian Reserves.

There are no statistics available for agricultural and timber production broken down in a sub-watershed format. However agriculture and timber are integral to the county economy. In 1997 Clackamas County's agricultural products had a market value of $276,251,000. (In 2001, within the seven counties of the N. Willamette Valley agricultural output totaled 1.42 billion dollars!). In the Clear and Foster Creek sub- watersheds, forest and agriculture consists primarily of private timber, small woodlots, and Christmas trees. In addition there are plant nurseries, some grass seed, hay, and berry production. Small businesses include cottage crafts, convenience and general stores, agricultural supply stores, and gas stations.

Rural Interface

There are no incorporated cities within the Clear and Foster Creek watershed. There are many rural residential properties with small pastures and a horse or two. Many landowners enjoy a rural residential lifestyle and commute to work-sites in the Metro area.

Forest management activities on BLM lands located adjacent to or near private non-forest uses, especially residential dwellings, can create potential concerns for the BLM and residential property owners. In an effort to address these concerns early in the project planning process, areas with a potential for high sensitivity were identified in the Salem District RMP, as Rural Interface Areas (RIA's). These RIA's include BLM lands within a ½ mile of private lands zoned for 1 to 20 acre lots or larger lots with homes nearby. Additional RIA's were identified on BLM lands within a ½ mile of private lands with a Rural Residential County Zoning.

There are several RIA's on BLM land in the Clear Creek Watershed. Timber management activities on BLM lands in this watershed are expected, given that they have a GFMA Land Use Allocation, which allows for the harvest of timber products. Most of the RIA's in this watershed have the potential for moderate to high sensitivity depending on the project type, size, and location. Some of the potential water quality and visual concerns associated with timber management activities may be mitigated by Riparian Reserves or green tree retention requirements. However consideration of RIA issues and public contact, early in the project planning process is very important in this watershed.

Watershed

Clear and Foster Creeks provide water for domestic use including stock watering, lawn and garden watering, and irrigation. There are 307 points of diversion for water rights within C&F watershed. Fish and wildlife habitat are also important economic watershed values.

Prohibited Uses

Prohibited uses on public and private lands generally involve illegal dumping, vehicle abandonment, long term occupancy, equipment and sign vandalism, wildlife poaching, unauthorized removal of forest products, and growing or manufacturing illegal drugs. Given the proximity of the Clear Creek watershed to both rural and larger urban communities, problems associated with prohibited uses are likely to continue and grow. The areas around Hillockburn Road have had particular problems related to dumping, vandalism and vehicle abandonment.

1.3.4 Trends

This area is one of the fastest growing regions of the state. Between 1990 and 2000 Clackamas County population grew 21.4%, from 278,850 to 338,391. (U.S. Census Bureau Census 2000 PHC-T-4 Table 1. See Figure 2-1: Clackamas County population, 1900 to 2000 (US Census Bureau, 2002).) There is a rapidly growing urban interface in the lower Clackamas River Watershed. The Metro Regional Government's urban growth boundary may expand near Beaver Creek and Clackamas Community College over the ridge into the adjacent watershed. These growth trends can be expected to have impacts on the Clear and Foster Creek sub-watersheds.

Property inside the Metro urban growth boundary tends to sell for roughly 10x more than that outside the boundary. This factor could stimulate conversion of rural residential and agricultural lands to more high-density residential and commercial uses.

Metro is required to review Portland's urban growth boundary every five years and calculate how much land must be added to meet a required twenty-year land supply for expected population growth. This presents interesting challenges and opportunities for the Northern Willamette Valley and local watersheds. In the next century the I-5 corridor from Vancouver B.C. to San Diego corridor from could conceivably become one continuous urban zone. By working together can we develop a long-term vision and support planning for growth for up to 100-150 years out – balancing a growing population and economy with stewardship of valuable agricultural and timberlands, and public trust values such as open space, clean water and wildlife?

1.4 IDENTIFICATION OF ISSUES

Issues for the watershed assessment were identified through an iterative process. WPN analysts reviewed existing maps, documents, and data sources and summarized this information in Checkpoint Report. Based on this review, the analysts developed a list of Key Questions and an initial List of Issues. The key questions and list of issues were presented to the CRBC Basin Research and Advisory Group and to the Council at separate workshops. The technical Advisory Group and the Council revised the List of Issues to provide direction to the WPN team in completing the watershed assessment. These issues are described in the relevant resource component.

1.5 PUBLIC INVOLVEMENT PROCESS

The CRBC is committed to working closely with local residents and to that principle that the community should guide the watershed assessment and action planning process. The CRBC saw the assessment as a rare opportunity to connect science, people and the land. As such, the CRBC provided many opportunities for the community to comment and review progress of the assessment. The CRBC intends to share the results of these and future studies with local residents.

The CRBC started the assessment process with outreach to community leaders and invited them to join representatives from the CRBC, local natural resource agencies and the consulting team on two tours to visit Clear and Foster Creeks. As local landowners they know the watersheds best. These tours provided a chance to learn about and share local knowledge. Six meetings were held in the local community. Four were held in local grange halls and two CRBC regular meetings, that focused on the assessment, were held in Viola and Fischer's Mill. In addition, the CRBC newsletter and mailings updated streamside residents on the latest information and activities.

The CRBC also convened a Technical Team and an Action Planning Team to guide and review the project. These teams included local residents and agency representatives including Oregon

Department of Fish and Wildlife, the Bureau of Land Management, Portland General Electric, US Forest Service, Clackamas Soil and Water Conservation District, Clackamas River Water, South Fork Water Board, and Sunrise Water District and others.

The assessment and the work completed in the watershed with local residents is only the beginning. The CRBC is hopeful that there will be many opportunities to join with neighbors as we work together to identify and partner on projects. The CRBC plans to continue to provide assistance and funding for landowners who want to be involved.

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2.0 HISTORICAL CONDITIONS

2.1 INTRODUCTION

This section of the watershed analysis report provides an overview of the historical conditions for the Clear and Foster Creek Watersheds. The historical record is summarized here to provide insights into what the area looked like at the time of Euro-American exploration and settlement, and to gain an understanding of how human uses have modified the watershed through time.

2.2 CRITICAL QUESTIONS

The goal of this section is to describe and summarize information on early development of the watershed and resource management activities. The following critical questions are addressed in this section.

Question 2-1: What are historical trends and locations of land use and other management impacts to the watersheds?

Question 2-2: What are historical accounts of fish and wildlife populations and distributions in the watersheds?

Question 2-3: Where are the locations of historic floodplain, riparian area, channel and wetland modifications and what were the types of disturbance?

2.3 METHODS

For the purpose of this description, the history of the Clear and Foster Watersheds is divided into three time periods: settlement, beginning resource management, and the transition to modern times (Table 2-1). Descriptions of watershed conditions during each of these historical periods are based on evidence from written and verbal first-hand accounts and summaries of explorers and watershed residents, resource inventories, maps, drawings, and photographs. Because there are detailed records that are available on fish catches and hatchery production and releases, most of the focus of the historical assessment is on fishery resources.

Table 2-1. Clear-Foster Watershed assessment historical time periods.

Dates	Period
1840s to 1870	Settlement
1871 to 1945	Beginning resource management
1946 to 1990s	Transition to modern times

2.4 RESULTS

2.4.1 Settlement: 1840s to 1870

Settlement by Euro-Americans in the Clear Creek and Foster Creek areas began in the 1840s. Sam Barlow, Joel Palmer, and their party traveling west late in 1845 explored the track that would become the Barlow Road. The next year, the road was opened as an extension of the Oregon Trail from The Dalles, south around Mt. Hood, past the Philip Foster place at Eagle Creek, across the terraces on the south side of the Clackamas River, and over the Clackamas Heights into Oregon City. The Barlow Road provided a convenient travel route into the area, so most of the early settlement focused along this corridor:

> "A pattern of settlement is evident along the route [Barlow Road]. The area east of Oregon City receiving the earliest interest in settlement was along lower Clear Creek and eastward along the current Baker's Ferry Road. Between 1843 and 1847, eight claims were settled in what became known as the 'Springwater Settlement area'…"
>
> (Beckham and Hanes, 1992, p. 18)

> "[The Clear Creek segment] of the Barlow Road is composed of three short traces interrupted by unpaved residential roads. The remains begin in the form of a short swale on the immediate west bank of Clear Creek. Being in the active floodplain, the association of the swale to past road use is somewhat uncertain…A short distance farther uphill, beyond the roadbed, is a short shallow swale extending more directly uphill in a heavily vegetated woodland settling …The swale is apparent above the road again for only 20 feet until it reaches the top of the hill to the next higher stream terrace."
>
> (Beckham and Hanes, 1992 p. 50)

A number of early accounts note the large trees in the area:

> "The timber was huge and there was plenty of water. The Indians had regularly burned off places where they often camped."
>
> (Shearer 1993, p. 7)

The thick forests covering the area were seen as an obstacle to settlement. The trees had to be cleared to create land suitable for farming:

> "The people of Viola as well as all other communities in the Willamette Valley had a hard time getting cleared land enough to farm. They would girdle trees by chopping off the bark in a ring around the tree about six inches wide. The tree would then die and the people could farm in among the trees."
>
> (Lankins, No Date, p 24)

By the 1850s, additional roads were providing avenues for settling other portions of the watershed:

> "The original Barlow Road route between Clear Creek and Oregon City likely served these farmsteads for only a brief few years before being significantly realigned by 1853.

Additionally, settlement quickly expanded away from the emigrant route in the 1840s with the new spur roads appearing to serve the farms and mills."

(Beckham and Hanes, 1992, p. 18)

"The survey in the Springwater area from Clear Creek to Feldheimer's Ford on the Clackamas River reveals a number of roads serving the early settlements by 1855."

(Beckham and Hanes, 1992, p. 10)

"…the road crossed the Clackamas River below the "Bluff", known as Feldheimer's Ferry. It came up the hill to the highway in front of Mrs. Allen's place. There it forked and those pioneers going into Oregon City went north through Carver, and those going into the Willamette Valley came down into Viola through…Richey and Eldon Lankins' places, where the road can still be seen. They crossed Clear Creek behind the church and went on up into Highland."

(Lankins, No Date, p. 23)

"Roads were needed for people to travel to and from the trading center. First, gravel was hauled out of Clear Creek and placed where needed."

(Lankins, No Date, p. 23)

Today, long-term residents in the Clear Creek and Springwater area recall traveling to Oregon City earlier in this century by the now-abandoned western segment of Holcomb Road. A short distance east of Hattan Road the new 1852 road course apparently joined the Barlow Road alignment at the crossing of Clear Creek (Beckham and Hanes, 1992, p. 11).

Proximity to the growing cities of Oregon City and Portland influenced the settlement patterns in the lower Clackamas River Basin. The early settlements east of Clear Creek in the Springwater and Eagle Creek areas consisted almost entirely of farmers. In contrast, those settling west of Clear Creek to Oregon City and immediately along the banks of the Clackamas River were skilled laborers (Beckham and Hanes, 1992, p. 19).

2.4.2 Beginning Resource Management: 1871 to 1945

The 1870s marked the beginning of intensive use of the resources in the Clear and Foster Creek Watersheds. Road building and tree removal continued, clearing the way for houses and agriculture. This period was also the beginning of large-scale timber removal in the area, and the first fish hatchery.

Road Building

Increasing settlement and agriculture in the watersheds required good road access. A number of accounts recorded the expanding road network:

"In 1883, a survey for County Road No. 207 was performed extending from near the Eagle Creek crossing of the Barlow Road following the north bank of the Clackamas River to a crossing in the Barton area, then reestablishing the 1852 surveyed portion of Baker's Ferry Road before joining the old emigrant route west of Foster Creek before coursing northward, crossing lower Clear Creek and terminating at the Clackamas River crossing just downstream from the mouth of Clear Creek."

(Beckham and Hanes, 1992, p. 12)

"[1905] Old timers say the plank road extended to the Lewellen's on the Metzler Park road, then to Clear Creek on Springwater Road, past the Springwater store, down to Estacada."

(Shearer, 1993, p. 11)

"[March 14, 1918] Work is now progressing in the building of a passable road from the Cox and Park Mill on Clear Creek to the top of the canyon connecting Springwater to the south…It was not until 1938 before a really passable road was built."

(Shearer, 1993, p. 14)

Logging Practices

Most of the early logging activity in the Clackamas River Basin was concentrated in the lower portions, including Clear and Foster Creek watersheds. The lack of good roads above the Estacada area and easy access to trees in the lower basin focused most logging to the lower forests until the 1940s (Taylor, 1999). To provide lumber for the growing market in the surrounding area and the city of Portland, a number of sawmills were developed in the area, particularly in the Clear Creek watershed. These mills usually had log ponds and dams across the streams. One early account mentions three dams on Clear Creek: one built in 1852 at Harding's Mill three miles above the confluence with the Clackamas River; another built in 1848 or 1850 at Viola; and a third built in 1865 at Springwater (Taylor, 1999, p. 23):

"… the Klaetsch Lumber Company of Springwater is overhauling his mill and placing it one half mile nearer to Springwater on the former Don Wilcox place. There is an abundance of first class timber in the new location. Capacity to cut per day is 35,000 to 40,000 board feet. They plan to take out the big fir and cedar trees along Clear Creek. The Klaetsch Mill is sawing dimension lumber from the stand adjoining the 150' dam constructed across the branch of Clear Creek. His mill pond has the capacity to handle one million board feet of timber."

(Shearer, 1993, p. 73)

Early logging practices and the sawmill waste products had an immense impact on the watershed's resources. Splash dams were used on several tributary streams to create an artificial flood of water to move logs to the mills on Clear Creek (Farnell, 1979). By the 1880s it was common practice to float logs to the mills on Clear Creek (Taylor, 1999). In March of 1896, Harvey Cross, owner of a sawmill at Gladstone, drove 500,000 board feet of saw logs one half mile down Clear Creek and then out into the Clackamas (S.P. Cramer and Associates, 2001). The log drives scoured stream channels, removed riparian vegetation, and created barriers to fish passage (Taylor, 1999). Water quality was also affected by sawmill production and logging activities. By 1890, sawdust and other mill wastes were common pollutants in any stream in the state (Oregon Fish Commission 1889-1890).

By the 1920s much of the original forests in the area had been cut and sawmills were moving or converting to second-growth timber supplies:

> "The sawmill was enlarged to cut about 60-80 thousand feet of lumber per day. Many of the employees built "sawmill cabins" and lived at the sawmill…The mill continued to operate until 1927 when they moved to Stephenson, WA. They had cut out about all of the 600 acres of timber by that time…In 1930 Lyman Elliot built a sawmill on up the [Clear] Creek farther and the Carver Railroad built up to it with a spur and this mill shipped all of the lumber out on it. The duration of that mill was only about 2 or 3 years."
>
> (Lankins, No Date, p. 26).

Floods and Fire

Fires, floods, and other natural disturbances have always shaped the landscape and the watershed's resources. Fires periodically swept through the forests. A major forest fire in 1902 was recorded by several sources:

> "The forest fire of September, 1902 was a never-to-be-forgotten spectacle to those who lived here at the time. It was said that one could see as many as seven separate barns burning at the same time. The fire spread from community to community, doing extensive damage to buildings and killing many of the livestock"
>
> (Barnett and Chelson, 2000, P. 6).
>
> The fire was four miles wide and five miles long. All of Thursday night and Friday morning, the fire raged fiercely, following down the Clackamas River and Clear Creek, crossing the Springwater ridge and stopping at the upper edge of Viola."
>
> (Shearer, 1993, p. 71).

Floods were noted in 1861, 1881, and 1890. One author commented that, "the flood of 1881 took more bridges because of the number built the previous decade…The Clear Creek bridge sailed down the Clackamas..." (Lynch, 1973, p. 275).

2.4.3 Transition to Modern Times: 1946 to 1990s

Following Word War II, the population in and around Portland grew rapidly. Improvements in transportation made it possible for many of the people settling in the area to live in outlying communities and commute into the city. In 1940, Clackamas County's population was 57,130; by 1950 the population was 86,716, and it increased to 333,391 by the end of the 1990s (Figure 2-1).

By the 1970s, the rapid population growth throughout the Willamette Valley was accompanied by housing sprawl and loss of agricultural lands. In response to this uncontrolled land use pattern, the 1973 Legislature, with support from both parties and Republican Governor Tom McCall, created the Oregon planning program. The legislation created the Land Conservation and Development Commission (LCDC), and directed it to adopt statewide planning goals to address a range of topics, including the preservation of prime forest and farmlands. The hope was the goals would encourage development and redevelopment in existing urban areas while protecting farm and forestlands and natural resources from urban sprawl (1000 Friends of Oregon, 2000).

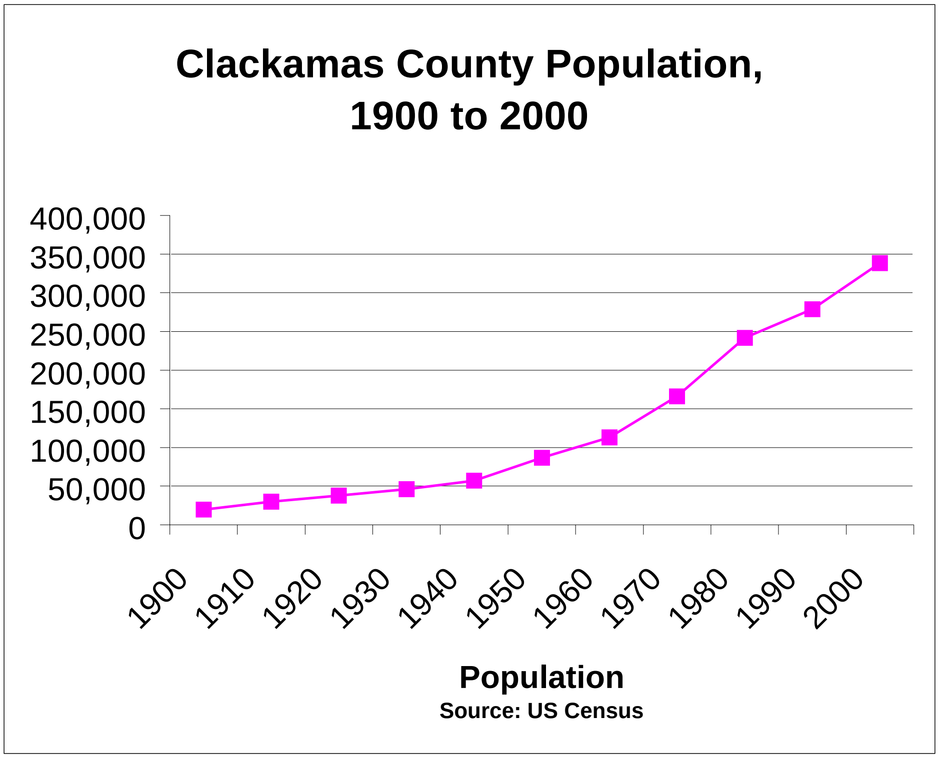


Figure 2-1: Clackamas County population, 1900 to 2000 (US Census Bureau, 2002).

2.4.4 Fish Populations

Residents and visitors to the lower Clackamas River Basin in the mid-1800s marveled at the abundant fish populations, particularly the salmon and steelhead runs. Native anadromous fish runs to the basin included spring chinook, fall chinook, coho salmon, and winter steelhead. Resident fish species included cutthroat trout, rainbow and bull trout and mountain whitefish.

Estimates of run sizes are unavailable, but harvest and hatchery records from the mid- to late-1800s suggest that the fish returned in significant numbers (Taylor, 1999). Local accounts described excellent fishing in Clear Creek and the lower Clackamas River:

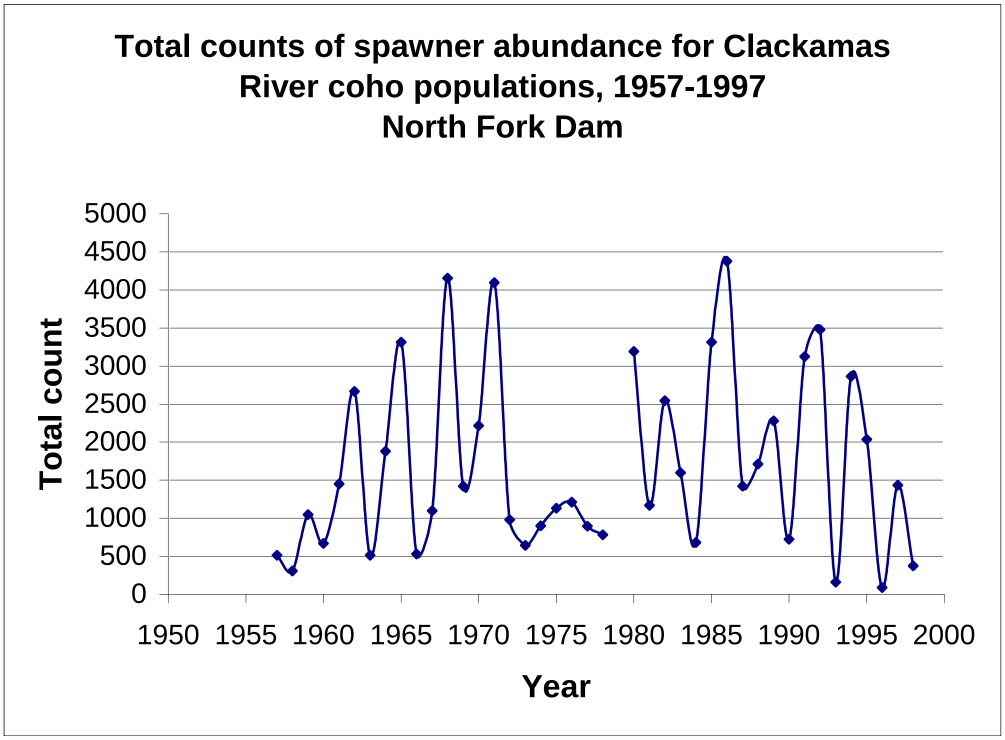
> “Viola and Clear Creek were known all over the west for the splendid fishing. The fishermen from Portland would come to Oregon City by streetcar and rent horse and buggy at the delivery barn and drive to Viola to fish. Trout and young salmon were the catch… The streams overflowed and let the fish come up out of the Clackamas River to the extent that they couldn’t get over the dam at Clear Creek sawmill and people were dipping the fish as if they were smelt!”
>
> (Lankins, No Date, p 25).

In 1886, a commercial fisher, A.S. Abernethy, reported fishing by several parties on the Clackamas River near the mouth of Clear Creek. The various parties fished with drift nets and short set-nets, and one party used a trap. He estimated that approximately 3,500 chinook salmon were caught before July 10. Fishing pressure probably then dropped off as late-season fish became soft and unfit for markets (Abernethy, 1886; as reported in Taylor, 1999, p 28).

Natural salmon and steelhead production began to drop sharply in the Columbia River and tributary streams, including the Clackamas, in the 1870s. The primary cause of the decline is believed to have been over harvest in the Columbia River. Commercial harvest peaked in 1873 with a take of 43 million pounds (Taylor, 1999, p. 31).

Systematic counting of salmon spawning numbers in the Clackamas River Basin did not begin until the 1950s. Beginning in 1957, migrating coho salmon on their way to spawning areas in the upper basin have been counted as they passed North Fork Dam. Since this information was collected on a daily basis, variation in the run return can be estimated with some precision (Chilcote, 1999). Figure 2-2 illustrates the large variation in the number of salmon counted passing the dam from1957 to 1998.

Figure 2-2. Coho salmon abundance recorded at the North Fork dam, 1957 to 1998 (Chilcote, 1999).



The First Fish Hatchery

The first fish hatchery in Oregon (the second in the United States) was located on the Clackamas River above the mouth of Clear Creek. The hatchery was completed in the late summer of 1877 with a capacity for 1 million eggs (U.S. Fish Commission of Fish and Fisheries 1877). According to Taylor (1999):

> "The hatchery operated four years. During the first year, about 200,000 eggs were secured, but most were lost with a sudden rise of the river. Hatchery records show that 88,680 eggs were taken in 1877 at the hatchery site, and 2,085,000, 2,035,100, and 2,838,000 were taken in 1878, 1879, and 1880, respectively. Hatchery personnel estimated that they caught 2,000 adults in the racks in 1878." (p. 33)

> "In 1887, the newly created Oregon Fish Commission leased the abandoned hatchery at Clear Creek. They operated the facility for about 1 year then shared operations with the U.S. Commission of Fish and Fisheries in 1888 after funds fell short. The federal commission bought the facility in 1889. The property, purchased for $5,155.60, included a rack 400 feet long, a 160-foot dam across Clear Creek, a flume, filtering tanks, a dwelling house, a house for workers, a hatching house and a stable--all in good condition. Fry from the station were planted in the Clackamas River and tributaries." (p. 33).

Table 2-2 illustrates the decrease in the productivity of the Lower Clackamas hatchery from its beginning in 1877 to the closing in 1895. Because of the poor hatchery performance, in 1893, 3,674,000 Sacramento River salmon ova were shipped up from St. Cloud station in California and released into the Clackamas River (Fish and Game Protector, 1894, p. 28).

Table 2-2. Egg collection and release, Lower Clackamas hatchery. All fry were deposited in the Clackamas River (Fish and Game Protector, 1894, p. 28).

Year	Eggs Collected	Eggs Distributed	Fry Distributed
1877-78	88,680		
1878-79	2,085,000		
1879-80	2,038,000		
1880-81	2,838,000		
1887-88	1,500,000		
1888-89	4,500,000		4,500,000
1889-90	4,314,000	1,000,000	2,766,475
1890-91	5,860,000	700,000	4,902,000
1891-92	2,036,000		1,332,400
1892-93	4,444,000		4,100,000
1893-94	277,000		
1894-95	23,000		

Early Fish Stocking Records

By 1902, H.G. Van Dusen, Oregon's Master Fish Warden, was noting the impacts to fishery resources from logging and other practices:

> "Dams are going in across our streams. Irrigation ditches are taking our waters. Sawmills and manufacturing plants are polluting our waters. Our people are complaining about them..."
>
> (Oregon Department of Fisheries, 1902, p. 99)

> "These waters once free from commercial industries and given over entirely to the salmon, are now being extensively used for irrigating, mining, milling, and other similar purposes that are detrimental to the natural habits of the fish."
>
> (Oregon Department of Fisheries, 1902, p. 9)

By the late 1800s artificial stocking of fish was seen as the solution to these worries about declining fish populations. The Oregon Master Fish Warden reported:

> "...all opposition to the advantages of artificial propagation has been overcome; and it is now a recognized fact, even by the most skeptical, that the salmon product in our rivers can be limited only by the number of young fry liberated from our hatcheries."
>
> (Oregon Department of Fisheries, 1902, p. 64)
>
> "I am very pleased to report, that the Columbia River demonstrated again this year that artificial propagation is the one thing that is preserving the great salmon industry."
>
> (Oregon Department of Fisheries, 1903, p. 9).

Hatchery fish released into the Clackamas River included fish from local hatcheries and stocks obtained from other basins. In 1901, the U.S. Commission of Fish and Fisheries reported that in the previous year "150,000 eggs of the silver salmon were received from the Rogue River in January, from which 146,000 fry were hatched and liberated in the Clackamas" (p. 92). This report also stated that "During May 10,000 cutthroat trout eggs were received from Verdi, Nev., and the fry hatched from them were planted in waters in Clackamas County, OR" (p.77).

Artificial stocking in the Clackamas Basin included fish species such as coho and chinook salmon that were native to the basin (though often with stocking populations derived from other basins) as well as "exotic" species such as brook trout and Montana grayling. There are limited records from the early 1900s of fish stocking in Clear Creek. Species stocked in Clear Creek included coho and introduced species such as brook trout (Table 2-3).

Table 2-3. Early fish stocking records for Clear Creek.

Species	Year	Number	Source
Coho salmon	1900	146,824 (Planted in both the Clackamas River and Clear Creek.)	(U.S. Commission of Fish and Fisheries, 1901)
Montana grayling	1901	10,000	Oregon Department of Fisheries, 1902
Brook trout	1901	20,000	Oregon Department of Fisheries, 1902
Brook trout	1902	7,000	Oregon Department of Fisheries, 1903
Rainbow trout	1902	192	Oregon Department of Fisheries, 1903

1947 to 1991 Stocking Records for Clear Creek

By the late 1940s, fish managers also started releasing large numbers of hatchery-produced fish in the basin annually (Taylor, 1999). During this period, extending into the early 1990s, there was extensive fish stocking in Clear Creek by ODFW. Stocking occurred most years with rainbow trout the most common species, and occasionally large numbers of other species, including brook trout. Other fish species planted included cutthroat trout, steelhead, and chinook salmon. In the 1980s, ODFW began stocking coho fry in Clear Creek. Table 2-4provides details on a selected stocking in Clear Creek. Appendix 1 contains the complete hatchery fish-stocking record for Clear Creek.

Table 2-4. A selection of hatchery fish species and numbers stocked in Clear Creek from 1947 to 1991 (Stream Net, 2002).

Species	Year	Number
Rainbow trout	1947	14,640
Brook trout	1949	9,960
Chinook salmon	1952	100,000
Steelhead	1955	8,960
Rainbow trout	1959	1,998
Brook trout	1961	61,245
Rainbow trout	1964	2002
Brook trout	1966	40,050
Cutthroat trout	1972	300
Rainbow trout	1974	1000
Brook trout	1978	517
Coho salmon	1980	69,829
Brook trout	1981	500
Steelhead salmon	1984	50,400
Coho salmon	1985	167,440
Steelhead	1991	10,087

Recent Harvest Records for Clear Creek

There are limited fish harvest records for Clear Creek. Figure 2-3 illustrates the recorded sport catch of winter steelhead in Clear Creek from 1979 to 1991.

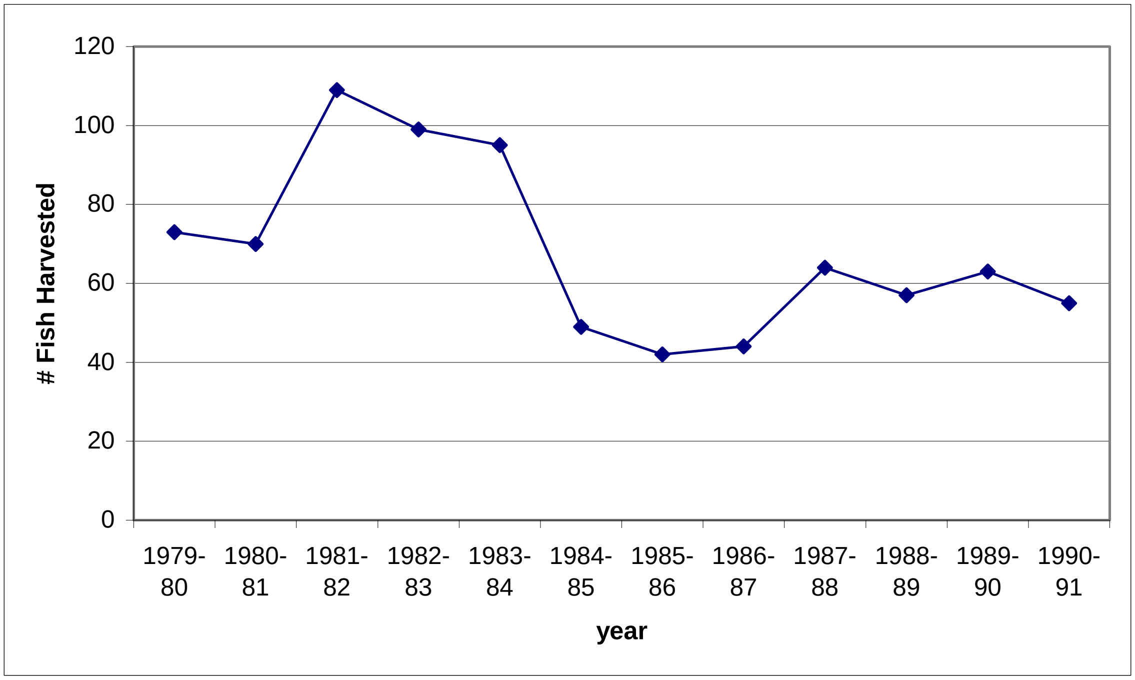


Figure 2-3. Winter steelhead harvest for Clear Creek, 1979 to 1991 (Murtagh et al., 199).

2.4.5 Time Line

Year	Event
1844-45	Barlow Road scouted and built
circa 1848	Dam built at Viola
1852	Dam built at Harding's Mill, three miles above the hatchery
1861	Flood
1861	Dam built at Springwater
1872	Sawmill located at Viola on Clear Creek
1877	Fish hatchery built on the Clackamas River, just above the mouth of Clear Creek
1879	Hatchery dam broke earlier in the winter of 1878-79, and all the fish produced at the station had to be released on January 2; over 2 million hatchery eggs collected in 1879
1880	Logs floated downstream on tributaries of Clear Creek
1880s	Census records indicate large numbers of gypo sawmills on Clear Creek, and large log floats occurred related to these mills (probably associated with splash dams to build up force to float the logs)
1881	Flood
1890	Flood; a dam across the Clackamas near Gladstone reported to prevent salmon from moving upstream during low flows
1890s	Sawdust and other mill waste are common stream pollutants
1900	Clackamas County population: 19,658
1902	Forest fire; 20,000 eastern brook trout and 5,000 black spotted trout (cutthroat trout) planted in Clear Creek (Fifth and Sixth Annual Reports of the Fish and Game Protector, 1895-1896. p. 61)
1909-1910	Flood
1910	Clackamas County population: 29,931
1912	Sawmill built on Clear Creek at present location of Metzler Park
1915	Covered bridge crossed Clear Creek 100 feet downstream from the cement bridge on Highway 211
1920	Clackamas County population: 37,698
1930	Clackamas County population: 46,205
1930s	Clackamas Fir Mill increases demand for timber from Clear Creek canyon (Shearer, 1993)
1940	Clackamas County population: 57,130
1950	Clackamas County population: 86,716

Year	Event
1950s	Fish managers start releasing large numbers of hatchery produced fish into Clear Creek.
1960	Clackamas County population: 113,038
1970	Clackamas County population: 166,088
1973	*Oregon land-use planning program created by Senate Bill 100*
1980	Clackamas County population: 241,919
1985	167,440 coho salmon stocked in Clear Creek
1990	Clackamas County population: 278,850
1991	10,087 steelhead stocked in Clear Creek
1990s	State implemented the Oregon Plan for Salmon and Watersheds; Forest Service and BLM implemented the Northwest Forest Plan; Clackamas River Basin Council formed
2000	Clackamas County population: 338,391

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3.0 CHANNEL HABITAT TYPE CLASSIFICATION AND CHANNEL MODIFICATION

3.1 INTRODUCTION

The goal of the channel habitat typing is to better understand; 1) the location of channel habitat types that provide key aquatic habitat conditions, 2) how land use impacts can alter the channel form and, 3) to identify how different types of channel will respond to restoration efforts. The channel modification assessment is designed to provide insight on how human activities have directly changed channel morphology and aquatic habitat. In the Oregon Watershed Assessment Manual (WPN 1999) the channel habitat type classification and channel modification assessments are separate modules. Both assessments require aerial photograph (air-photo) analyses and field verification to minimize duplication of effort; the assessments were combined together.

3.2 CRITICAL QUESTIONS

Question 3-1: What is the distribution of channel habitat types throughout the watershed?

Question 3-2: What is the location of channel habitat types that are likely to provide specific aquatic habitat features, as well as those areas that may be the most sensitive to changes in watershed condition?

Question 3-3: What are the types and relative magnitudes of past and current channel modifications?

Question 3-4: Where were historic channel disturbances, such as dam failures, splash damming, hydraulic mining, and stream cleaning, located?

3.3 METHODS

3.3.1 GIS Mapping

The GIS analyst completed an initial classification of channel habitat type (CHT) classification by identifying the channel gradient classes (<1%, 1-2%, 2-4%, 4-8%, 8-16% and, >16%) and calculating the channel confinement classes (unconfined, moderately confined and confined), then assigning the stream segments specific CHT designations. The initial channel CHT map was then created and used as the working map for the air-photo analysis and field verification.

3.3.2 Aerial Photograph Review

The air-photo review of channel habitat types and channel modification used the most recent aerial photos available. Two sets of aerial photos in stereo pairs were used in order to have complete coverage of the entire watershed. Photographs purchased from a private company (Spencer Gross, Inc.) covered the watershed north of Fischers Mill Road; the photos were taken in 1998 at a scale of about 1:10,200. The southern portion of the watershed was covered by photos taken by BLM in 1998 at a scale of 1:12,000.

The photos were used to identify broad-scale features, such as the locations of valley walls relative to the stream channels, ponds, and ditched stream segments. Features that were not readily identifiable on the aerial photos were flagged for field verification; these included streams mapped as disconnected, large wetland complexes and areas of exposed soil or unusual conditions. Notes were made on the working map, and a list was generated for each subwatershed of locations and features that needed field verification.

3.3.3 Field Verification

The field verification was completed in April and May 2002. Specific sites highlighted in the aerial photo review were visited and checked. The verification effort was designed to focus on representative reaches covering a variety of gradient and confinement types as well as, key fish habitat areas and the general range of land management activities. Observed conditions were described, CHT type was verified and in some cases fish habitat data was collected. These observations are included in *Appendix 1: CHT and Aquatic Habitat Field Report*.

The types and relative magnitudes of past channel modifications as well as historic channel disturbances, such as dam failures, splash damming, and stream cleaning, were identified as part of the historical conditions assessment.

3.4 FINDINGS

3.4.1 CHT Map and Summary of CHTs

Map2: Channel Habitat Types illustrates the distribution of CHT types throughout the Clear and Foster Creek watersheds. A number of the small tributaries to Clear Creek and a portion of Foster Creek had been straightened and are actively maintained as ditches. These stream segments are identified on the CHT map as ditches because the channel function in these segments is not the same as for an unmodified CHT. The miles of stream in each CHT type by subwatershed are summarized in Table 3-1. Figure 3-1 illustrates the distribution of the different gradient classes for CHTs in the watersheds. The largest group of channels (35%) falls into the moderate gradient class; about two-thirds of these channels are moderately confined, and valley walls confine the remaining third. Figure 2 illustrates the distribution of CHT gradient classes within each subwatershed. This figure shows that the floodplain and low-gradient CHTs are more common in the basins lowest in the watershed. Upper Clear Creek subwatershed is dominated by moderate gradient reaches, and also has the highest proportion of steep and very steep CHT types.

Table 3-1: Summary of miles of stream in each CHT by subwatershed.

Subwatershed	FP1 (<1%)	FP2 (<1%)	FP3 (<1%)	LC (<2%)	LM (<2%)	MM (2-4%)	MC (2-4%)	MH (1-6%)	MV (4-8%)	SV (8-16%)	VH (>16%)	Ditch	Total Miles
Foster Creek	0.00	1.53	1.19	0.62	0.86	0.00	0.23	0.00	0.00	0.00	0.00	0.33	4.75
Little Clear Creek	1.98	1.05	0.36	0.30	0.48	7.32	2.07	0.36	3.94	1.74	0.93	0.00	20.53
Lower Clear Creek	8.62	0.40	2.81	1.13	3.92	7.21	3.22	1.55	3.86	0.57	0.00	3.06	36.36
Middle Clear Creek	4.39	0.79	0.29	0.36	5.38	5.59	1.23	0.74	5.53	3.47	0.25	0.32	28.33
Upper Clear Creek	0.00	0.00	1.04	0.40	3.12	12.98	9.88	1.26	7.49	7.95	8.12	0.00	52.22
Total Miles	14.99	3.77	5.68	2.82	13.76	33.10	16.64	3.90	20.83	13.72	9.29	3.70	142.20
Gradient Class Subtotals			24.44 (17%)		16.58 (12%)		49.74 (35%)		24.17 (17%)		23.01 (16%)	3.70 (3%)	

FP1= Large Floodplain CHT (<1% gradient, unconfined)

FP2= Medium Floodplain CHT (<2% gradient, unconfined)

FP3= Small Floodplain CHT (<2% gradient, unconfined)

LC= Low Gradient Confined CHT (<2% gradient, confined)

LM= Low Gradient Moderately Confined CHT (<2% gradient, moderately confined)

MM= Moderate Gradient Moderately Confined CHT 2-4 % gradient, moderately confined)

MH= Moderate Gradient Headwater CHT (1-6 %, confined)

MV= Moderately Steep Narrow Valley CHT (3-10% gradient, confined)

SV= Steep Narrow Valley (8-16% gradient, confined)

VH= Very Steep Headwater (>16%, Confined)

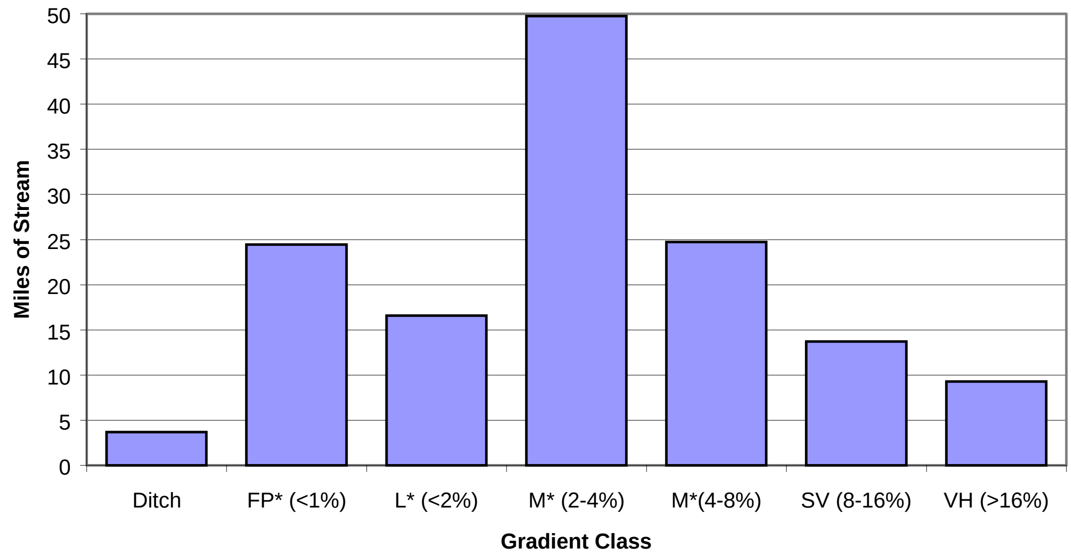

Figure 3-1: Distribution of channel gradient classes in the Clear and Foster Creek watersheds.

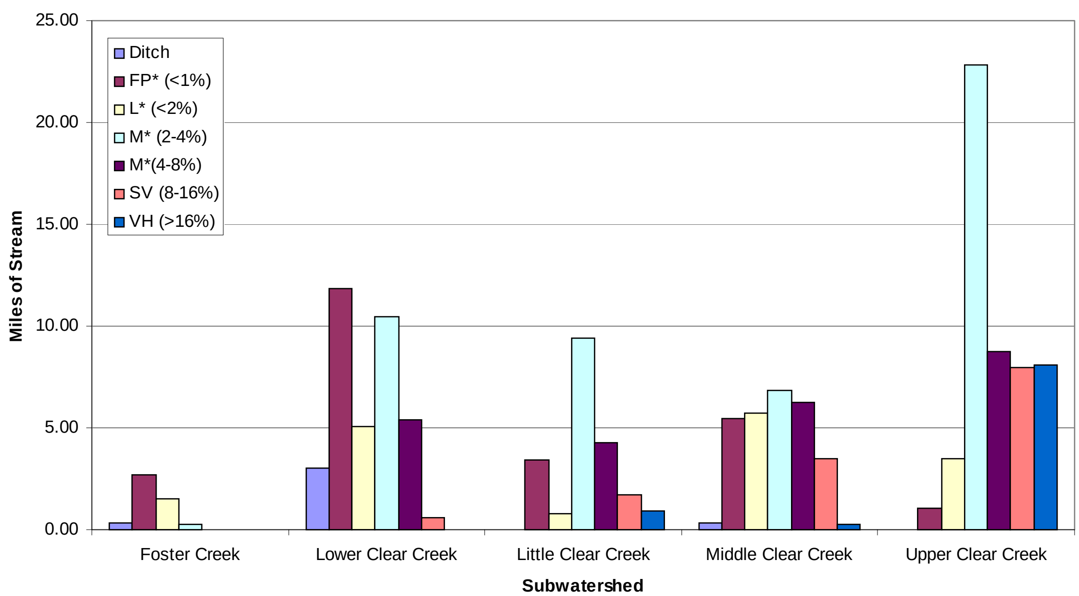

Figure 3-2: Distribution of CHT gradient classes within the Clear and Foster Creek watersheds.

3.4.2 Geologic Channel-Forming Processes

Channel characteristics in the Clear and Foster Creek basins reflect the geologic and geomorphic processes that have been active in the region, especially over the past couple of million years. Uplift of the Cascades, volcanic eruptions, and deposition of fluvial sediments created the materials and relief of the area; abundant rainfall has generated surface and subsurface runoff that stimulated mass wasting and stream erosion. The channels in the basin can be sorted into a small number of landform types based on their combinations of geologic materials, terrain, and history.

In the mountainous parts of the basins, mostly small streams are eroding into resistant volcanic and volcaniclastic rocks, on moderate to steep slopes. On Goat Mountain, Green Mountain and the higher parts of the Boring Lava hills (such as Highland Butte and Outlook), most of the streams are small, and flow in relatively steep, narrow channels cut into bedrock. A few ponds and wetlands are associated with landslides or past glacial processes (Clear Lake). The larger streams have eroded deep gorges, such as those along the main stem of Clear Creek and (southern) Little Clear Creek near Dodge and Elwood.

The terrain in about two-thirds of the Clear-Foster area is dominated by a series of plateaus and terraces, built up by a combination of local volcanic eruptions (from Boring Lava vents) and the deposition of fluvial sands, silts, and gravels by streams flowing off the Cascades. The weathered soils and rocks of the lava plateaus and the older/higher terraces have been eroded into rolling surfaces by small tributary streams, flowing away from the volcanic centers or down the inherited terrace slopes at gentle gradients. But where they flow over the terrace edges into the deeper canyons, these streams have eroded ravines of varying lengths and depths. The channels in these ravines are typically narrow and steep, and local gradients are controlled by the rocks' resistance to incision. In many places, hard layers of basalt, conglomerate, sandstone, or mudstone form ledges, waterfalls, and step-pools (such as on Swagger Creek); in others, stream incision has left narrow slices into bedrock (as at the mouth of Foster Creek).

The Clackamas River, Clear Creek, and their major tributaries have eroded deeply into the old upland surfaces, while stream meandering (particularly by the Clackamas) shaped the terraces and left steep terrace scarps. Along Clear Creek (especially from Dodge-Elwood to Fischer's Mill) and the major tributaries (Mosier, Little Clear, Little Cedar, and Bargfeld Creeks, etc.), the combination of stream incision and landsliding has produced deep, complex ravines. Almost all of the scarps have been affected by shallow mass movement to one degree or another, and most show evidence of deep-seated landsliding, with some slide complexes hundreds of acres in area. Where the ravines are narrow, such sliding has on occasion blocked the creeks (at least temporarily), altering local base levels and depositional patterns. Even in the wider Clear Creek canyon, sliding has deflected the stream toward the opposite wall in places, changing local erosional patterns and channel behavior. The smaller tributaries that cross or originate on the irregular surfaces of the large landslide bodies typically have gentle gradients, commonly interrupted by small ponds and wetlands. The landslides are major contributors to the supplies of coarse sediment (including boulders and cobbles, locally) and large woody debris to the streams.

Although terrace scarps and bluffs remain important elements, in terms of constraining channel migration and supplying sediment from landslides, downstream of Springwater Clear Creek flows dominantly on alluvium (as opposed to bedrock) in a generally wider valley bottom. There, low-gradient streams meander across their valley bottoms, occasionally abandon channel segments, and inundate their floodplains and low terraces during high flows. The younger/lower terraces of the north end of the area (including most of the Foster Creek basin) are typically flatter than the rolling higher surfaces in the south. Consequently, the tributaries flowing on them tend to have very gentle gradients, except where they have eroded ravines into the terrace scarps, as near the mouth of Foster Creek. On the lower terraces and floodplains, small streams can flow into abandoned channels or onto the inboard edges of lower terraces, or originate there from seepage. These small back-terrace or wall-base channels provide important rearing and refuge habitat.

3.4.3 Channel Disturbance & Modification

Based on the air-photo analysis and field visits, approximately 3% of the stream channel has been modified into ditches. This is most common in the Lower Clear Creek subwatershed, where 8% of the stream channel has been ditched. This is only in tributaries, many of which are not accessible to fish due to naturally steep drops into the Clear Creek ravine (see *Map 7: Fish Distribution*). However these tributaries do have the potential for significant water quality degradation due to straightening of the channel, proximity to road and farm property, and commonly complete lack of shade or any cover.

There are approximately 76 ponds located on the stream network, an additional 59 ponds are located off the stream channel but in the watershed. . Many of these ponds are constructed farm ponds and the ones on the stream channel provide limited or no fish passage opportunities. Other ponds are natural features created by the landforms and/ or landslide toes which capture and hold water or block the channel. Table 3-2 summarizes distribution of these ponds within the subwatersheds.

Table 3-2: Summary of ponds in Clear and Foster Creek watersheds.

Off Stream Ponds		
Foster Creek	5	Total Off Stream Ponds 59
Little Clear Creek	6	
Lower Clear Creek	24	
Middle Clear Creek	15	
Upper Clear Creek	9	
On Stream Ponds		
Foster Creek	1	Total On Stream Ponds 76
Little Clear Creek	5	
Lower Clear Creek	21	
Middle Clear Creek	40	
Upper Clear Creek	9	

Evidence of historic modifications of current channel conditions is not readily apparent. Log drives to sawmills are documented as occurring in the late 1800s. At the time sawmills were located in Viola, Metzler Park, and other areas in the watershed. It is likely that logs and at least small splash dams were located along most the main stem and large tributaries. (See *Section 2.0: Historical Conditions* for more detail).

No documentation of stream cleaning efforts was found. Although, it is likely ODFW did clear LWD from main Clear and Foster Creeks as part of the region wide stream cleaning efforts in the 1970s and 1980s.

3.4.4 Descriptions of CHTs in the watershed

3.4.4.1 Low Gradient Floodplain (<1%) - FP1, FP2, FP3; Low Gradient Moderately Confined (<2%) - LM

The low gradient floodplain channels are located on the main Clear Creek and middle Foster Creek. Conditions in Foster Creek differed from those in Clear Creek. In Foster Creek the floodplain Channel Habitat Types tended to be relatively straight and incised at a number of locations. The relatively small drainage basin and lack of channel structure either in the form of large wood, boulders or bedrock probably contributes to the uniform channel conditions.

Along the main stem of Clear Creek and some larger tributaries, where the channels are incised into old terraces and volcanic plateaus, it was often difficult to determine from the air-photos if the channel was a truly unconfined floodplain (with a width 4x the bankfull width) or moderately confined (>2x but<4x bankfull width). Most of the main stem of Clear Creek alternates between unconfined and moderately confined low gradient CHTs. Very similar patterns and habitat conditions were observed during field checks of both channel habitat types (see Appendix A – Field Report).

The typical pattern observed at several locations along main Clear Creek are high mudstone walls alternating with gravel bars or landslide debris along the channel margins. The landslide debris appears to be a source of gravel, boulders and large wood; large pools commonly are present near the landslide tail-outs. Overflow and side channels tend to be present on these areas. The bars of sorted gravels provide excellent spawning habitat.

3.4.4.2 Low Gradient Confined (<2%) - LC

These CHTs occur along less than 2% of the stream network. The longest section of this stream type is along upper Bargfeld Creek. Due to the steep valley walls access was relatively difficult, there is no development along the creek in this section. The creek itself appeared to have a long history of beaver dam activity. Creek substrate consisted of small gravels and sand, with a number of wood-formed plunge and scour pools. Foster Creek above Gerber Road also falls into this CHT classification and observed channel conditions were similar.

This CHT provides good resident fish spawning (lamprey were observed) due to the smaller substrate, and potentially excellent rearing habitat. A dam on a downstream property (see Appendix A) blocks fish passage limiting access to this CHT.

3.4.4.3 Moderate Gradient Moderately Confined (2-4%) - MM

This is the most common CHT in the watershed: 23 % of the stream network falls into this classification. Most of the tributaries to the main stem in lower, middle and Little Clear Creeks fall into this classification. In upper Clear Creek this is the most common CHT, comprising 25% of the channels in this subwatershed. Due to the valley confinement and increase in gradient, these channels tend to be straighter than the gentler reaches. Substrates were gravels and small cobbles providing good resident fish spawning habitat. Stream segments in this CHT that flow into the main Clear Creek probably are used for refuge during winter or high flows.

3.4.4.4 Moderate Gradient Confined (2-4%) - MC

Sixty percent of the stream miles in this CHT classification are in the Upper Clear Creek subwatershed, above habitat that is accessible to anadromous fish. One site in this CHT classification located in Swagger Creek was visited. The channel was bedrock dominated, and resembled a bedrock chute with small pools, few gravels, and no off-channel areas. These conditions provide no spawning and limited rearing habitat. Large wood is a key to habitat formation, gravel retention and pool scour in this gradient class. There were only a few pieces of old large wood in the reach that was sampled; habitat conditions may be better in reaches where more large wood is present.

3.4.4.5 Moderate Gradient Headwater (1-6%) – MH

These CHTs make up less than 3% of the total stream network and occur mostly along tributaries to lower Clear Creek and in Upper Clear Creek. These gentle to moderate headwater streams generally have low streamflow volumes and low stream power. They provide limited resident fish habitat.

3.4.4.6 Moderately Steep Narrow Valley (4-8%) – MV

Approximately 21 miles (15%) of the stream channel falls into this CHT classification, making it the most extensive CHT in the watershed. The longest segments are in the Middle and Upper Clear Creek subwatersheds. These channels are moderately steep and confined by adjacent moderate to steep hill slopes. High flows are generally contained within the channel banks and some channels may become dry during the low flow season. A narrow floodplain may develop locally and some beaver dams were observed. This CHT is likely to provide only resident fish habitat.

3.4.4.7 Steep Narrow Valley (8-16%) – SV & Very Steep Headwater (>16%) - VH

These two channel types are very similar except that VH channels are steeper. Most of these channel types are in the headwater portions of the upper Clear Creek subwatershed. These channel types are usually small headwater streams with vertical steps of boulders, cascades and falls. The lower portions of Swagger Creek, Golf Course Creek and other small tributaries fall into this classification. Lower Swagger Creek has at least one 10' falls blocking fish passage (see Appendix A) below the crossing of Highland Road. It is likely that similar falls or bedrock chutes exist in other segments inhibiting fish passage to upstream areas.

3.4.5 Conclusions & Recommendations

1. Steep valley walls along Clear Creek and in tributaries provide some degree of protection by keep portions of the channel inaccessible to human development and modifications.

2. Ponds located on the stream channels have the potential to significantly impact water quality and impede passage of fish. In channel ponds on fish bearing streams should be evaluated for potential impacts to water quality and fish passage. Ponds on stream segments potentially used by fish should be evaluated.

3. Ditching of tributaries in Lower Clear Creek is a common channel-modification and should be evaluated for water quality implications.

4.0 HYDROLOGY AND WATER USE

4.1 INTRODUCTION

This section of the watershed analysis report presents the results of the hydrology and water use assessment. The assessment uses existing information to summarize what is known about streamflow patterns, water use, and land use effects on streamflow in the Clear Creek and Foster Creek watersheds. The results are followed by recommendations on future monitoring needs to fill data gaps and steps that can be taken to improve streamflow conditions.

4.2 CRITICAL QUESTIONS

The Hydrology and Water Use assessment methodology outlined in the Oregon Watershed Assessment Manual (WPN, 1999) is designed around a series of critical questions that form the basis of the assessment. These critical questions are:

Question 4-1: What land uses are present in the watershed?

Question 4-2: What is the flood history in the watershed?

Question 4-3: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?

Question 4-4: For what beneficial use is water primarily used in the watershed?

Question 4-5: Is water derived from a groundwater or surface-water source?

Question 4-6: What type of storage has been constructed in the basin?

Question 4-7: Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin?

Question 4-8: Are there any illegal uses of water occurring in the basin?

Question 4-9: Do water uses in the basin have an effect on peak and/or low flows?

The critical questions were discussed at meetings with the Clackamas Basin Research and Advisory Group and with the Clackamas River Basin Council. The outcome of the meetings was a clarification on hydrology and water use issues of concern in the basin. These issues include:

1. Flood history of the watershed (provides context to interpret current channel conditions)
2. Possible increases in peak flows due to land use (i.e., forest harvest, agricultural disturbance, urbanization)
3. Actual water use vs. water rights.
4. Inability to meet instream flow requirements in certain (summer) months

4.3 METHODS

The purpose of the hydrology and water use section is to summarize existing information sources, identify data gaps that may require further study, and identify opportunities for improving stream flow conditions. In general, the methodology follows the outline presented in the *Oregon Watershed Assessment Manual* (WPN, 1999). Critical question #1, "What land uses are present in the watershed?" is addressed in Section 1.2.9 of this report above. The remainder of the assessment is divided among three primary tasks. Section 4.4.1 describes the flood history of the area (Section 1.2.6 above provides a summary of available streamflow information and estimated monthly stream flows). Data used in Section 4.4.1 was available primarily from the U.S. Geological Survey (USGS). Section 4.4.2 characterizes water use among the subwatersheds. Water use information was obtained from the Oregon Water Resources Department (OWRD). Finally, Section 4.4.3 provides a discussion on the effects that current land use has on streamflow in the watersheds. The only study that we are aware of that has evaluated land use effects on either peak or low stream flows within the watersheds is the Upper Clear Creek Watershed Analysis (BLM, 1995). Additional analysis on land use effects was performed as part of this assessment using methodologies outlined in the *Oregon Watershed Assessment Manual* (WPN, 1999).

4.4 RESULTS

Results of the Hydrology / Water Use assessment are presented within Sections 4.4.1 - 4.4.3 below. Within each of the four sections the applicable Critical Questions are identified, and a summary is provided at the end of the section on the current status, trend, and causal linkages.

4.4.1 Flood History

Critical Question: What is the flood history in the watershed?

The primary peak flow generating processes[5] active in Oregon are rainfall, snowmelt, and rain-on-snow (ROS). Rain-on-snow is the common term used to describe wintertime conditions when relatively warm wind and rain combine to produce rapid snowmelt. Appendix A of the *Oregon Watershed Assessment Manual* (WPN, 2001) identifies the dominant peak flow generating processes by EPA level IV ecoregion. Within the level IV ecoregions found within the vicinity of the Clear and Foster Creek watersheds the dominant peak flow generating processes are estimated as rainfall in all areas below 2,300 feet elevation, and as ROS in areas above 2,300 feet elevation. The Bureau of Land Management's (BLM) *Upper Clear Creek Watershed Analysis* (BLM, 1995) identified the ROS zone as occurring between 1,800-2,800 feet elevation in the vicinity of the Upper Clear Creek subwatershed. Regardless of the actual location of the ROS zone, it is important to recognize that ROS processes may occur within all elevation ranges; it is just that ROS has the greatest likelihood of significantly affecting peak flows within the ROS zone. Approximately 30% of the Upper Clear Creek watershed is located between 1,800-2,800 feet elevation, and none of the remaining subbasins have any area within this elevation range (Figure 1-1, Table 1-1).

No data on annual peak flows are available from any location within the Clear and Foster Creek watersheds (Table 1-3). Consequently, gages having peak flow records from adjacent watersheds were used to estimate peak flow history within the Clear and Foster Creek watersheds. Peak flow records from six USGS stream gages were used to construct the peak flow history. For purposes of comparison, the data are presented as a time series showing the recurrence interval of the annual flow event (Figure 4-1). This approach allows for a comparison of events from a wide variety of watershed sizes. Recurrence intervals were calculated for the period of record at each station using techniques described by the Interagency Advisory Committee on Water Data (1982). Peak flow magnitude was next plotted against probability (i.e., 1/recurrence interval) on log-probability paper. Recurrence interval was then interpolated for each event from the plotted values.

Five peak flow events having a ten-year or greater recurrence interval are estimated to have occurred at one or more locations over the period of record shown in Figure 4-1. The largest peak flow event that occurred in recent times was the flood that occurred on 12/21/1964 during water year 1965 (i.e., the "'64 flood"). This event was the largest annual event in water year 1965 at all five gages that had records. Interestingly, the '64 flood had an estimated recurrence interval of ~ 200 years at the Molalla River gage, 80 years at Dubois Creek, and 57 years at Whisky Creek; but was only estimated to be a 10 year event at Bull Creek and a ~7 year event at Rock Creek. This disparity is due no doubt in part to the uncertainty in estimating recurrence intervals from short data records. However, it is probable that the lack of significant snow pack at low elevations probably resulted in much lower magnitude flooding in the lower elevation watersheds.

[5] The hydrologic conditions responsible for generating peak stream flows in a watershed are referred to as the peak flow generating processes.

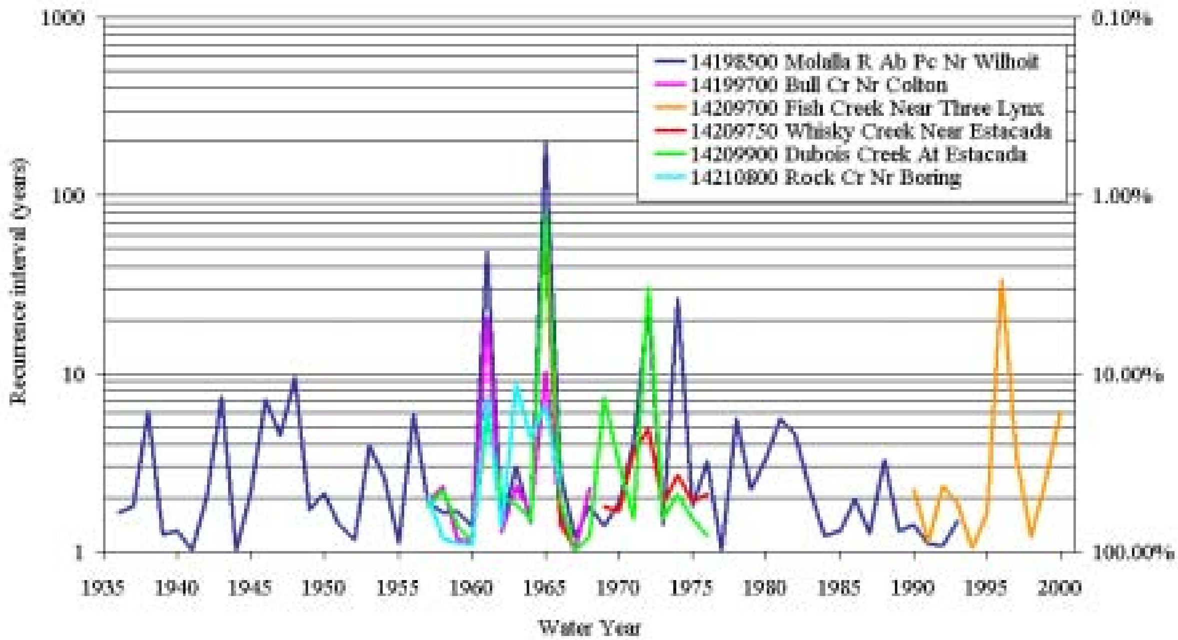

Figure 4-1. Recurrence interval associated with annual peak flow events at six USGS stream gages in the vicinity of the Clear and Foster Creek watersheds. Probability of occurrence (%) Data source: USGS (2002a).

The annual peak flow event for water year 1961 occurred on 11/24/1960 at the Molalla River gage (recurrence interval (Tr) = 48), the Bull Creek gage (Tr = 20), and the Rock Creek gage (Tr = 7); but occurred on 2/10/1961 at the Dubois Creek gage (Tr = 6). These differences in flood magnitude at different locations and the occurrence of the annual event during a completely different storm event at one of the gages, further points out the variability even at the local scale in watershed response to storm conditions.

Unfortunately, most of the gages used in this assessment were discontinued by the time of the 1996 flood which occurred on 2/7/1996 at the Fish Creek gage (Tr = 33 years). Again, the short data record available for this location adds uncertainty to the estimated recurrence interval of the event; however anecdotal information suggests that this event was locally significant with respect to channel morphology and fisheries habitat.

Peak flow estimates were calculated for the 2- to 100-year peak flow events ($Q_2 – Q_{100}$) for the subwatersheds in the Clear and Foster Creek watersheds to provide context on the possible magnitude of peak flows within the area. Estimates were made using the following regional USGS equations (Harris et al., 1979), and results are presented in Table 4-1:

Equation 4-1: Regional USGS Equations (Harris Et Al., 1979),

EQNs: Standard error (%)

Q_2	$=8.70\ A^{0.87}\ I^{1.71}$	33
Q_5	$=15.6\ A^{0.88}\ I^{1.55}$	33
Q_{10}	$=21.5\ A^{0.88}\ I^{1.46}$	33
Q_{25}	$=30.3\ A^{0.88}\ I^{1.37}$	34
Q_{50}	$=38.0\ A^{0.88}\ I^{1.31}$	36
Q_{100}	$=46.9\ A^{0.88}\ I^{1.25}$	37

Where: Q_n = Discharge for selected recurrence interval (cfs)

A = Drainage area (mi2)

I = Precipitation intensity (inches)

Table 4-1. Estimated peak flow magnitudes by recurrence interval

Subwatershed	Drainage area (mi^2)	Predicted peak flow magnitude (cfs) by recurrence interval:						
		Precipitation Intensity (in.)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Foster Creek	3.5	2.75	146	225	284	365	431	500
Upper Clear Creek	27.1	3.36	1,220	1,862	2,301	2,908	3,391	3,891
Middle Clear Creek	44.3	3.27	1,786	2,751	3,408	4,317	5,043	5,797
Little Clear Creek	9.1	2.97	382	589	736	940	1,104	1,277
Lower Clear Creek	72.7	3.10	2,508	3,916	4,875	6,205	7,271	8,385

4.4.2 Water Use

Critical Question: For what beneficial use is water primarily used in the watershed?

Critical Question: Is water derived from a groundwater or surface-water source?

Critical Question: What type of storage has been constructed in the basin?

Critical Question: Are there any withdrawals of water for use in another basin (interbasin transfers) Is any water being imported for use in the basin?

Critical Question: Are there any illegal uses of water occurring in the basin?

Data available from the OWRD (OWRD, 2001a; OWRD, 2002b) were used to identify locations and characteristics of water use in the Clear and Foster Creek watersheds[6]. Only those water rights whose current status is given as "non-cancelled" were included in this assessment. *Appendix 2: Water Rights Within Clear and Foster Creek Watersheds* contains a summary of all water rights, listed by subbasin and stream.

4.4.2.1 Overview of Water Rights

Water rights entitle a person or organization to use the public waters of the state in a beneficial way. Oregon's water laws are based on the principle of prior appropriation (OWRD, 2001b). The first entity to obtain a water right on a stream is the last to be shut off in times of low stream flows. In times when water is in short supply, the water right holder with the oldest date of priority can demand the water specified in their water right regardless of the needs of junior users. The oldest water right within the Clear and Foster Creek watersheds has a priority date of 3/16/1922, and the newest a priority date of 4/19/2000 (OWRD, 2002b).

Certain water uses do not require a water right (OWRD, 2001b). Exempt uses of surface water include natural springs which do not flow off the property on which they originate, stock watering, fire control, forest management, and the collection of rainwater. Exempt groundwater uses include stock watering, less than one-half acre of lawn and garden watering, and domestic water uses of no more than 15,000 gallons per day.

In Oregon, any entity wanting to use the waters of the state for a beneficial use has had to go through an application/permit process administered by the OWRD. Under this process an entity applies for a permit to use a certain amount of water, and then establishes that the water is being used for a beneficial use. Once the beneficial use is established, and a final proof survey is done to confirm the right, a certificate is issued.

The OWRD also approves instream water rights for fish protection, minimizing the effects of pollution or maintaining recreational uses (OWRD, 2001b). Instream water rights set flow levels to stay in a stream reach on a monthly basis, have a priority date, and are regulated the same as other water rights. Instream water rights do not guarantee that a certain quantity of water will be present in the stream; under Oregon law, an instream water right cannot affect a use of water with a senior priority date (OWRD, 2001b).

Two locations within the Clear Creek watershed have designated instream water rights for the "support of aquatic life" (OWRD, 2001a; OWRD, 2002c). These locations are at the mouth of Clear Creek, and Clear Creek upstream of Little Clear Creek. Both instream water rights have priority dates of 5/25/1966. The instream water right at the mouth of Clear Creek sets minimum stream flows for the months of June and July at 40 cfs, and for the months of August and September at 20 cfs. The instream water right for Clear Creek above Little Clear Creek sets

[6] Of the two sources of data used in this portion of the assessment, the Water Rights Information System data (OWRD, 2002b) is the most accurate and up to date (K. Boles, OWRD, pers. comm., 2/22/2002). The available GIS data (OWRD, 2001a) was used primarily to show locations of diversions and water use and may not accurately reflect current conditions.

minimum stream flows for the months of June and July at 25 cfs, and for the months of August and September at 15 cfs. No other months have instream flow requirements at either location.

4.4.2.2 Locations of Water Withdrawals

The OWRD identifies 307 points[7] of diversion for water rights within the Clear and Foster Creek watersheds (OWRD, 2002b). The approximate locations of these points of diversion are shown in Figure 4-2 (OWRD, 2001a). Points of diversion for water rights are found within all subbasins, and are predominately from surface water sources (Figure 4-3).

4.4.2.3 Withdrawal Rates

Information on withdrawal rates associated with water rights within the Clear and Foster Creek watersheds is available through the OWRD (2002b), and is included in the appendix in section 0. Rate of withdrawal given in the OWRD data is expressed either as an instantaneous rate (i.e., cubic-feet per second or gallons per minute) or as a total yearly volume (i.e., acre-feet). Some (but not all) of the water rights whose withdrawal rate is expressed in acre-feet have further restrictions that specify an instantaneous rate that water can be applied (for example, 1/40 cfs per irrigated acre) as well as the maximum volume that can be applied in a given season or over any 30-day period. It would be most convenient, when summarizing the rate of water withdrawals, to be able to express the withdrawal rate in common units of measurement for all water uses within a subbasin. However, this type of estimate is not possible at the current time using the publicly-available information from the OWRD. The OWRD is considering changes to their Water Rights Information System (WRIS) that will allow estimation of instantaneous withdrawals (K. Boles, OWRD, pers. comm., 2/22/2002).

[7] The actual number of physical locations where water is diverted may be less then 307. Diversion points appear to be duplicated in the OWRD GIS coverage in some situations. For example, when more then one water right applies to a physical diversion the number of points may be duplicated

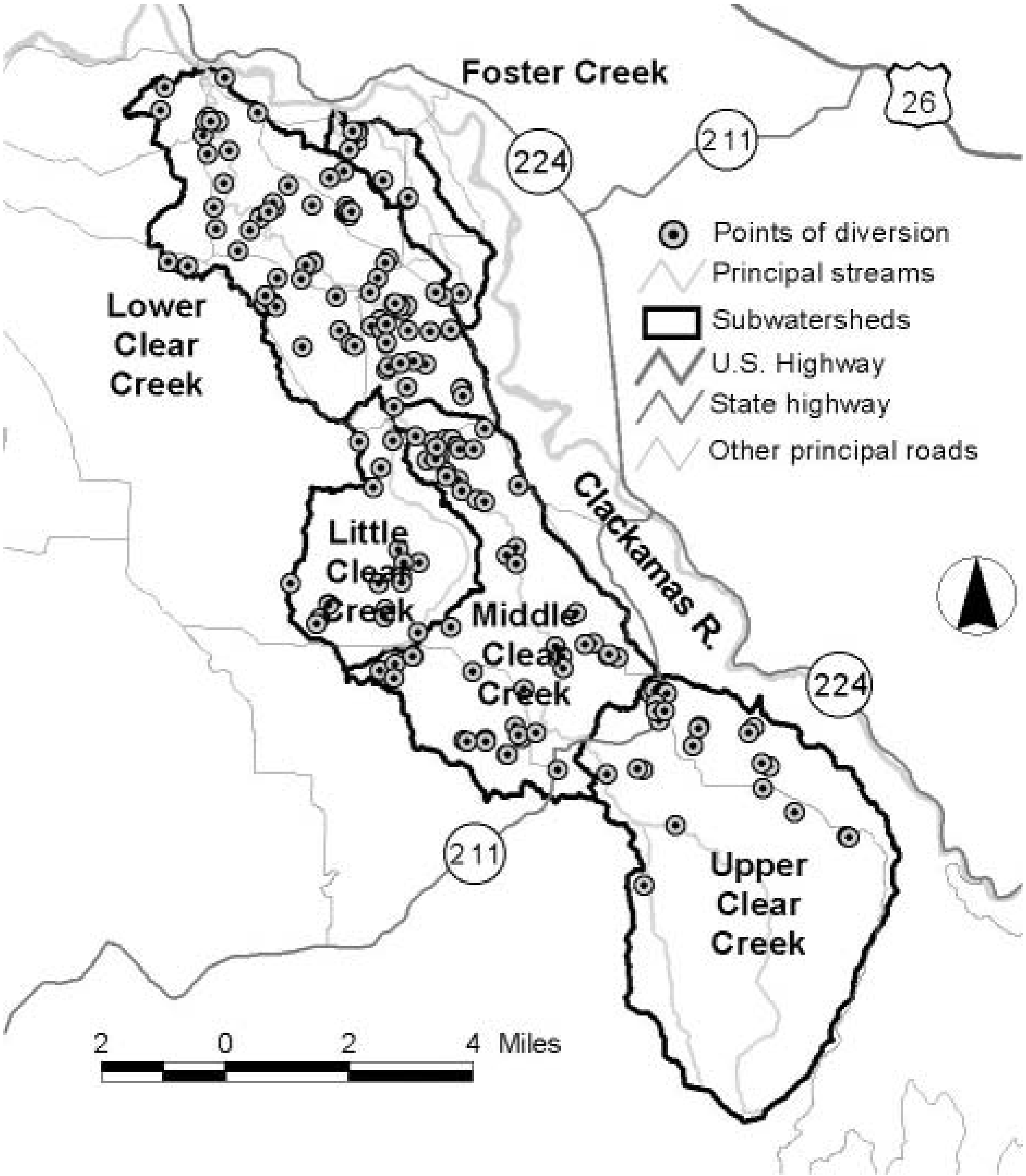

Figure 4-2. Points of diversion for water rights within the Clear and Foster Creek watersheds. Data sources: BLM (2002a, 2001a), OWRD (2001a).

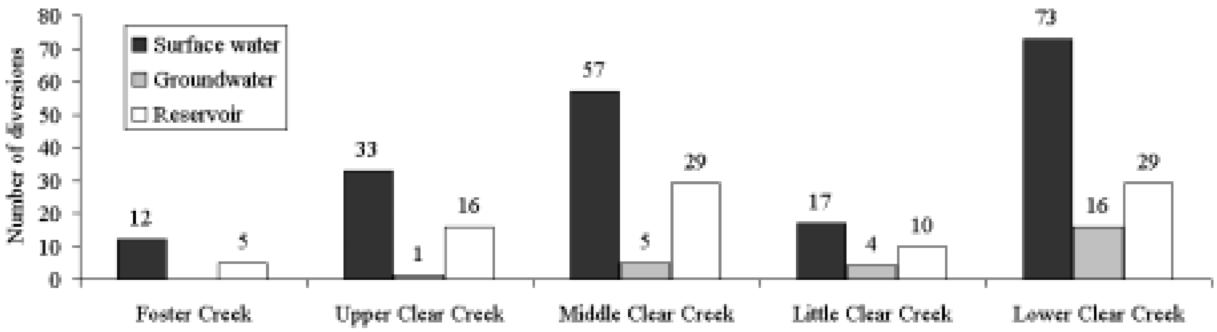

Figure 4-3. Distribution of water right points of diversion by subwatershed and water source (i.e., surface water, groundwater, and reservoir) within the Clear and Foster Creek watersheds. Data source: OWRD (2002b).

Given the limitations described above, the withdrawal rates for the Clear and Foster Creek watersheds had to be estimated separately for those water rights whose rate of withdrawal is given as a total yearly volume (acre-feet), and those whose rate are given as an instantaneous rate (cfs). Summaries for these two units of measure are given in Figure 4-4 and Figure 4-5.

Despite the difficulty in expressing all water rights in a common set of units, it is clear that irrigation is the primary use of water withdrawals in the watershed, accounting for 60% of the volume reported in units of acre-feet (Figure 4-4), and 53% of the amount reported as an instantaneous rate (Figure 4-5). Irrigated areas within the Clear and Foster Creek watersheds are shown in Figure 4-6 (OWRD, 2001a). The majority of the irrigated lands are located within the Lower and Middle Clear Creek subwatersheds (Figure 4-7).

The category "Agriculture" accounts for 6% of the total volume reported in units of acre-feet (Figure 4-4), and 3% of the amount reported as an instantaneous rate (Figure 4-5). This category includes areas listed as "nursery use". All areas within the agriculture category are located within the Middle Clear Creek subwatershed (Figure 4-6 and Figure 4-7).

The category "Fish" accounts for 18% of the total volume reported in units of acre-feet (Figure 4-4), and 33% of the amount reported as an instantaneous rate (Figure 4-5). The holders of these water rights are all identified as individuals or farms; consequently, it is unlikely that these water rights are used for commercial-scale aquaculture. Most of these water rights are probably used for backyard fish ponds.

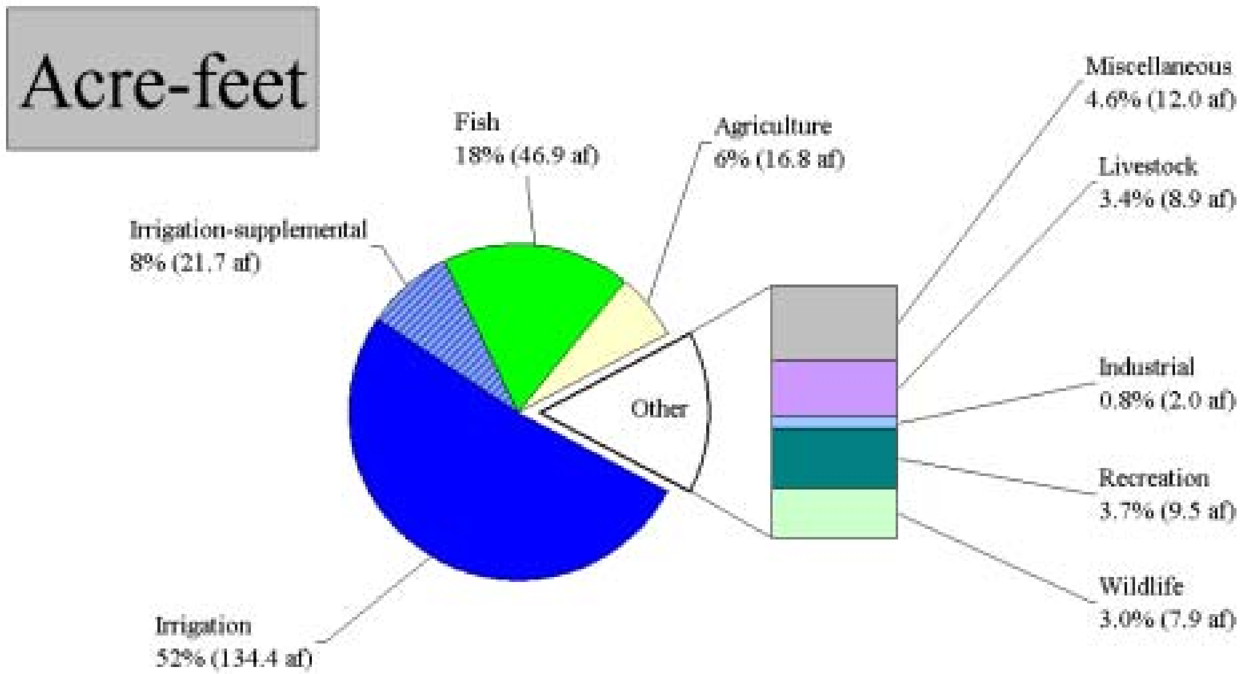

Figure 4-4. Summary of the water rights within the Clear and Foster Creek watersheds that are reported in units of acre-feet. Data source: OWRD (2002b).

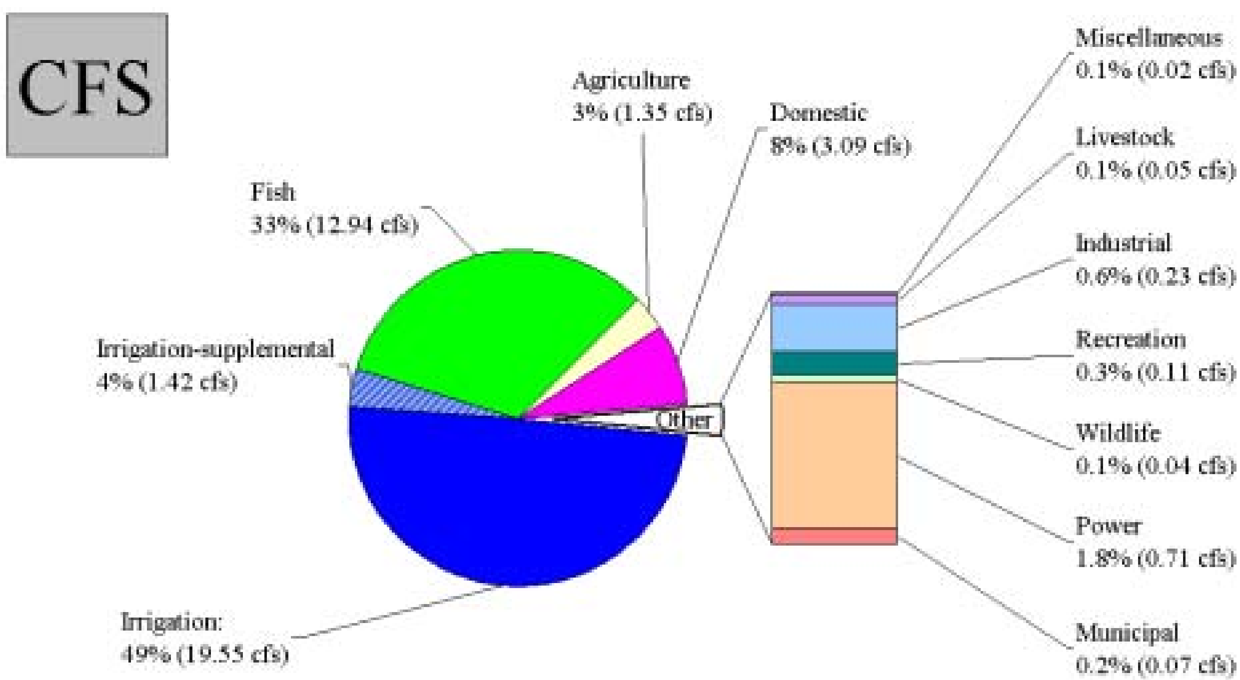

Figure 4-5. Summary of the water rights within the Clear and Foster Creek watersheds that are reported in units of cubic feet per second (cfs). Data source: OWRD (2002b).

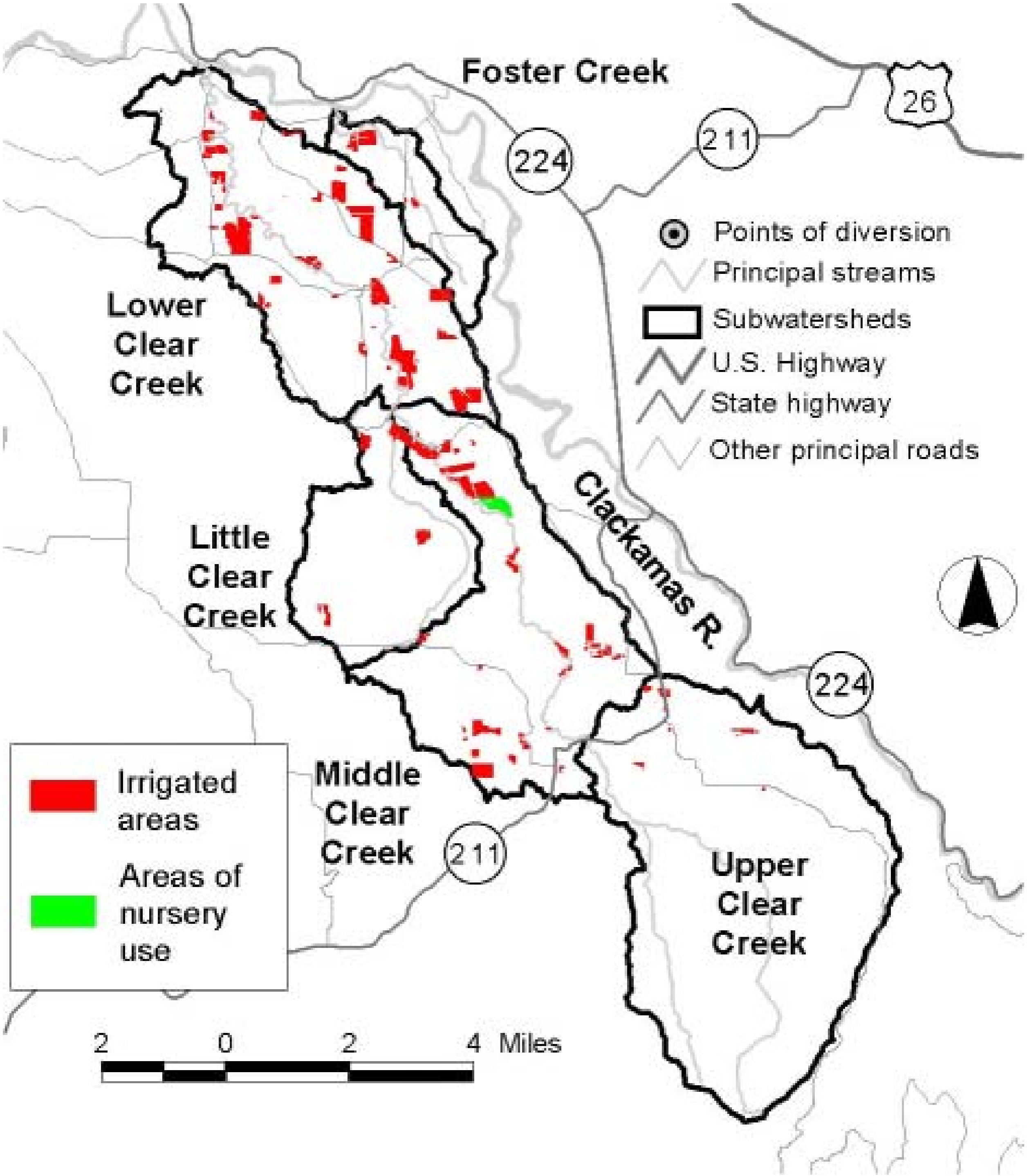

Figure 4-6. Irrigated areas within the Clear and Foster Creek watersheds. Data source: OWRD (2001a).

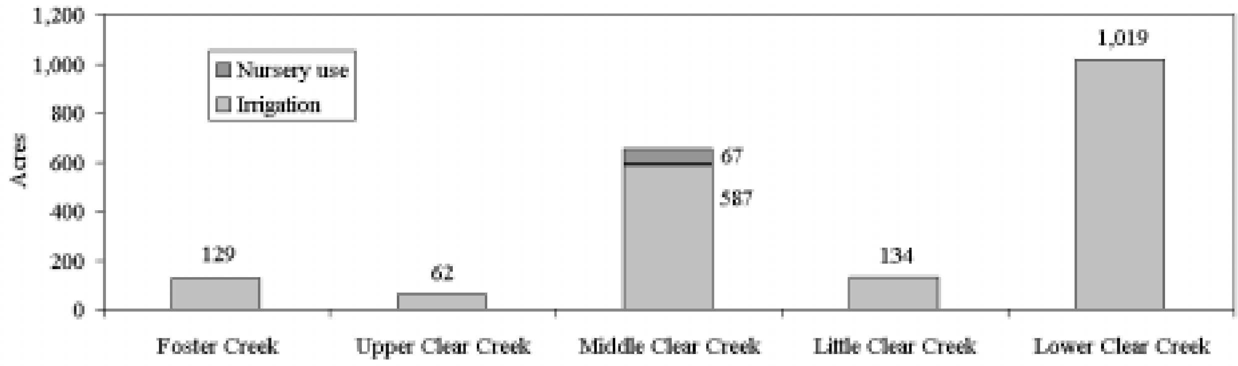

Figure 4-7. Distribution of irrigated areas by subwatershed. Data source: OWRD (2001a).

The category "Domestic" accounts for 8% of the amount reported as an instantaneous rate (Figure 4-5). In addition to water diverted for domestic consumption, this category includes waters used for lawns and gardens, and some stock watering. Also included are group domestic uses.

The remaining categories account for 16% of the total volume reported in units of acre-feet (Figure 4-4), and 3% of the amount reported as an instantaneous rate (Figure 4-5). These groups include livestock watering, wildlife use, recreation, municipal uses (one water right), power (seven water rights; all in the names of individuals), industrial use (commercial and manufacturing), and miscellaneous. The miscellaneous category includes four water rights whose use is identified as "aesthetic", and thirteen water rights for fire protection

4.4.3 Land Use Effects on Flow Regime

4.4.3.1 Water Withdrawals

Critical Question: Do water uses in the basin have an effect on peak and/or low flows?

Two pieces of information are needed to estimate the net effects of water use on stream flows at any given location; an estimate of the natural stream flow volume, and an estimate of the consumptive portion of all upstream water withdrawals.

4.4.3.1.1 Estimates of Natural Stream Flows

Unfortunately, the gage records available for the Clear and Foster Creek watersheds are of insufficient duration to allow for a direct estimate of monthly stream flows at locations within the watersheds. The Oregon Water Resources Department (OWRD) has estimated natural monthly stream flows at the mouths of several water availability basins (WABs) within the vicinity of the Clear and Foster Creek watersheds (Figure 4-8). Two of these locations correspond with subwatersheds defined for this analysis. The "Clear Creek at Mouth" WAB corresponds with the Lower Clear Creek subwatershed, and the"Clear Creek above Little Clear Creek" WAB corresponds with the Middle Clear Creek subwatershed (Figure 4-8).

The Natural Streamflow estimates available from the OWRD for each WAB (OWRD, 2002c) are the monthly 50% and 80% exceedance flows. The 50% exceedance stream flow is the stream flow that occurs at least 50% of the time in a given month. Conversely, the stream flow is also less than the 50% exceedance flow half the time. The 50% exceedance flow can be thought of as the average stream flow for that month. The 80% exceedance stream flow is exceeded 80% of the time. The 80% flow is smaller than the 50% flow, and can be thought of as the stream flow that occurs in a dry month. These exceedance stream flow statistics are used by the OWRD to set the standard for over-appropriation: the 50% exceedance flow for storage and the 80% exceedance flow for other appropriations (OWRD, 2002c). These estimates of natural monthly stream flows were made by the OWRD using statistical models derived from multiple linear regressions.

Values of the natural 50% and 80% exceedance flows were estimated for the Upper Clear Creek, Little Clear Creek, and Foster Creek subwatersheds by adjusting values available from OWRD for the Lower and Middle Clear Creek subwatersheds. Values for the Upper Clear Creek subwatershed were estimated by multiplying monthly unit-area values from the "Clear Creek above Little Clear Creek" WAB by subwatershed size. Values for the Little Clear Creek and Foster Creek subwatersheds were estimated by multiplying monthly unit-area values from the "Clear Creek at Mouth" WAB by subwatershed size. In calculating the unit-area values for the "Clear Creek at Mouth" WAB the difference in flow magnitudes between the "Clear Creek above Little Clear Creek" and "Clear Creek at Mouth" WABs was used to better-represent the character of the Foster Creek and Little Clear Creek subwatershed (i.e., lower elevation, lower basin relief).

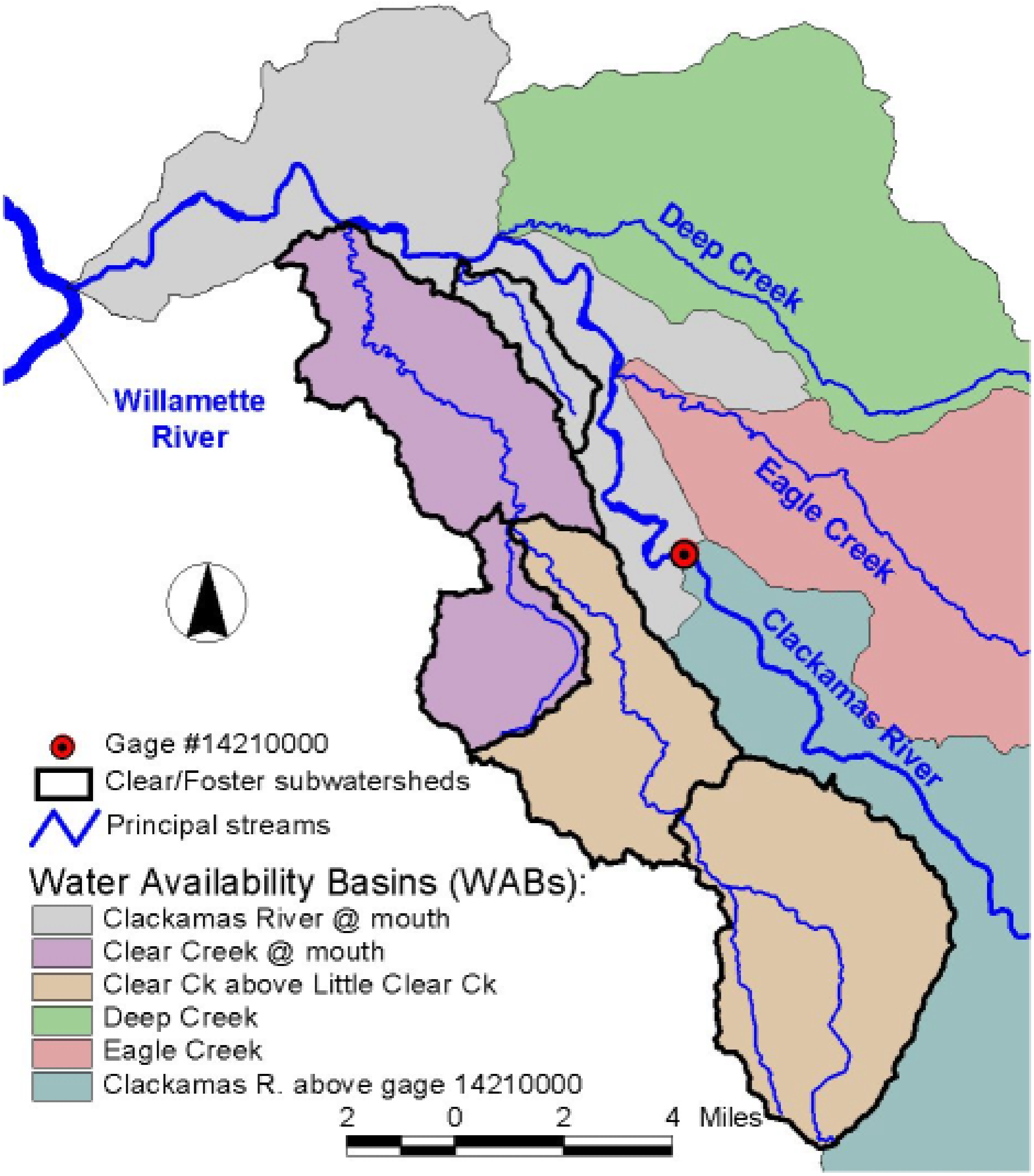

Figure 4-8. Water availability basins (WABs) in the vicinity of the Clear and Foster Creek watersheds.

4.4.3.1.2 Estimates of Consumptive Uses

A consumptive use is defined as any water use that causes a net reduction in stream flow (OWRD, 2002c). These uses are usually associated with an evaporative or transpirative loss. The OWRD recognizes four major categories of consumptive use: irrigation, municipal, storage, and all others (e.g., domestic, livestock). The OWRD estimates the consumptive use for irrigation using estimates made by the USGS; including estimates from the 1987 Census of Agriculture, estimates from the OSU Cooperative Extension Office, 1989-90 Oregon Agriculture and Fisheries Statistics, and an OSU Study of Crop Water Requirements (OWRD, 2002c). Irrigation uses are not estimated to be 100 percent consumptive. Consumptive use from other categories of use is obtained by multiplying a consumptive use coefficient (e.g., for domestic use, the coefficient is 0.20) by the maximum diversion rate allowed for the water right. The OWRD assumes that all of the non-consumed part of a diversion is returned to the stream from which it was diverted. The exception is when diversions are from one watershed to another, in which case the use is considered to be 100 % (i.e., the consumptive use equals the diversion rate).

Consumptive use estimates available from the OWRD (2002c) for the outlets of the “Clear Creek at Mouth” and ”Clear Creek above Little Clear Creek” WABs were used to represent conditions at the outlets of the Lower Clear Creek and Middle Clear Creek subwatersheds respectively. Consumptive uses for the remaining subwatersheds were estimated using the consumptive use calculation procedure available in the OWRD Water Availability Report System (OWRD, 2002c). Use of this procedure required summing the total acres irrigated in each subwatershed (Figure 4-7), and the total diversion rate for other uses by use category (e.g., domestic, industrial, etc.). The irrigation season was assumed to be from March – October. For all other water uses it was assumed that use was constant throughout the year. Consumptive use coefficients used were 0.10 for industrial/manufacturing uses, 0.20 for domestic and livestock uses, and 0.50 for general agricultural use other than irrigation. All other uses that occur in these subwatersheds (i.e., aesthetic, fish, fire protection, power, recreation, and wildlife) were assumed to be non-consumptive.

4.4.3.1.3 Estimated net effects of water use

The net effect of water withdrawals on monthly stream flows were estimated at the outlets[8] of each of the five subwatersheds in the following manner:

1. The estimated monthly natural stream flows for average and dry years (represented by the 50% and 80% exceedance flow respectively) were first plotted for each location.

2. The portion of all water withdrawals that does not return to the stream (i.e., the consumptive uses) was added to water diverted for storage for each month and plotted on the same graph.

3. If an instream water rights exists for the subwatershed this was also shown on the graph

4. Finally, the sum of instream water rights, consumptive uses, and storage was plotted on the graph.

The estimated net effect of water withdrawals on monthly stream are shown for each of the five subwatersheds in Figure 4-9, Figure 4-10, and Figure 4-11.

Figure 4-9 (top graph) shows the estimated net effect of water withdrawals on monthly stream flows at the mouth of Foster Creek. These estimates indicate that consumptive water use plus storage exceeds the estimated volume of natural stream flow in the months of July and August in average years (50% exceedance flows), and in the months of July – September in dry years (80% exceedance flows). In other words, if all of the water is withdrawn that is allowed under the existing water rights, there would be no flow remaining in the stream during these months. No instream water rights exist for Foster Creek.

Figure 4-9 (bottom graph) shows the estimated net effect of water withdrawals on monthly stream flows at the outlet of the Upper Clear Creek subwatershed. These estimates indicate that consumptive water use plus storage does not exceed the estimated volume of natural stream flow in any month in both average (50% exceedance flows) and dry (80% exceedance flows) years. These results are due to the relatively small amount of irrigated land in the subwatershed (Figure 4-7), and the small number of other water uses. No instream water rights exist for the Upper Clear Creek subwatershed.

Figure 4-10 (top graph) shows the estimated net effect of water withdrawals on monthly stream flows at the outlet of the Middle Clear Creek subwatershed. These estimates indicate that consumptive water use plus storage does not exceed the estimated volume of natural stream flow in any month, either in average (50% exceedance flows) or dry (80% exceedance flows) years. However, when the instream water right is added to the sum of consumptive uses and storage there is insufficient flow to meet all uses in the months of July – September in either average or dry years. Based on these estimates it appears unlikely that instream flow rates would be attained during these months in most years.

[8] All upstream subwatersheds were included. For example, the results for the Lower Clear Creek subwatershed includes results from the Little, Middle, and Upper subwatersheds as well.

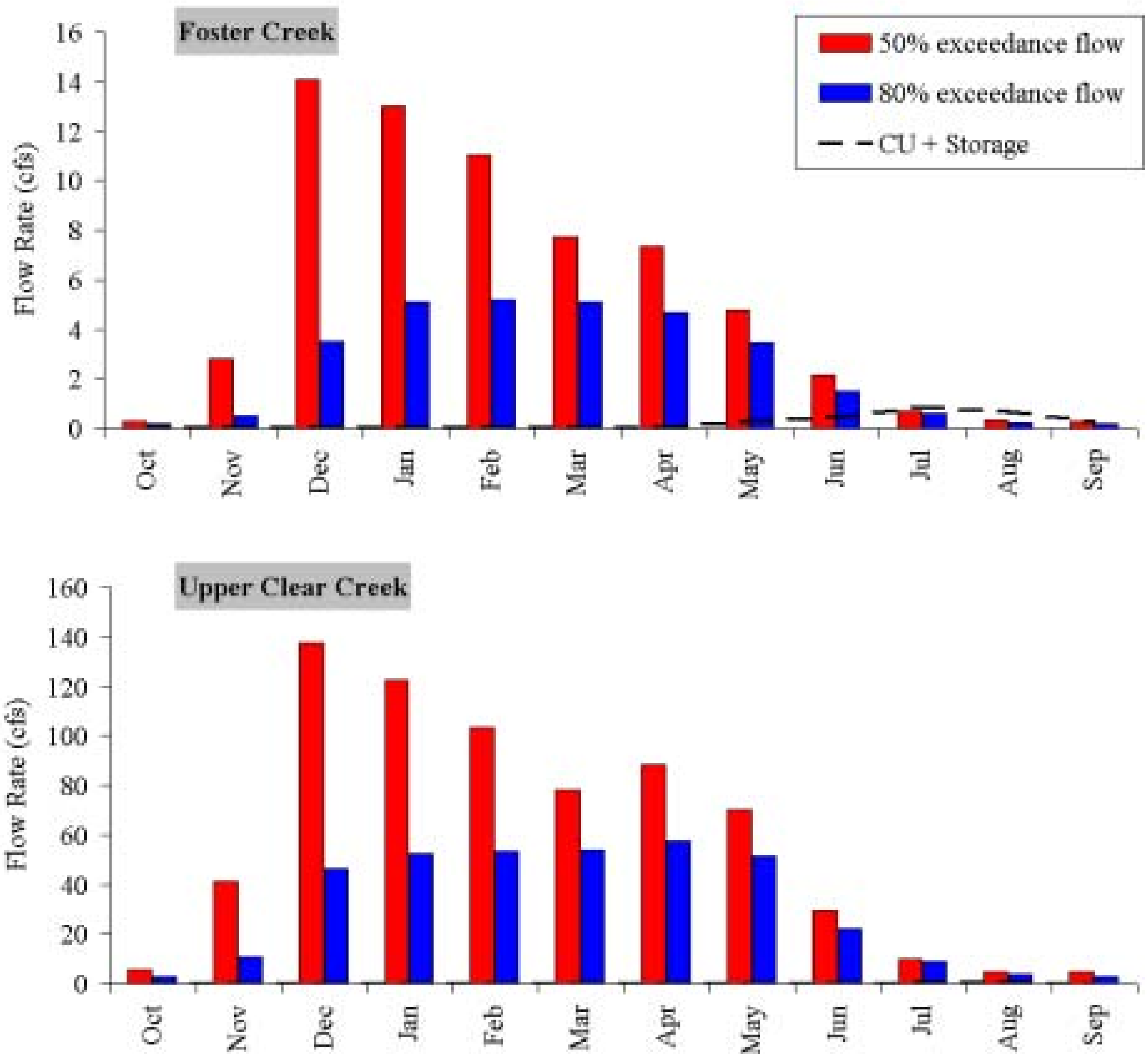

Figure 4-9. Estimated net effect of water withdrawals on monthly stream flows at the mouth of Foster Creek (top graph), and at the outlet of the Upper Clear Creek subwatershed (bottom graph). Shown are estimated natural stream flows for average and dry years (50% and 80% exceedance flows); and the sum of consumptive uses (CU) and water storage. Data source: OWRD (2002c).

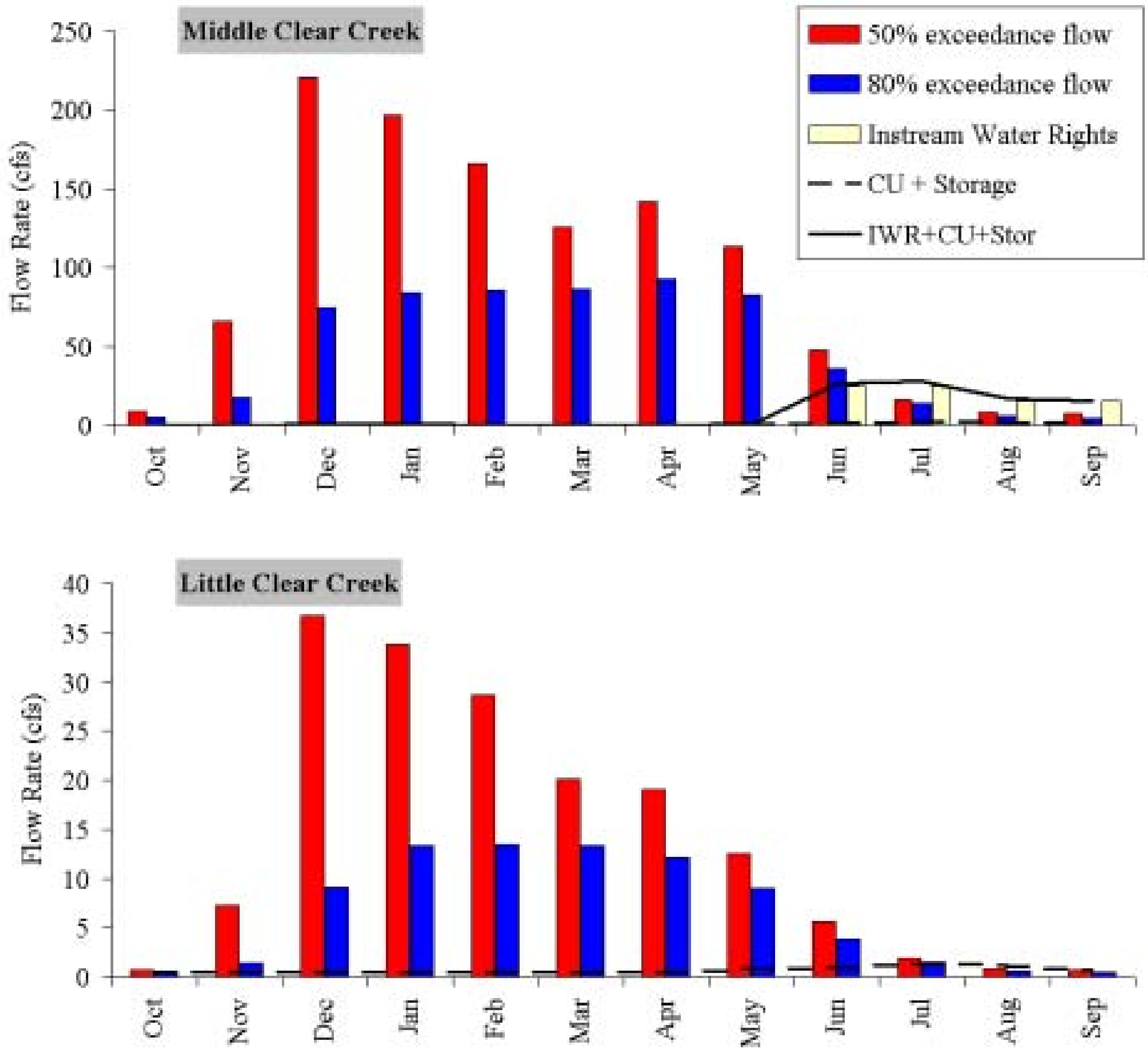

Figure 4-10, Estimated net effect of water withdrawals on monthly stream flows at the outlets of the Middle Clear Creek (top graph) and Little Clear Creek (bottom graph) subwatersheds. Shown are estimated natural stream flows for average and dry years (50% and 80% exceedance flows); the sum of consumptive uses (CU) and water storage; instream water rights; and the sum of instream water rights (IWR), consumptive uses (CU) and storage (STOR). Data source: OWRD (2002c).

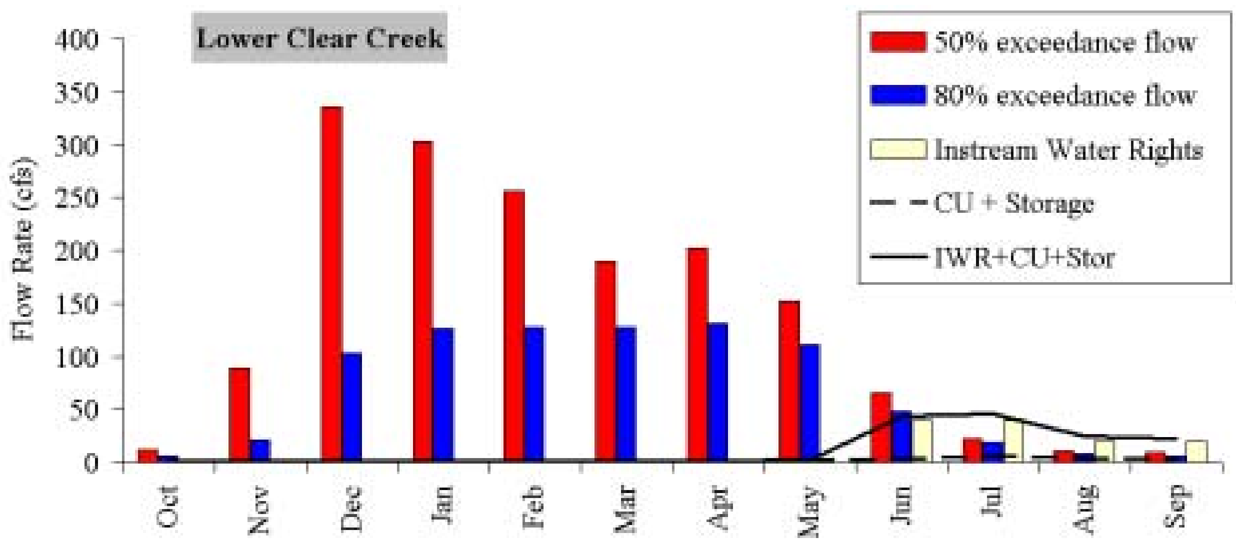

Figure 4-11. Estimated net effect of water withdrawals on monthly stream flows at the mouth of Clear Creek. Shown are estimated natural stream flows for average and dry years (50% and 80% exceedance flows); the sum of consumptive uses (CU) and water storage; instream water rights; and the sum of instream water rights (IWR), consumptive uses (CU) and storage (STOR). Data source: OWRD (2002c).

Figure 4-10 (bottom graph) shows the estimated net effect of water withdrawals on monthly stream flows at the mouth of Little Clear Creek. These estimates indicate that consumptive water use plus storage exceeds the estimated volume of natural stream flow in the month August in average years (50% exceedance flows), and in the months of August – October in dry years (80% exceedance flows). In other words, if all of the water is withdrawn that is allowed under the existing water rights, there would be no flow remaining in the stream during these months. No instream water rights exist for Foster Creek.

Figure 4-11 shows the estimated net effect of water withdrawals on monthly stream flows at the outlet of the Lower Clear Creek subwatershed. These estimates indicate that consumptive water use plus storage does not exceed the estimated volume of natural stream flow in any month, either in average (50% exceedance flows) or dry (80% exceedance flows) years. However, when the instream water right is added to the sum of consumptive uses and storage there is insufficient flow to meet all uses in the months of July – September in either average or dry years. Based on these estimates it appears unlikely that instream flow rates would be attained during these months in most years.

4.4.3.2 Other Land Uses

Critical Question: Is there a probability that land uses in the basin have a significant effect on peak and/or low flows?

Very little data or studies are available that address the effects of other land uses on peak and/or low stream flows within the Clear and Foster Creek watersheds. The following narrative is broken into four parts. Section 4.4.3.2.1 provides background information on the primary ways that land use activities affect stream flows. An assessment of possible augmentation of rain-on-snow (ROS) peak flows due to vegetation removal is given in Section 4.4.3.2.2. A qualitative look at possible streamflow impacts due to wetland loss is provided in Section 4.4.3.2.3. And an evaluation of possible peak flow increase due to impervious area is presented in Section 4.4.3.2.4.

4.4.3.2.1 Background information on land use effects on stream flow

Figure 4-12 is a generalized diagram showing the primary interactions between land uses found in the Clear and Foster Creek watersheds and changes in peak, annual, and low stream flows. Note that Figure 4-12 does not include "top-level" land uses (e.g., Urbanization, Agriculture, Forest Management, etc.). The reason for this is that there is considerable overlap between top-level land uses and the underlying hydrologic processes that they affect. For example, both urbanization and agricultural practices have the ability to affect vegetation removal, soil erosion/mass wasting, wetland degradation, channel down cutting, dike/levee construction, soil compaction, and road development. This analyst believes that, rather than discussing impacts by top-level land uses, it is more appropriate to discuss land use impacts in terms of the underlying processes.

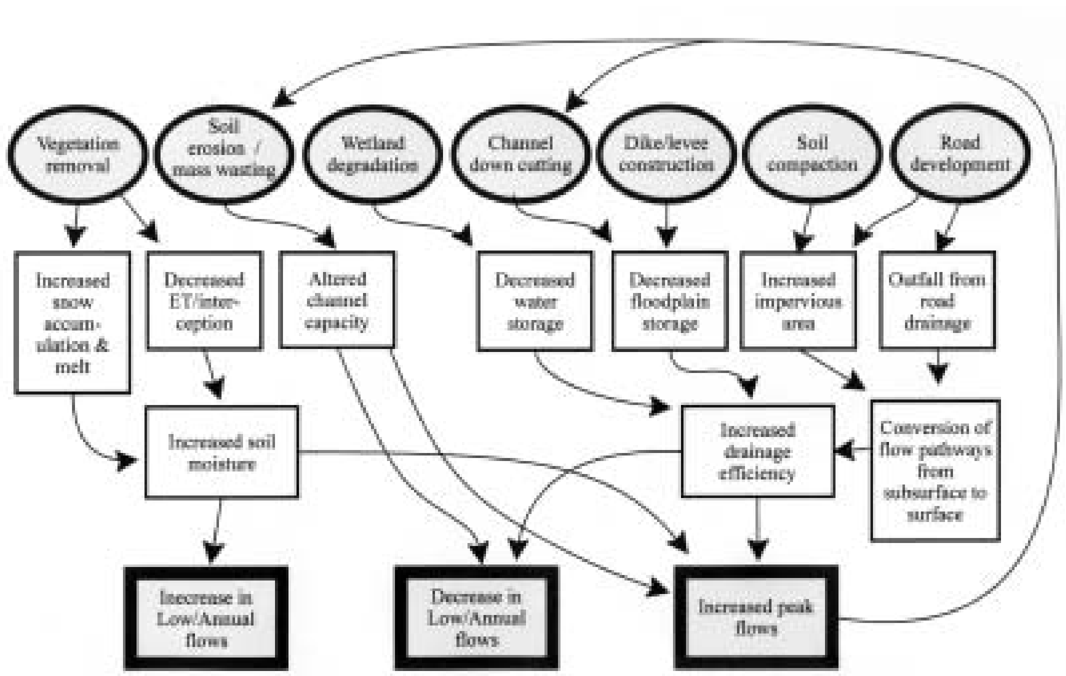

Figure 4-12. Generalized diagram of the primary interactions between land uses and changes in peak, annual, and low stream flows (adapted from Ziemer, 1998).

Vegetation Removal: Rain-on-snow (ROS) is the common term used to describe wintertime conditions when relatively warm wind and rain combine to produce rapid snowmelt (Coffin and Harr, 1992). ROS flood events may occur in areas having significant wintertime snow packs, and are independent of land use. Removal of the forest canopy can augment ROS peak flows by increasing snow accumulation in openings (Troendle, 1983; Bosch and Hewlett, 1982) and increasing the rate of snowmelt by increasing the effective wind speeds at the snowpack surface (Harr, 1981; Harr, 1986; Coffin and Harr, 1992). The extent to which forest removal may augment ROS peak flows is a function of the amount of harvesting within the elevation range that defines the ROS zone. At low elevations (below the ROS zone) winter temperatures are generally too warm to allow for significant snow accumulation, and at higher elevations wintertime precipitation generally falls as snow. As discussed in section 4.4.1 above, ROS appears to be an important process in peak flow generation within the Clear Creek watershed; consequently the potential exists for peak flows to be augmented by vegetation removal.

Vegetation can intercept a portion of the precipitation falling on a watershed, a further portion of which is evaporated back to the atmosphere during or after a storm event, thereby reducing the net precipitation reaching the soil (Dunne and Leopold, 1978). Evapotranspiration by vegetation removes moisture from the soil profile and returns it to the atmosphere (Dunne and Leopold, 1978). Increases in peak flows have been observed in some situations following harvest of trees, which are presumed to be the result of loss of canopy interception and evapotranspiration (Ziemer, 1998). Several studies (Harr et al., 1979; Helvey, 1980; Harr and Krygier, 1972; Bosch and Hewlett, 1982; Harr, 1983; Hetherington, 1987; Kattelmann et al., 1983; Troendle, 1983; and Keppeler, 1998) have shown that water yield increases throughout the year, with the largest relative increases occurring during the summer and early fall months following logging. These studies have reported increases in summer flows ranging from 15 to 148 %.

An assessment of possible augmentation of rain-on-snow (ROS) peak flows due to vegetation removal is given in Section 4.4.3.2.2 below.

Soil erosion and mass wasting: Soil erosion and mass wasting can increase quantities of sediments transported in stream systems. Deposition of both coarse and fine sediments in stream channels can result in a decrease in channel conveyance capacity, leading to an effective increase in frequency of flooding (Dunne and Leopold, 1978). In addition to the effects on peak flows, increases in aggradation of coarse sediments can increase the proportion of streamflow that travels subsurface, resulting in a reduction of effective summer low flows. Furthermore, as shown in Figure 4-12, increased peak flows can further exacerbate sedimentation problems through increased bank erosion and mass wasting.

Wetland degradation: Wetlands have the ability to intercept and store storm runoff, thereby reducing peak flows (Mitsch and Gosselink, 1986). This water is released over time and may be important to augment summertime low flows. A qualitative look at possible streamflow impacts due to wetland loss is provided in Section 4.4.3.2.3.

Channel down cutting and channelization: Channel down cutting and channelization have the same effect on the stream system; decreasing the amount of water that can be stored in channel banks and the floodplain. The difference between the two processes are that channel down cutting occurs without direct human assistance in response to changes in water volume and sediment loads, whereas channelization occurs through conscious human design through the construction of dikes and levees. Potential disadvantages to dikes and levees include loss of floodwater storage within the floodplain, which can result in higher downstream peak flows, reduced groundwater recharge, and subsequently lower summertime base flows.

Soil compaction: Soil compaction can increase the amount of impervious area occurring in a watershed. Increases in the amount of impervious area, result in increased peak flow magnitudes by eliminating or reducing infiltration of precipitation, thereby shortening the travel time to stream channels (Dunne and Leopold, 1978). In addition to the effects on peak flows, increases in impervious area also reduce summer low flows by reduction of groundwater recharge (Dunne and Leopold, 1978). May and others (1997) suggest that impairment begins when percent total impervious area in a watershed reaches 10%. And an evaluation of possible peak flow increase due to impervious area is presented in Section 4.4.3.2.4.

Outfall from road drainage In addition to increasing soil compaction, road networks have the potential to affect watershed hydrology by changing the pathways by which water moves through the watershed. Road networks affect flow routing by interception of subsurface flow at the road cutslope (Megahan, 1972; Burroughs et al., 1972; King and Tennyson, 1984; Best et al., 1995) and through a reduction in road-surface infiltration rates resulting in overland flow (Ziemer, 1998). The net result may be that surface runoff is routed more quickly to the stream system if the road drainage network is well-connected with the stream channel network.

4.4.3.2.2 Vegetation removal

Overview

Possible augmentation of rain-on-snow (ROS) peak flows were assessed using methods outlined in the *Washington Forest Practices Board Manual: Standard Methodology for Conducting Watershed Analyses* (WFPB, 1997). Baseline flood discharge estimates (Table 4-1) were related to 24-hour precipitation events having the same recurrence interval to produce subwatershed-specific equations of peak flow as a function of 24-hour precipitation[9] (Table 4-2). The baseline flood discharge estimates were assumed to represent the Historic condition against which increases due to vegetation removal were compared. Water available for runoff (WAR), the sum of precipitation and snow melt, was calculated for each subwatershed under two canopy coverage scenarios (historical and current conditions), for average storm conditions corresponding with the 2, 5, 10, 25, 50, and 100 year recurrence interval (Tr) storm events. Finally, the calculated WAR values were used in the subwatershed-specific peak flow equations to predict increases in peak flow magnitudes given current vegetation conditions.

[9] The underlying assumption here is that it is appropriate to relate peak flows to 24-hour precipitation events having the same recurrence interval.

Table 4-2. Regression equations for peak discharge (Q) as a function of 24-hr. precipitation (P). Discharge in cfs, precipitation in inches. All r^2 values > 0.99.

Subwatershed	Equation
Foster Creek	Q = 141.05P - 239.11
Upper Clear Creek	Q = 887.37P – 1756
Middle Clear Creek	Q = 1430P – 2878
Little Clear Creek	Q = 353.22P - 681.32
Lower Clear Creek	Q = 2181.5P - 4218.4

Hydrologic Maturity

Estimates of historic and current vegetation canopy conditions are needed in order to assign hydrologic maturity ratings (Table 4-3) within the subwatersheds. Historic hydrologic maturity was estimated using EPA Level IV ecoregions found within the Clear and Foster Creek watersheds Figure 1-15. Most of the landscape within ecoregion 3c (Prairie Terraces), is estimated to have been historically dominated by prairies and oak savannas with less than 30% crown closure (WPN, 2001). Consequently, historic hydrologic maturity was rated as "intermediate" within ecoregion 3c (Figure 4-13). All remaining ecoregions were estimated to have been historically dominated by dense conifer stands; consequently, historic hydrologic maturity within all remaining areas was rated as "mature" (Figure 4-13).

Table 4-3. Hydrologic maturity ratings. From WFPB (1997).

Hydrologic maturity rating	Criteria
Mature	>70% forest crown closure AND <75% of the crown in hardwoods or shrubs
Intermediate	10%-70% forest crown closure AND <75% of the crown in hardwoods or shrubs
Immature	<10% forest crown closure AND/OR <75% of the crown in hardwoods or shrubs

Current hydrologic maturity was estimated using information from the Western Oregon Digital Image Project (WODIP), available from the Bureau of Land Management (BLM, 2000). The WODIP data was particularly useful because dominant vegetation type (i.e., conifer, hardwoods, mixed) was identified, and an estimate of canopy closure was provided. The WODIP data is based on 1993 imagery; consequently it is representative of conditions nine years ago. Current hydrologic maturity was rated using the criteria given in Table 4-3, and is also shown in Figure 4-13.

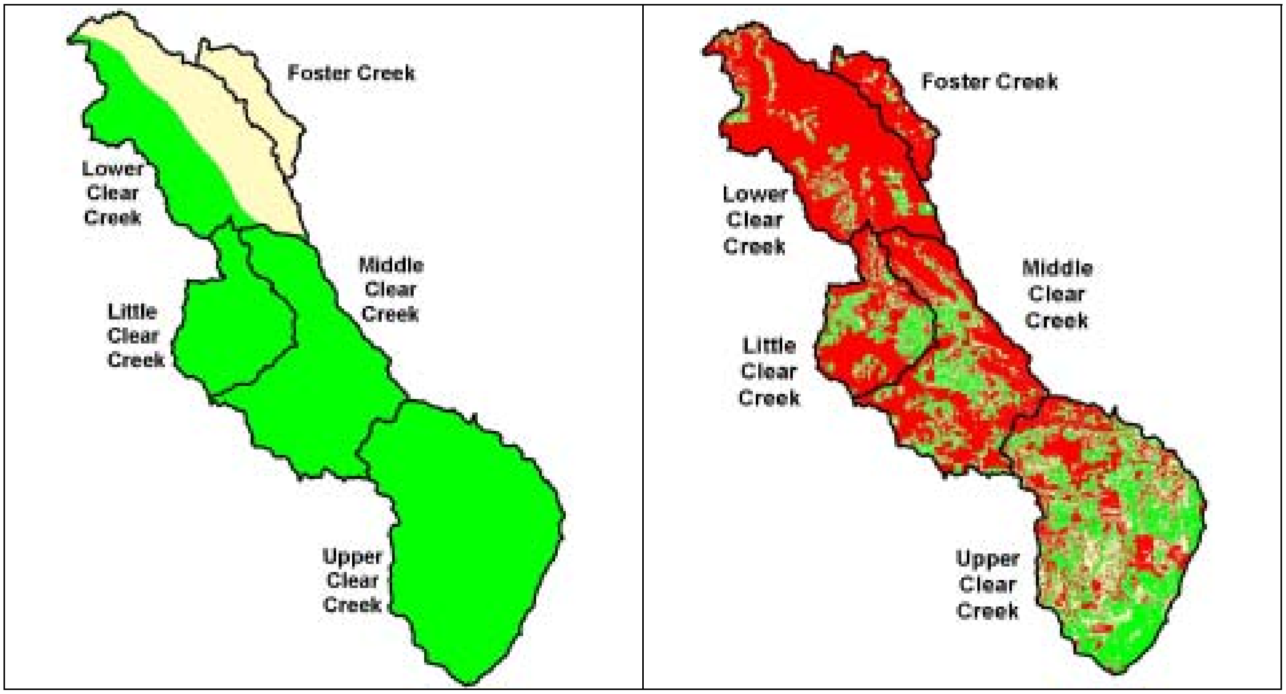

Figure 4-13. Estimated historic (left) and current (right) hydrologic maturity within the Clear and Foster Creek watersheds. Data sources: EPA (2001), BLM (2000). Green – Mature, Tan – Intermediate, Red – Immature.

Climatic Input Data

Estimates of several climatic parameters are needed to generate the estimates of water available for runoff (WAR) under historic and current conditions. Estimation of these parameters is based on elevation. To simplify the assessment, the subwatersheds were broken into areas by 500-foot elevation band[10]. Climatic data was estimated at the midpoint elevation of each band.

Snow accumulation was estimated for the midpoint of each 500-foot elevation band using the January 1st regression equation for the Lewis-Cowlitz region in southwest Washington (WFPB, 1997). Comparison of predicted results with data available from the Peavine Ridge SNOTEL site (Figure 1-9) suggest that this equation is reasonable to use in the vicinity of the Clear and Foster Creek watersheds. Snow accumulation values were adjusted by hydrologic maturity classes using the ratios given in Table 4-4.

[10] The first elevation band was from 79' (the lowest point in the assessment area) to 300'. The remaining bands were in 500' intervals (e.g., 300'-800', 800'-1,300', etc.). The reason for this was to capture the ROS zone within two elevation bands (i.e., 1,800'-2,300' and 2,300'-2,800')

Table 4-4. Snow water equivalent ratios (R) by elevation and hydrologic maturity rating. From WFPB (1997).

Elevation zone	Elevation range (ft)	Immature	Intermediate	Mature
Rain-dominated	<1,800	2.5	1.75	1
Rain-on-snow	1,800 - 2,800	2	1.5	1
Snow-dominated	> 2,800	1.5	1.25	1

Storm temperature was estimated for the midpoint of each 500-foot elevation band using the storm temperature equation for Western Washington (WFPB, 1997):

$T = 10 - (0.006\ E)$

Where T = temperature (degrees C), and E = elevation (in meters)

Wind speed was estimated using the Portland Airport frequency curve (WFPB, 1997). A baseline storm wind speed of 7.8 knots (4 m/s) was used for average conditions. Baseline storm wind speeds were adjusted for canopy conditions using the following canopy density factors (WFPB, 1997): Immature - 0.05; Intermediate - 0.4; Mature - 0.85

Estimated increases in peak flows

Water available for runoff (WAR) was calculated for each hydrologic maturity type polygon in each 500-foot elevation zone, and an area-weighted WAR was then calculated for each subwatershed[11]. Water available for runoff values was substituted into the equations given in Table 4-2 to estimate peak discharge by HAU for each of the canopy cover scenarios.

The estimated percent increase in peak flows under current hydrologic maturity conditions is shown in Figure 4-14. Predicted increases due to vegetation removal are greatest in the smaller magnitude, higher frequency flood events (i.e., the peak flow having a 2-year recurrence interval) due to the greater role that snowmelt plays in these smaller events (i.e., in larger-magnitude events rainfall makes up a much larger proportion of the total water available for runoff. Predicted increases for the 2-year event range from no increase in the Foster Creek subwatershed (low elevation, low amounts of snow accumulation), to a 29% increase in the Little Clear Creek subwatershed (Figure 4-14). Predicted increases for the 100-year event range from no increase in the Foster Creek subwatershed, to an 11% increase in the Little Clear Creek subwatershed (Figure 4-14).

The results presented in Figure 4-14 are heavily-influenced by the large proportion of non-forest areas that currently exist within the subwatersheds. In a practical sense, these areas have been devoid of forest vegetation for a long period of time (~100 years or more), and stream channels have most likely adjusted to this permanent increase in peak flow magnitude. A more useful approach may be to consider the peak flow increases associated with just the forest lands.

[11] When calculating WAR the entire upstream drainage area was used. For example, results given for the Middle Clear Creek subwatershed include both the Middle and Upper Clear Creek subwatersheds.

Hydrologic maturity on forest lands changes much more frequently, as stands are constantly being harvested, replanted, and are in a state of re-growth. To better-understand the impacts that forest harvest alone may be having, the model was rerun using the assumption that all non-forest areas are in a hydrologically mature state. Figure 4-15 shows the estimated percent increase in peak flows assuming that all non-forested areas are hydrologically mature. The predicted increases due to vegetation removal have the same pattern as in the initial results (i.e., greatest increases in the smaller magnitude, higher frequency flood events), however the overall increases are much lower. Predicted increases for the 2-year event range from no increase in the Foster Creek subwatershed to a 9% increase in the Upper Clear Creek subwatershed (Figure 4-15). Predicted increases for the 100-year event range from no increase in the Foster Creek subwatershed, to a 4% increase in the Upper Clear Creek subwatershed (Figure 4-15). The *Standard Methodology* (WFPB, 1997) rates peak flow increases of 10% or less as having a low probability of causing significant impacts to fisheries resources.

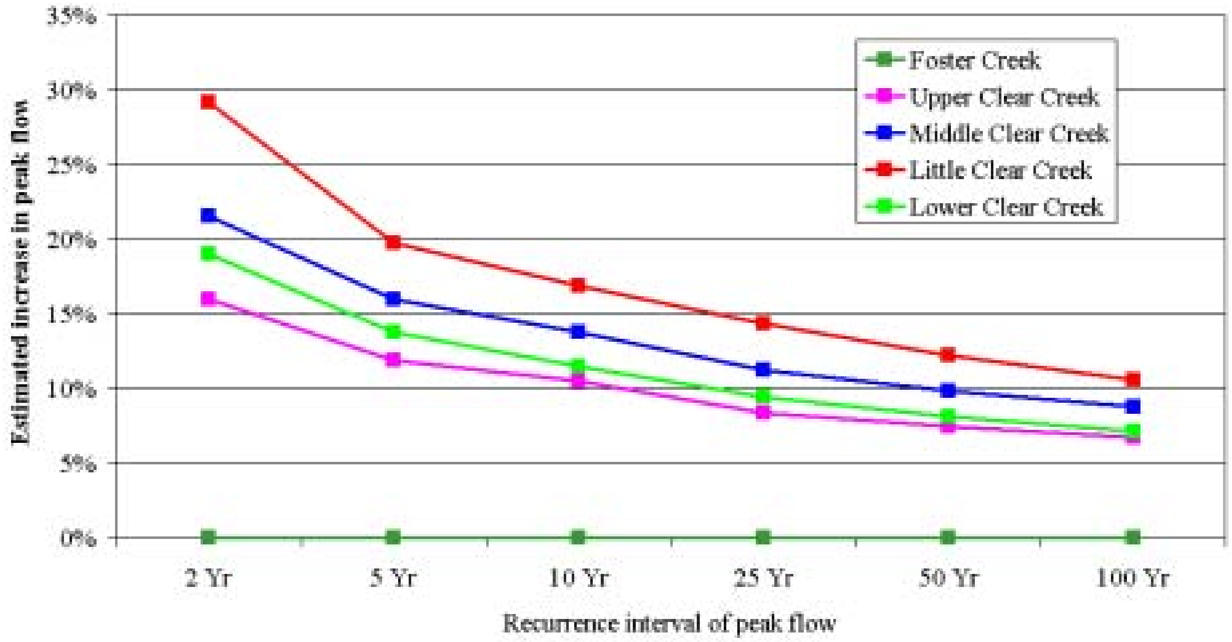

Figure 4-14. Estimated percent increase in peak flows under current hydrologic maturity conditions within the Clear and Foster Creek watersheds.

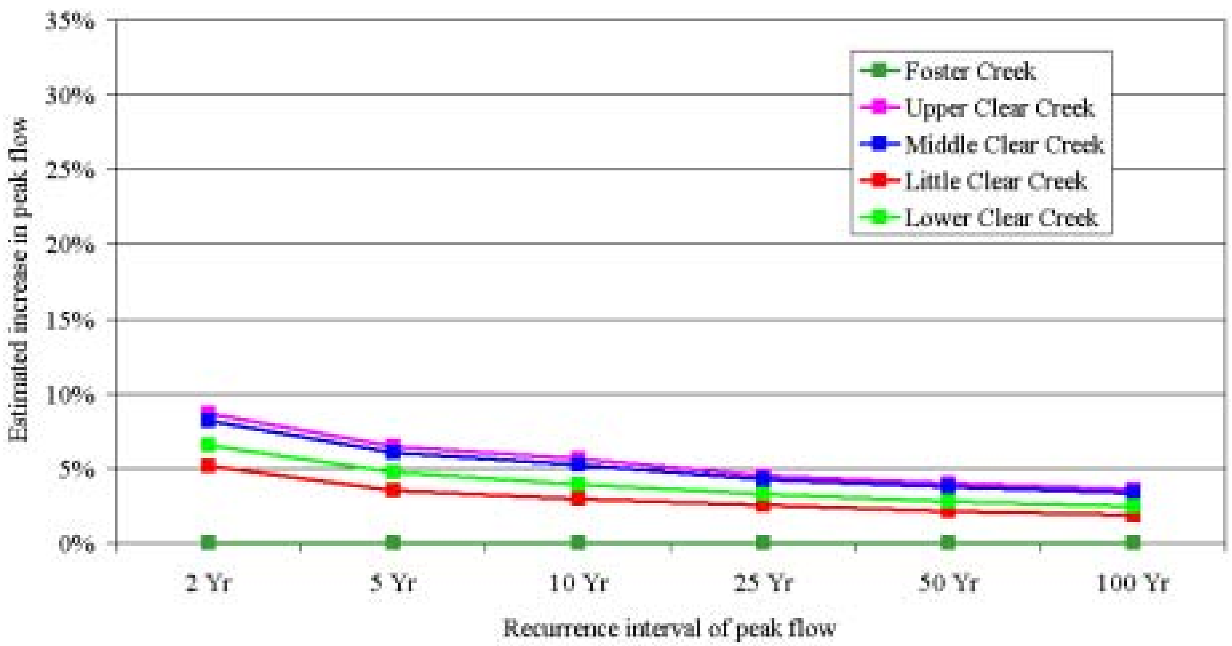

Figure 4-15. Estimated percent increase in peak flows under current hydrologic maturity conditions within the Clear and Foster Creek watersheds, assuming that all non-forested areas are hydrologically mature.

4.4.3.2.3 Wetland Loss

The purpose of this portion of the assessment is to identify those subwatersheds where wetland loss may have a significant impact on current stream flows. No quantitative assessment was performed.

One approach to estimating the area historically occupied by wetlands is by comparing present-day wetlands to the area within the watershed that is classified as having hydric soils. Hydric soils are soils that are, or have been, saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part. If soils classified as hydric do not currently support wetlands they may be areas where wetlands formerly were located.

The NRCS soil survey of the Clackamas area (NRCS, 1985; 1998) identifies hydric soils within the Borges Silty Clay Loam, Concord Silt Loam, Cove Silty Clay Loam, Dayton Silt Loam, Delena Silt Loam, Huberly Silt Loam, Wapato Silt Loam, and Wapato Silty Clay Loam soil series. Not all of the area within these mapping units contains hydric soils, and not all of the hydric soils necessarily supported wetlands historically. However, this information provides us with an approximation of the extent that may have been occupied by wetlands historically.

Current wetland locations are available from the National Wetland Inventory (NWI) produced by the U.S. Fish and Wildlife Service (USFWS, 1983; 2001). The area currently occupied by wetlands, and the area of hydric soils within the Clear and Foster Creek watersheds, is shown in Figure 4-16. Figure 4-17 provides a summary of the potential area of hydric soils compared to the area currently occupied by wetlands.

Overall the Clear and Foster Creek watersheds have approximately 2,710 acres within soil mapping units that contain hydric soils and 360 acres currently occupied by wetlands (Figure 4-17). If all of these mapping units historically contained wetlands this would indicate that wetlands currently occupy only 13% of the area that they occupied historically. Significant wetland loss may have occurred in the Foster Creek, Lower Clear Creek, and Middle Clear Creek subwatersheds, where current wetland area makes up only 1%, 10%, and 21% respectively of the potential area of hydric soils. The Upper Clear Creek and Middle Clear Creek currently have a greater or approximately equal area in wetlands as in hydric soils.

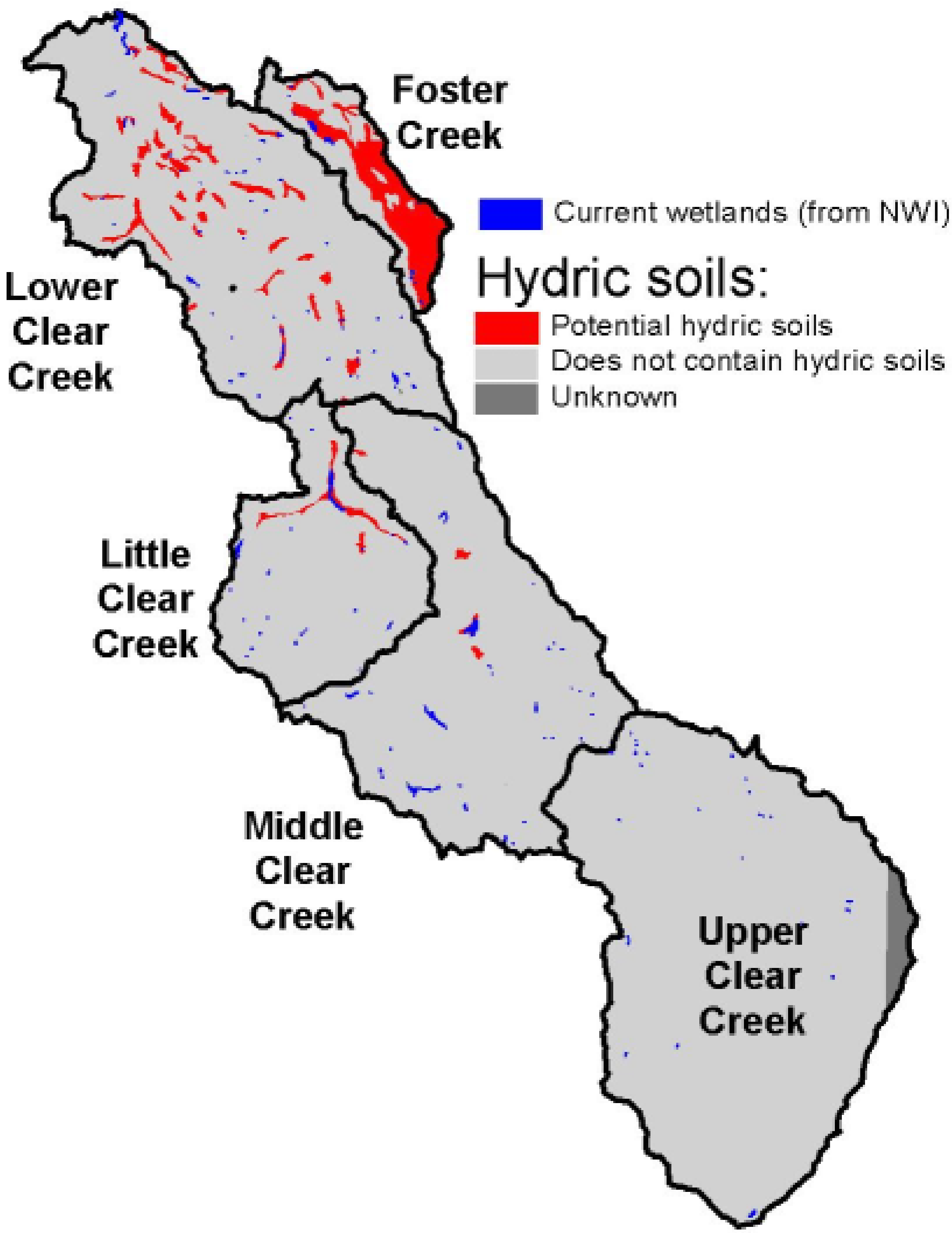

Figure 4-16. Current wetland locations, and soil mapping units that contain hydric soils within the Clear and Foster Creek watersheds. Data sources: NRCS (1998), (USFWS, 1983; 2001).

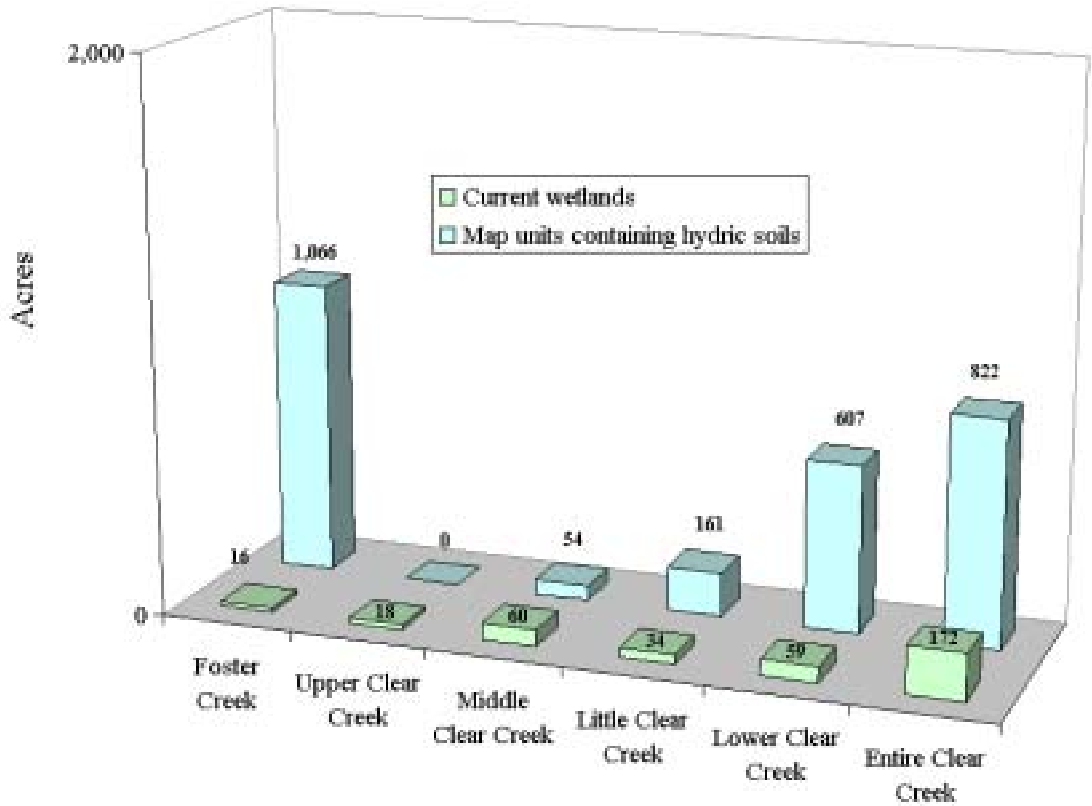

Figure 4-17. Comparison of area occupied by soil mapping units that contain hydric soils and area currently occupied by wetlands.

4.4.3.2.4 Impervious area

Increases in the amount of impervious area in a watershed, result in increased peak flow magnitudes by eliminating or reducing infiltration of precipitation, thereby shortening the travel time to stream channels (Dunne and Leopold, 1978). In addition to the effects on peak flows, increases in impervious area also reduce summer low flows by reduction of groundwater recharge (Dunne and Leopold, 1978). May and others (1997), in a summary of several previous studies (Klein, 1979; Steedman, 1988; Schueler, 1994; Booth and Reinelt, 1993), suggest that impairment begins when percent total impervious area (%TIA) in a watershed reaches 10%. May and others (1997) recommend that for Puget Sound lowland streams, the level of imperviousness should be limited to the <5%-10% TIA, unless extensive riparian buffers are in place.

May and others (1997) developed a relationship between % TIA and road density (expressed in miles of road/mi^2 watershed area). Watershed %TIA of 5% and 10% equates to a road density of 4.2 and 5.5 mile/ mi^2 respectively. Road density was calculated for each subwatershed in the Clear and Foster Creek watersheds (Table 4-5) using road data from the BLM (2002a).

Table 4-5. Road density by subwatershed. Data Source: BLM (2002a).

Subwatershed	Road length (miles)	Subbasin area (mi^2)	Road density ($miles/mi^2$)
Foster Creek	11.5	3.5	3.3
Upper Clear Creek	139.7	27.1	5.2
Middle Clear Creek	70.6	17.2	4.1
Little Clear Creek	36.0	9.1	4.0
Lower Clear Creek	86.9	19.3	4.5

Road densities among the subwatersheds range from 3.3 $miles/mi^2$ in the Foster Creek subwatershed to 5.2 $miles/mi^2$ in Upper Clear Creek (Table 4-5). Based on the indices discussed above, TIA may be adversely impacting hydrologic processes in the Upper and Lower Clear Creek subwatersheds. However, these results should not be considered conclusive – the relationship between road density and TIA was developed for urbanized areas where sources of imperviousness (i.e., parking lots, structures, etc.) are highly correlated with road density. The high density of roads in the upper Clear Creek watershed are associated with logging activities, therefore the same relationship may not be valid. Further modeling would need to be performed to determine if increases in impervious area are significant.

4.5 INFORMATION GAPS AND MONITORING NEEDS

The following are recommendations that address the most significant information gaps affecting the assessment presented above:

- Establish continuous stream flow monitoring locations within the subwatersheds

Efforts to characterize stream flow were hampered by the lack of continuous stream flow data from within the watersheds. Continuous stream flow data would improve understanding of peak flow history, allow for better estimation of natural stream flows, provide calibration data for any future modeling activity, and allow for better understanding of the effects of water use within the subwatersheds. Reinstalling gages at the locations of the four former OWRD gages that were located within the Clear Creek watershed (Figure 1-11, and Table 1-7) would build upon existing data sets, and would adequately represent streamflow at the outlets of all of the Clear Creek subwatersheds. No continuous stream flow data are available for the Foster Creek subwatershed. Installation of a stream gage at or near the mouth of Foster Creek is also recommended.

- Support efforts of the OWRD to improve the Water Rights Information System (WRIS).

The OWRD is considering changes to their Water Rights Information System (WRIS) that will allow estimation of instantaneous withdrawals associated with water rights. This information would allow a better understanding of the impacts of withdrawals on stream flows. It is recommended that the BRAG support these proposed improvements to the system. Furthermore, the BRAG should encourage and support efforts of the OWRD to improve the WRIS to identify the current status of all water rights within the watershed, and the actual amount and timing of use.

- Investigate historical extent of wetlands within the watershed.

A comparison of current wetland area to watershed area containing hydric soils indicates that wetlands may have historically occupied a much greater portion of the watershed than they currently do. Further analysis is needed to define the historic extent of wetland area within the watershed.

- Perform functional assessment of wetlands within the watershed.

More information on wetland condition and function is needed in order to identify and prioritize any wetland enhancement efforts

- Model possible impacts to watershed hydrology associated with wetland loss and increase in impervious area.

It is recommended that a modeling tool such as the Distributed Hydrology-Soil-Vegetation Model (DHSVM) developed by the University of Washington and Battelle Pacific Northwest Research Labs be used in any further hydrologic modeling. Such a modeling effort should include an evaluation of all items included in Figure 4-12 (Generalized diagram of the primary interactions between land uses and changes in stream flows) of this report.

4.6 RECOMMENDATIONS AND POSSIBLE COUNCIL ACTIONS

- Identify and implement opportunities to improve summertime stream flows

Despite the uncertainty in the magnitude of water use effects on low stream flows the BRAG may wish to identify and implement opportunities to improve summertime stream flows through increased water use efficiency, transfer of water rights to instream uses, and other voluntary actions by water right holders. Actions should be focused on those subwatersheds where the sum of consumptive use, storage, and instream water rights exceeds the estimated volumes of natural stream flow during the certain summer months. Voluntary measures such as an increase in the efficiency of water distribution and application to irrigated areas will help improve summertime flow conditions. Further reductions in withdrawals through voluntary transfer of water rights (either temporarily or permanently) to organizations such as the Oregon Water Trust should also be considered.

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5.0 RIPARIAN / WETLAND HABITAT CONDITIONS

5.1 INTRODUCTION

This section of the watershed analysis report presents the results of the riparian and wetlands assessment. The assessment uses existing information to summarize what is known about current riparian and wetlands conditions in the Clear Creek and Foster Creek watersheds. The results are followed by recommendations on future monitoring needs to fill data gaps and steps that can be taken to improve riparian and wetland conditions.

5.2 CRITICAL QUESTIONS

The Riparian/Wetlands assessment methodology outlined in the Oregon Watershed Assessment Manual (WPN, 1999) is designed around a series of critical questions that form the basis of the assessment. These critical questions are:

Question 5-1: What are the current conditions of riparian areas in the watershed?

Question 5-2: How do the current conditions compare to those potentially present for this ecoregion?

Question 5-3: How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/ enhancement opportunities might be?

Question 5-4: Where are the wetlands in this watershed?

Question 5-5: What are the general characteristics of wetlands within the watershed?

Question 5-6: What opportunities exist to restore wetlands in the watershed?

The critical questions were discussed at meetings with the Clackamas Basin Research and Advisory Group and with the Clackamas River Basin Council. The outcome of the meetings was a clarification on riparian and wetlands issues of concern in the basin. These issues include:

a. Identification of degraded riparian and wetland conditions (relative to potential conditions) and prioritization of enhancement efforts.

b. Identification and prioritization of high quality riparian and wetland areas for protection.

5.3 METHODS

5.3.1 Riparian Assessment Methods

The purpose of this portion of the assessment was to evaluate current riparian vegetation[12] conditions for their ability to provide recruitment[13] of large woody material[14] (LWM) and stream shading. The assessment was conducted using the methodology outlined in the OWEB manual (WPN, 1999).

Three sources of information on current riparian conditions were available for the study area. The Upper Clear Creek Watershed Analysis, conducted by the Bureau of Land Management (BLM, 1995) classified riparian areas in the entire Upper Clear Creek subwatershed into general vegetation classes (e.g., agricultural lands, hardwood forest, conifer <40 yrs old, etc), and identified stream shading by five categories (e.g., 0-20% shade, 20-40%, etc). Unfortunately, the BLM information is not available in digital format (W. Barney, BLM, pers. comm., 4/2/2002), and the hardcopy maps included in the report were of too small of a resolution to use in this assessment. The second source of information available for the study area consists of current (as of 1993) vegetation data for the Clear and Foster Creek watersheds in a 30-meter grid format (ONHP, 2001). The ONHP data are classified by primary cover type (e.g., conifer-closed, deciduous-open, emergent wetland, industrial, etc.). Unfortunately, a preliminary analysis of the ONHP data showed that it is not of a high enough resolution to use in mapping current riparian conditions. The third source of information available for the study area consists of stereo aerial photographs[15] . Color stereo aerial photos at 1:12,000 scale, taken in 1998 and available from the BLM, were used for the southern portion of the assessment area (roughly south of Redland and Logan), while 1:10,200 scale color photos, also taken in 1998 and available from Spencer B. Gross, were used for the remaining portion of the assessment area

Current riparian conditions in the watersheds were evaluated using the color stereo aerial photographs described above. The spatial distribution of historic vegetation was estimated using USEPA level IV ecoregion maps (EPA, 2001), and descriptions of potential riparian conditions were taken from WPN (2001).

A limited amount of field-verification was performed during the months of March and April, 2002. Field-verification was limited to the publicly-accessible portions of the watersheds, and was used to verify aerial photo interpretations of vegetation type and size. All known streams in the subwatersheds were included in this assessment, totaling approximately 140 miles in length. Of the total length of streams included, approximately 60% were identified by the Oregon Department of Forestry as having fish use.

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[12] Riparian vegetation refers to the vegetation found on stream banks and adjoining floodplain

[13] Recruitment, in the context of riparian function, refers to the natural addition over time of new large wood pieces to a stream channel from riparian forests. It is the physical movement of large wood from stream-side forest into the stream channel

[14] Large woody material, as it is used in this context, refers to pieces of wood (either tree trunks, stumps, or large branches) important in the formation of channel shape, and consequently, in creating and enhancing fish habitat.

[15] Stereo aerial photographs refer to high-resolution aerial photographs that are taken from an airplane along a straight flight line. When sequential pairs are viewed with a device called a stereoscope the land features appear three-dimensionally

5.3.1.1 Riparian condition units (RCUs)

The fundamental mapping unit, for which all information in this portion of the assessment was collected, is the Riparian Condition Unit or RCU. An RCU is a portion of the riparian area for which riparian vegetation type, size, and density remain approximately the same. When riparian characteristics change a new RCU is defined. Each RCU occurs on only one side of the stream (i.e., riparian areas on the opposite side of the stream are separate RCUs).

Riparian characteristics typically change with distance from the stream as soil moisture and stream-related disturbance changes. Typically, the immediate streamside area will contain hardwoods or shrub species, while areas farther away from the stream will be dominated by upland vegetation. In recognition of these differences in vegetation, two data collection zones were defined moving laterally away from the edge of the stream:

Riparian area #1 (RA1) was defined from the edge of the stream channel out to the approximate limit of the streams immediate influence. The lateral distance of RA1 varied from a 25 feet to 75 feet depending on the characteristics of the stream (see examples, Figure 5-1). The widths of RA1 were defined based on the channel habitat type (CHT) defined for the stream segment by the channel analyst (see section 3.0 for further discussions on CHTs). The width of RA1 was 25 feet along channels that were classified within the "constrained" group of CHTs. These included channels classified as ditched/channelized streams (D), Low gradient confined (LC), Moderate gradient confined (MC), Moderate gradient headwater (MH), Moderately steep narrow valley (MV), Steep narrow valley (SV), and Very steep headwater (VH). The width of RA1 was 50 feet along channels that were classified within the "semi-constrained" group of CHTs. These included channels classified as Low gradient moderately confined (LM) and moderate gradient moderately confined (MM). The width of RA1 was 75 feet along channels that were classified within the "unconstrained" group of CHTs. These included channels classified as low gradient small, medium, or large floodplain (FP1, FP2, or FP3).

A second mapping unit, riparian area #2 (RA2), was defined from the outer edge of RA1 to a distance of 100 feet from the edge of the stream channel (see examples, Figure 5-1). The purpose of including this additional riparian area was to account for additional recruitment that may come from as far away as 100 feet from the stream edge[16]. Consequently, the width of RA2 also varied depending on the CHT defined for the stream segment. The width of RA2 was 75 feet along channels that were classified within the "constrained" group of CHTs, 50 feet along channels that were classified within the "semi-constrained" group of CHTs, and 25 feet along channels that were classified within the "unconstrained" group of CHTs.

[16] Although recruitment has the potential to come from as far away from the stream as the site potential tree height, the majority of functional wood is recruited within 100 feet (horizontal distance) or less of the stream's edge (McDade et al. 1990).

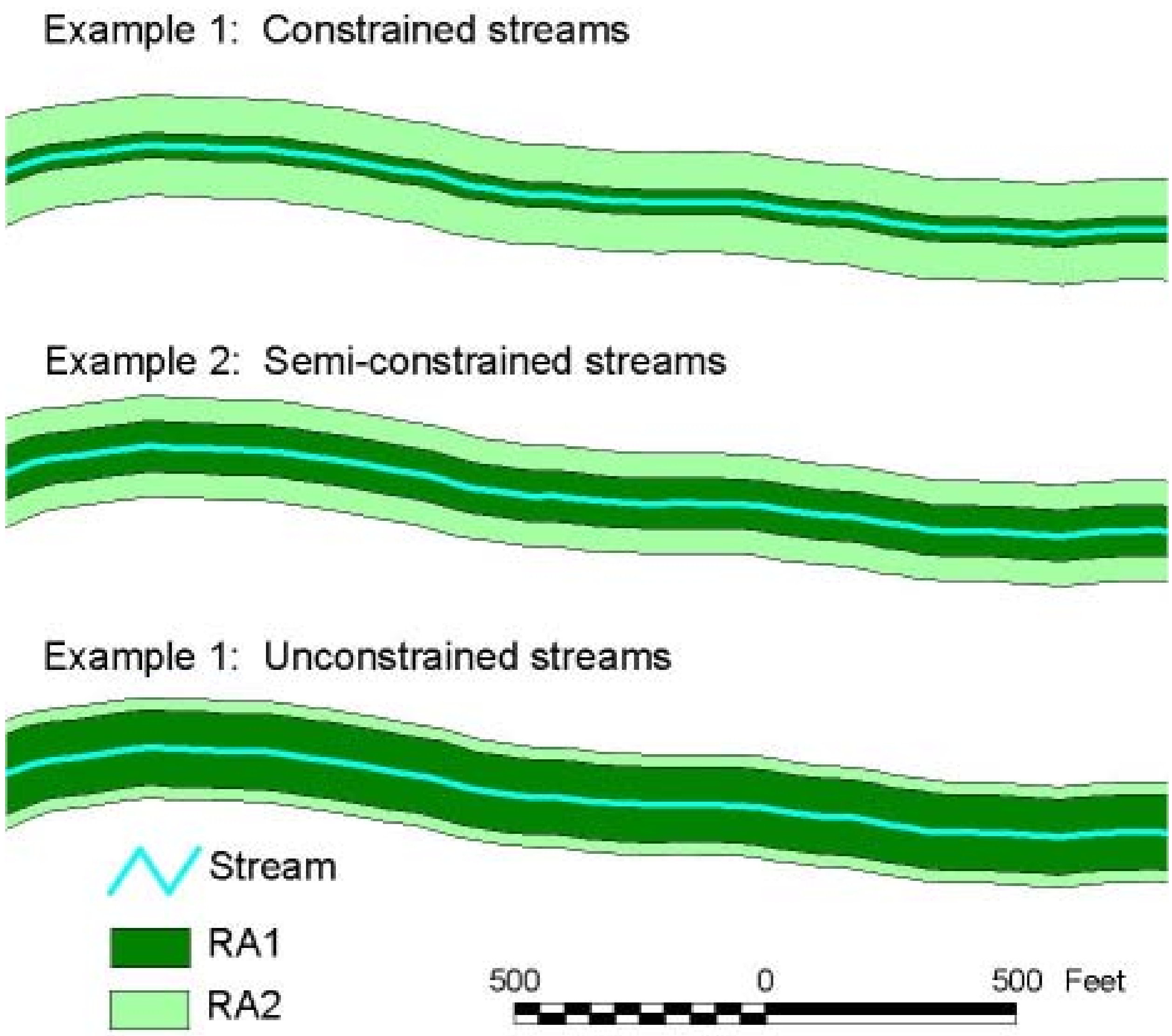

Figure 5-1. Examples illustrating riparian condition units (RCUs).

Information for each RCU was mapped directly in ArcView GIS, using USGS orthophotos as a backdrop to properly place the RCU location. RCUs were mapped within ArcView as polygon units. The following information was collected for each RCU and is included in the attribute table of the GIS coverage:

- **ID number**: Unique number assigned to each RCU.

- **Stream Bank**: The stream bank that each RCU lies on: "R" for right bank looking downstream or "L" for left bank looking downstream

- **Stream**: Name of the stream segment (e.g., "Little Cedar Creek")

- **Subwatershed**: Subwatershed that the channel segment falls within.

- **Ecoregion**: EPA level IV ecoregion (see section 1.2.7 for a discussion of ecoregions) that the stream segment falls within.

- **CHT**: Channel habitat type of the stream segment, as defined by the channel analyst.

- **Fish**: Presence or absence of fish[17] within the stream adjacent to the RCU

- **RA1 Width**: Width (horizontal distance) of RA1 (for riparian area #1 as described above) measured perpendicular to the stream as estimated from aerial photographs.

- **RA1 Code**: Vegetation characteristics within RA1 were noted using a three-letter code that describes vegetation type (first letter), vegetation size (second letter), and vegetation density (third letter). The choices are given in

- Table 5-1. For example, "CSD" would mean a riparian stand that is predominantly conifer, small in size (i.e., 4-12 inch average stand diameter at breast height), and dense. Note that size and density only apply to forested stands.

- **RA2 Code**: Same as previous, but for RA2 (i.e., riparian area #2 as described above).

- **Source of limitation to riparian forest development**: The primary, secondary (if any), and tertiary (if any) source(s) of limitation to riparian forest development was estimated from aerial photographs. The sources identified within the Clear and Foster Creek watersheds included agricultural operations, residential development, infrastructure (roads, power lines, etc.), logging, and site conditions (e.g., wetland conditions).

- **Notes**: Additional notes were taken describing, to the extent possible from aerial photographs, other notable features within the RCU, such as dominant vegetation type (e.g., "cultivated fields"), disturbances (e.g., "recently logged"), or sources of permanent discontinuities (e.g., "roads").

[17] The initial determination of fish use was based on ODF stream maps. This information was modified in some areas by the fisheries analyst.

Table 5-1. Codes used to describe vegetation (from WPN, 1999).

Vegetation type code	
C	Mostly conifer trees (>70% of area)
H	Mostly hardwood trees (>70% of area)
M	Mixed conifer/hardwoods
B	Brush species
G	Grass/meadow
N	No riparian vegetation
Size class code	
R	Regeneration (<4-inch average diameter at breast height (DBH)
S	Small (4- to 12-inch average DBH)
M	Medium (>12- to 24-inch average DBH)
L	Large (>24-inch average DBH)
N	Non-forest (applies to vegetation Types B, G, and N)
Stand density code	
D	Dense (<1/3 ground exposed)
S	Sparse (>1/3 ground exposed)
N	Non-forest (applies to vegetation Types B, G, and N)

5.3.1.2 Shade mapping

Current shade conditions were mapped separately from the RCUs. Riparian shading was estimated from the aerial photographs using the criteria given in Table 5-2. Streams were broken into segments having similar riparian shading using the indicators of riparian shading given in Table 5-2. Stream orientation (i.e., the compass direction that the stream runs) and topographic shading (i.e., the shade provided by hills and other landscape features) were not assessed due to the difficulty in evaluating their importance from aerial photographs.

Table 5-2. Shade estimation criteria (from WFPB, 1997)

Indicator	% Shade
Stream surface not visible	>90%
Stream surface slightly visible or visible in patches	70-90%
Stream surface visible but banks not visible	40-70%
Stream surface visible and banks visible at times	20-40%
Stream surface and banks visible	0-20%

5.3.1.3 Determination of current riparian large wood recruitment potential

The approach to assessing current riparian large wood recruitment potential involves defining what historic recruitment potential was likely to have been, and comparing current recruitment potential against this benchmark to decide if current potential is "satisfactory" (i.e., defining areas that should be protected and where no enhancement is needed), and what factors are limiting current recruitment potential in the areas that are not "satisfactory".

The Oregon Watershed Assessment Manual (WPN, 1999) uses EPA Level IV ecoregions to describe potential streamside recruitment conditions. The Clear and Foster Creek watersheds fall within four Level IV ecoregions (see Figure 1-15). Potential streamside vegetation descriptions for the four ecoregions found in the assessment area are given in Table 5-3. Potential conditions would vary within an ecoregion depending on the geomorphic conditions of a given reach, as well as varying over time in response to disturbance. For example, in the absence of fire suppression, only approximately 2/3 of the forested area in Western Oregon would be expected to be in an old-growth condition in any given year, due to fire re-setting the growth cycle (G. Shibley, pers. comm., 7/7/2002). The potential conditions listed in Table 5-3 can perhaps be considered a "most probable condition" of the riparian vegetation, recognizing that there would be some variability over time.

The Oregon Watershed Assessment Manual (WPN, 1999) provides a methodology for placing similar RCUs into groupings that can help summarize the major riparian impacts in the watershed. These groupings, called *riparian recruitment situations*, also provide a way to categorize riparian areas in ways that will respond similarly to restoration treatments.

The first step in developing riparian recruitment situations for the Clear and Foster Creek watersheds was to determine which RCUs currently have "satisfactory" riparian recruitment. Determination of current satisfactory recruit potential followed the approach given in the Manual (WPN, 1999); current conditions in both RA1 and RA2 were compared to potential conditions given in Table 5-3. Areas where current riparian vegetation is similar (with respect to type, size, and density) to potential conditions were rated as having "satisfactory" current recruitment potential. The remaining RCUs in the watershed currently have unsatisfactory riparian conditions as compared to the potential conditions shown in Table 5-3. These remaining RCUs were further divided into a set of riparian recruitment situations that are appropriate for the watershed. (See also *Map 14: Riparian Recruitment Situation*.)

Table 5-3. Potential streamside vegetation within the Clear and Foster Creek watersheds (WPN, 2001).

Level IV ecoregion	RA1 description	RA2 description	Other considerations
Prairie Terraces (3c)	**Type**: Hardwoods (black cottonwood, willows, Oregon ash, bigleaf maple, western hawthorn) & shrubs (Douglas spirea, snowberry). **Size**: Large **Density**: Dense	Same	Reed canarygrass and Himalayan blackberry (invasive species) often dominate in areas without trees. Oregon white oak, Douglas-fir, and grand fir grow on adjacent terraces that are well-drained.
Valley Foothills (3d)	**Type**: Mixed (Douglas-fir, western hemlock, red alder, bigleaf maple) and shrubs (willow, snowberry, Douglas spirea). **Size**: Medium **Density**: Dense	**Type**: Mixed (Douglas-fir, grand fir, and bigleaf maple) **Size**: Large **Density**: Dense	Few conifers where slopes are unstable or perpetually wet. Vegetation is often highly altered where there is significant beaver browsing and dam building.
Western Cascades Lowlands and Valleys (4a)	**Type (Constrained streams)**: Hardwoods (red alder, cotton-wood, bigleaf maple) and shrubs (vinemaple, red osier dogwood, devil's club, stink currant and salmonberry). **Type (Semi- & Unconstrained streams)**: Mixed (Western red cedar, red alder, cotton-wood, bigleaf maple) and shrubs such as vinemaple, red osier dogwood, devil's club, stinkcurrant and salmonberry. **Size**: Medium **Density**: Dense	**Type**: Conifers (Douglas-fir, western hemlock, western redcedar, true firs at higher elevations). Some hardwoods may be present. **Size**: Large **Density**: Dense	Under certain circumstances, there are a few potential plant communities which have no woody vegetation, and are characterized by herbaceous plants such as Oregon and great oxalis, Cooley's hedgenettle and ladyfern, skunk cabbage, and lenticular sedge. See Diaz and Mellen (1996) and Campbell and Franklin (1979) for more details about specific plant communities and where they occur.
Western Cascades Montane Highlands (4b)	**Constrained streams**: **Type**: Shrubs, such as devil's club, stinkcurrant and salmonberry. **Size**: N/A **Density**: N/A **Semi- & Unconstrained streams**: **Type**: Mixed (Western red cedar, red alder) and shrubs (mountain alder, ovalleaf and Alaska huckleberry, red osier dogwood, devil's club, stinkcurrant and salmonberry). **Size**: Medium **Density**: Dense	**Type**: Conifer (Douglas-fir, western hemlock, western redcedar, and true firs) **Size**: Large **Density**: Dense	Under certain circumstances, there are a few potential plant communities that have no woody vegetation, and are characterized by herbaceous plants such as Oregon and great oxalis, brook saxifrage and arrowleaf groundsel, Cooley's hedgenettle and ladyfern, skunkcabbage, lenticular sedge, and yellow monkeyflower See Diaz and Mellen (1996) for more details about specific plant communities and where they occur.

Riparian recruitment situations were defined using the information that was collected in section 5.3.1.1 above. The riparian recruitment situations defined for the Clear and Foster Creek watersheds are as follows:

Satisfactory: Current riparian recruitment potential is satisfactory as compared with potential conditions for the ecoregion. RCUs included in this grouping generally consist of dense stands of large-sized conifers within RA2.

Approaching satisfactory: Trees within the RCUs that are included in this classification are smaller than the potential size for the ecoregion; generally falling in the Medium (>12- to 24-inch average DBH; Table 5-1) size class. However, the trees are of an adequate size to currently provide adequate LWM recruitment and shade. These stands are not as productive (in terms of riparian function) as they can be. However, if protected, these stands will attain potential conditions over time. RCUs included in this grouping generally consist of dense stands of medium-sized conifers and mixed conifer/hardwood within RA2

Hardwood: Trees within these stands are generally approaching a size that is large enough to provide satisfactory recruitment potential, but are dominated by hardwoods where the potential vegetation is conifer or mixed stands. RCUs included in this grouping generally consist of dense stands of medium-sized hardwood trees within RA1 and/or RA2.

Narrow buffers: RCUs included in this classification generally have trees in the near-stream area that are of a size (generally medium-sized , with a few areas of large-sized trees) and species (conifer or mixed conifer/hardwood) approaching satisfactory relative to potential conditions. However, these areas are very narrow. The source of limitation is split approximately evenly between agricultural operations, residential development, infrastructure (roads, power lines, etc.), and past logging. The outer (farthest from the stream) portions of these stands consist of a variety of vegetation types and sizes. Within areas of forestry land use the stands generally consist of regeneration-sized (<4 inch average DBH; Table 5-1) and small-sized (4-12 inch average DBH; Table 5-1) conifers and mixed conifer/hardwoods. Tree and shrub vegetation is absent in many areas of agricultural and residential land use.

Small-sparse: This grouping of RCUs includes both stands of small- or regeneration-sized trees (see Table 5-1), and sparse stands of medium- and large-sized trees. In both cases current recruitment potential is far removed from potential conditions, however (unlike the following grouping), these stands are forested.

Absent: This grouping includes RCUs that are devoid of riparian tree vegetation. Vegetation within the RCUs included in this grouping consists primarily of riparian grass species, brush species, and non-riparian vegetation (cropland, pasture, and some areas of non-native vegetation).

5.3.2 Wetlands Assessment Methods

The methods used in this assessment are described in the Oregon Watershed Assessment Manual (WPN, 1999), with exceptions noted below. The purpose of this assessment was to identify locations of wetlands within the Clear and Foster Creek watersheds and to summarize available data on current wetland conditions.

All information about wetland locations and current conditions used in this assessment was derived from digital and hardcopy National Wetland Inventory (NWI) data produced by the U.S. Fish and Wildlife Service (USFWS); no local wetland inventory information being available for the watershed. Digital NWI information (USFWS, 2001) was available for all USGS 7.5" quad maps within the watersheds with the exception of the Colton quad, which was digitized for this assessment from the hardcopy NWI map (USFWS, 1983). The dates of the source imagery used to produce the digital maps is not known, but is probably sometime in the 1980's. No additional aerial photo interpretation was performed for this assessment.

The Oregon Watershed Assessment Manual suggests assessing only the wetlands that are greater than 200 feet from the channel to avoid having to examine the very complex NWI mapping that can occur near stream channels. In this assessment all wetland polygons were included regardless of distance from stream channels, however, wetlands that appear in the NWI as line features (i.e., riparian wetlands) were not included.

The Cowardin classification code (Cowardin et al., 1979) was available for each wetland included in the NWI. The System-Class-Subclass, Water Regime Modifiers, and Special Modifiers for wetlands found within the Clear and Foster Creek watersheds is shown in Table 5-4.

Table 5-4. Classification for NWI wetlands found in the Clear and Foster Creek watersheds (Cowardin and others, 1979).

<u>**System-class-subclass**</u>	
PEM1 Palustrine emergent persistent	
PEM1/OW	Palustrine emergent persistent / open water
PEM1/UB	Palustrine emergent persistent / unconsolidated bottom
PFO1 Palustrine forested – broad leaved deciduous	
PFO/EM1	Palustrine forested / palustrine emergent persistent
PFO/SS1	Palustrine forested / scrub-shrub
PFO1/EM1	Palustrine forested – broad leaved deciduous / emergent persistent
PFO1/OW	Palustrine forested – broad leaved deciduous / open water
PFO5/OW	Palustrine forested – dead / open water
POW Palustrine open water	
PSS1 Palustrine scrub-shrub – broad leaved deciduous	
PSS/EM1	Palustrine scrub-shrub / emergent persistent
PUB Palustrine unconsolidated bottom	
<u>**Water regime modifiers:**</u>	
K = Artificially flooded	
W = Intermittently flooded/temporary	
Y = Saturated/semi permanent/seasonal	
Z = Intermittently exposed / permanent	
<u>**Special modifiers:**</u>	
d =Partially drained/ditched	
h =Diked/Impounded	
x =Excavated	

5.4 RESULTS

5.4.1 Current riparian vegetation conditions

Critical Question: ***What are the current conditions of riparian areas in the watershed?***

Riparian vegetation was mapped for approximately 2,900 individual riparian condition units (RCUs) along a total length of 142 miles of stream within the Clear and Foster Creek watersheds. The material presented in this section of the report summarizes current riparian vegetation conditions as estimated through aerial photo interpretation. The distribution of riparian vegetation by type, size, and density classes within the entire Clear and Foster Creek watershed is summarized in Figure 5-2, Figure 5-3, and Figure 5-4.

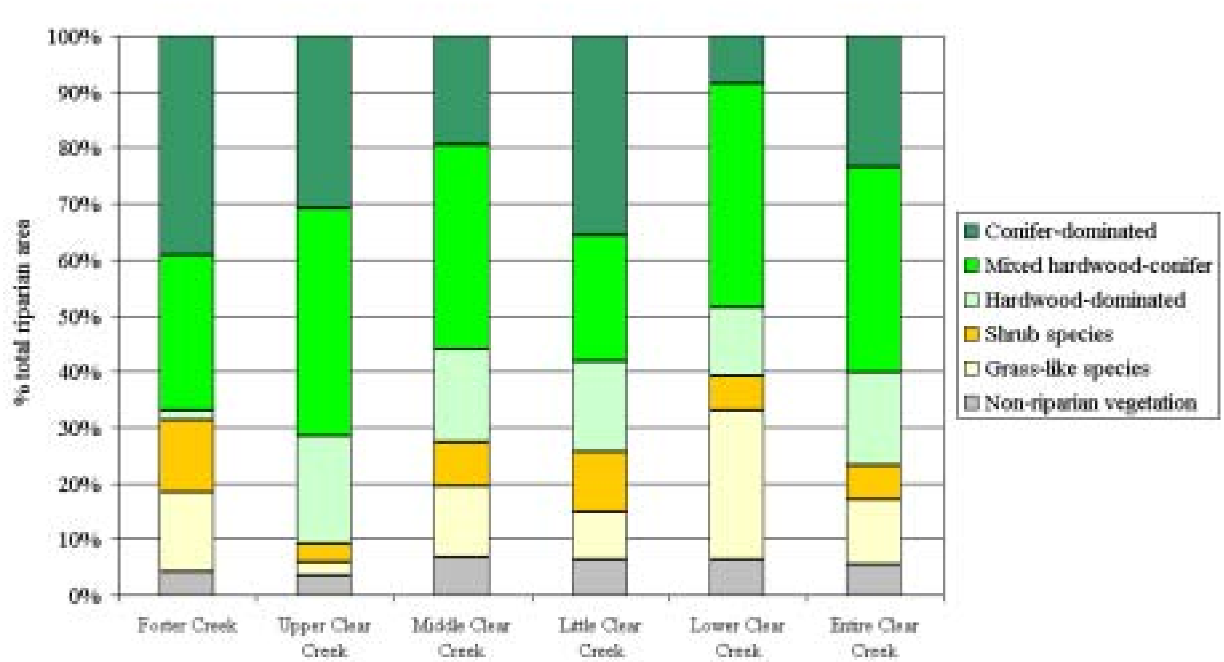

Figure 5-2. Distribution of riparian vegetation by primary types within subwatersheds.

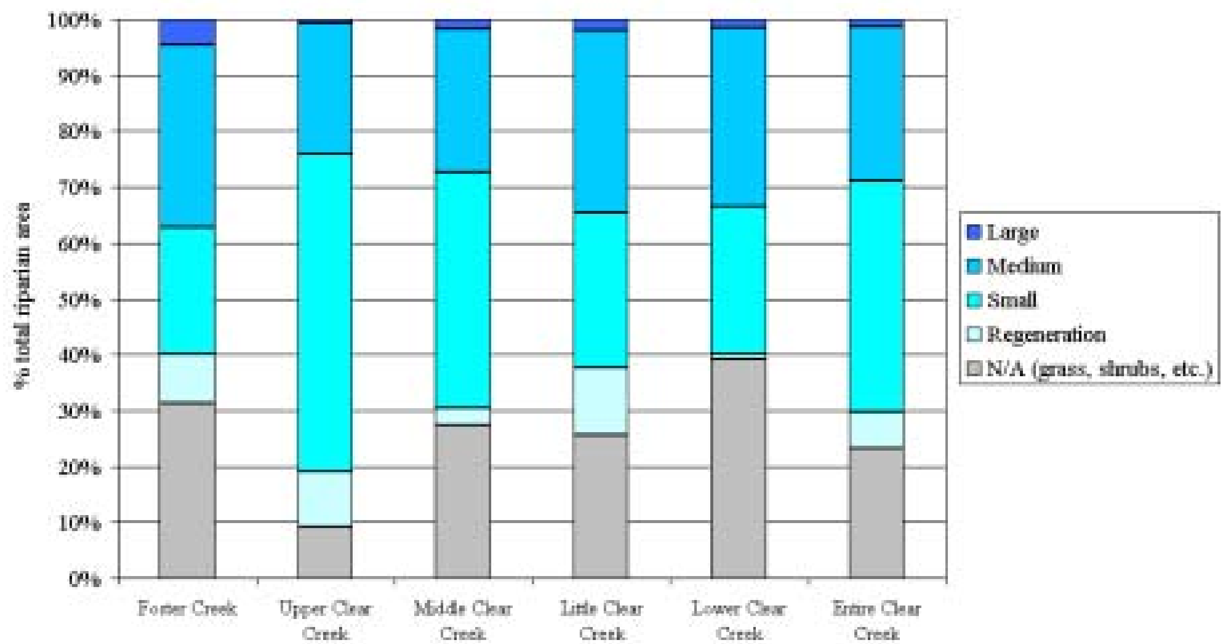

Figure 5-3. Distribution of riparian vegetation by size class within subwatersheds. See Table 5-1 for a description of size classes.

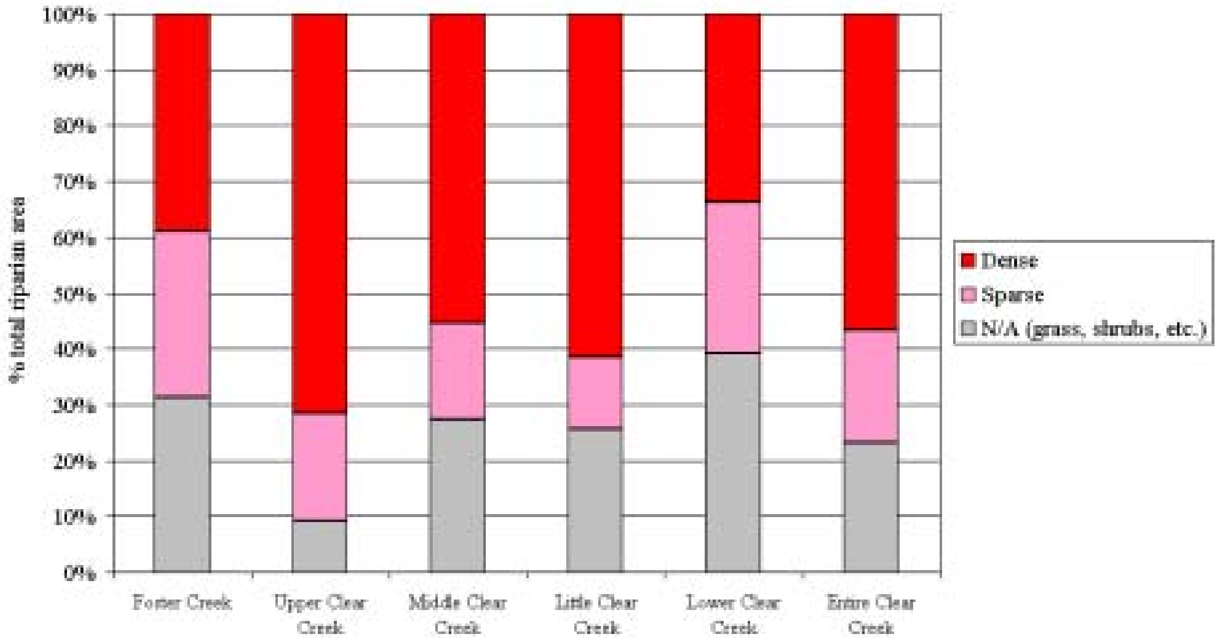

Figure 5-4. Distribution of riparian vegetation by canopy density class within subwatersheds.

The proportion of riparian area composed of grass-like vegetation ranged from approximately 2% of total riparian area in the Upper Clear Creek subwatershed to 27% in the Lower Clear Creek subwatershed (Figure 5-2). This classification includes areas that are completely comprised of riparian and upland grasses (or grass-like plants), as well as areas that contain some scattered trees and shrubs, but the dominant vegetation are grasses. The proportion of riparian area composed of shrub species ranged from 3% of total riparian area in the Upper Clear Creek subwatershed to 13% in the Foster Creek subwatershed. Hardwood-dominated riparian areas make up from 2% of the total riparian area in Foster Creek to 19% of the total riparian area in the Upper Clear Creek subwatershed. The proportion of total riparian area classified as mixed hardwood-conifer ranged from 23% in the Little Clear Creek subwatershed to 41% in the Upper Clear Creek subwatershed. The proportion of total riparian area classified as conifer-dominated ranged from 9% in the Lower Clear Creek subwatershed to 39% in the Foster Creek subwatershed. The classification "non-riparian vegetation" includes primarily cultivated fields, pastures, and lawns that fall within the riparian assessment area. The proportion of total riparian area classified as non-riparian vegetation ranged from 4% in both the Foster Creek and Upper Clear Creek subwatersheds to 7% in the Middle Clear Creek subwatershed.

The distribution of riparian vegetation by size class (See Table 5-1 for a description of size classes) within subwatersheds is shown in Figure 5-3 (refer to Table 5-1 for a description of the size classes used). The size class designation only applies to tree-vegetation. Consequently from 9% (in the Upper Clear Creek subwatershed) to 39% (in the Lower Clear Creek subwatershed) of the total riparian area is listed as “N/A” in Figure 5-3. The proportion of total riparian area classified in the “regeneration-size” classification ranges from 1% in the Lower Clear Creek subwatershed to 10% in the Upper Clear Creek subwatershed. The proportion of total riparian area classified in the “Small-size” classification ranges from 23% in the Foster Creek subwatershed to 57% in the Upper Clear Creek subwatershed. The proportion of total riparian area classified in the “Medium-size” classification ranges from 23% in the Upper Clear Creek subwatershed to 33% in the Little Clear Creek subwatershed. The proportion of total riparian area classified in the “Large-size” classification ranges from 1% in the Upper and Lower Clear Creek subwatersheds to 5% in the Foster Creek subwatershed.

The distribution of riparian vegetation by canopy density classes (See Table 5-1 for a description of canopy density classes) within subwatersheds is shown in Figure 5-4. The canopy density designation only applies to tree-vegetation. Consequently from 9% (in the Upper Clear Creek subwatershed) to 39% (in the Lower Clear Creek subwatershed) of the total riparian area is listed as “N/A” in Figure 5-4. The proportion of total riparian area classified as having “sparse” canopy density ranges from 13% in the Little Clear Creek subwatershed to 30% in the Foster Creek subwatershed. The proportion of total riparian area classified as having “dense” canopy density ranges from 34% in the Lower Clear Creek subwatershed to 62% in the Little Clear Creek subwatershed.

5.4.2 Riparian recruitment potential

Critical Question: How do the current conditions compare to those potentially present for this ecoregion?

Critical Question: How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/ enhancement opportunities might be?

Current riparian recruitment potential was organized by the six riparian recruitment situations described in section 5.3.1.3 above. Riparian recruitment situations within the Foster Creek and Lower Clear Creek subwatersheds is shown in Figure 5-5, within the Little and Middle Clear Creek subwatersheds in Figure 5-6, and within the Upper Clear Creek watershed in Figure 5-7. A summary of current riparian situations by subwatershed is given in Figure 5-8 for all streams, and a summary by fish-bearing streams only is given in Figure 5-9. This information is combined in *Map 14: Riparian Recruitment Situation.*

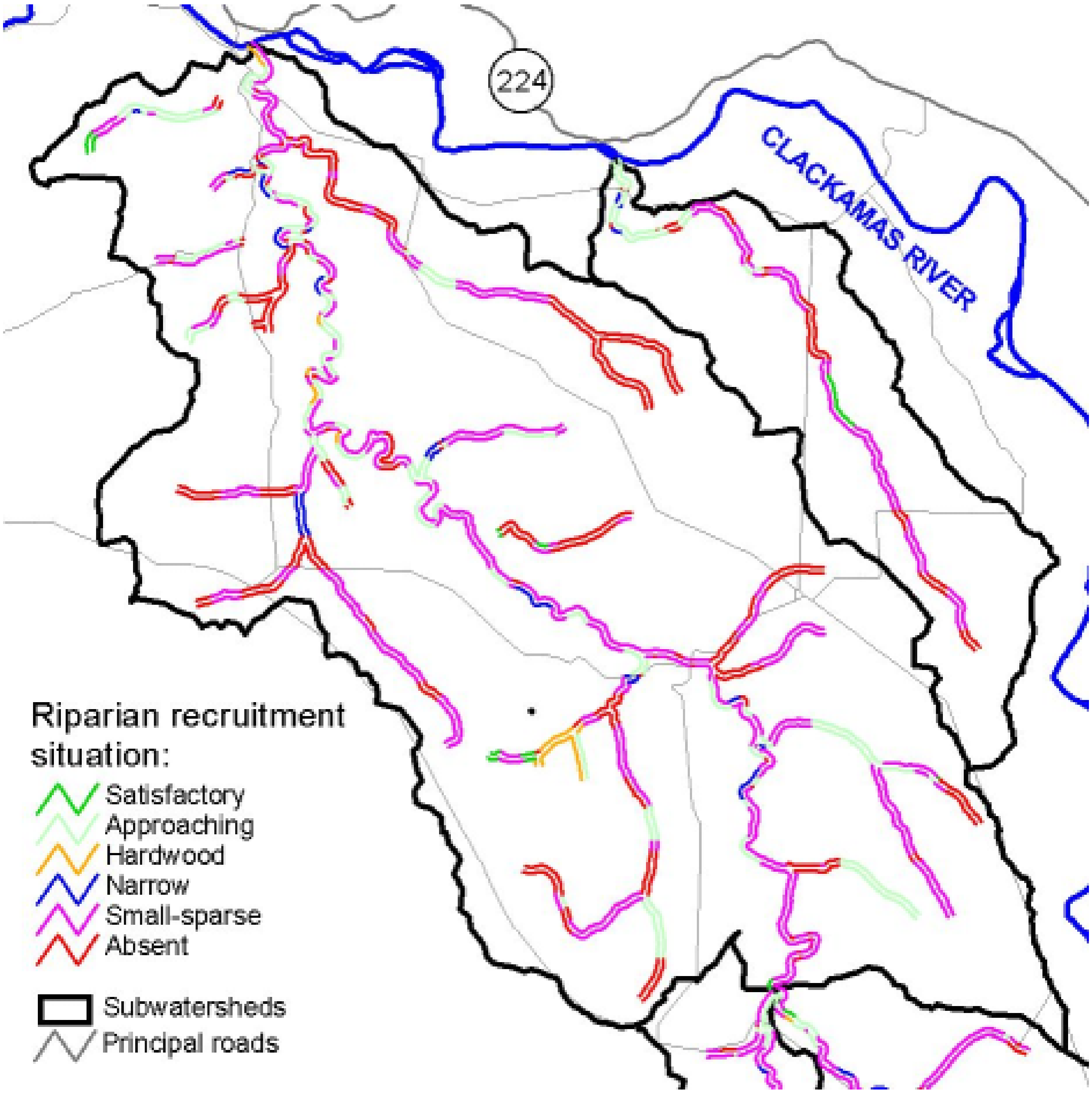

Figure 5-5. Riparian recruitment situations in the Foster Creek and Lower Clear Creek subwatersheds.

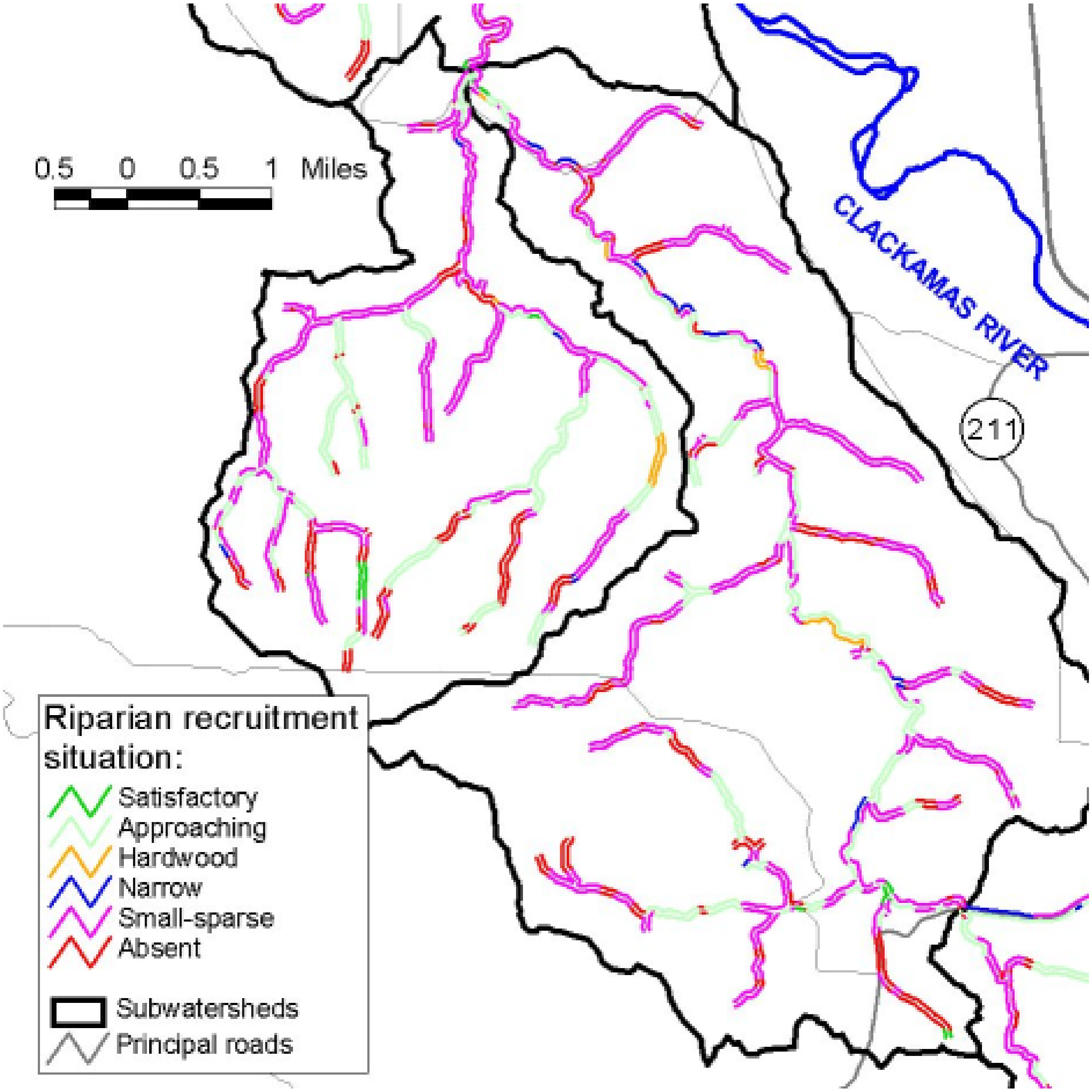

Figure 5-6. Riparian recruitment situations in the Middle and Little Clear Creek subwatersheds.

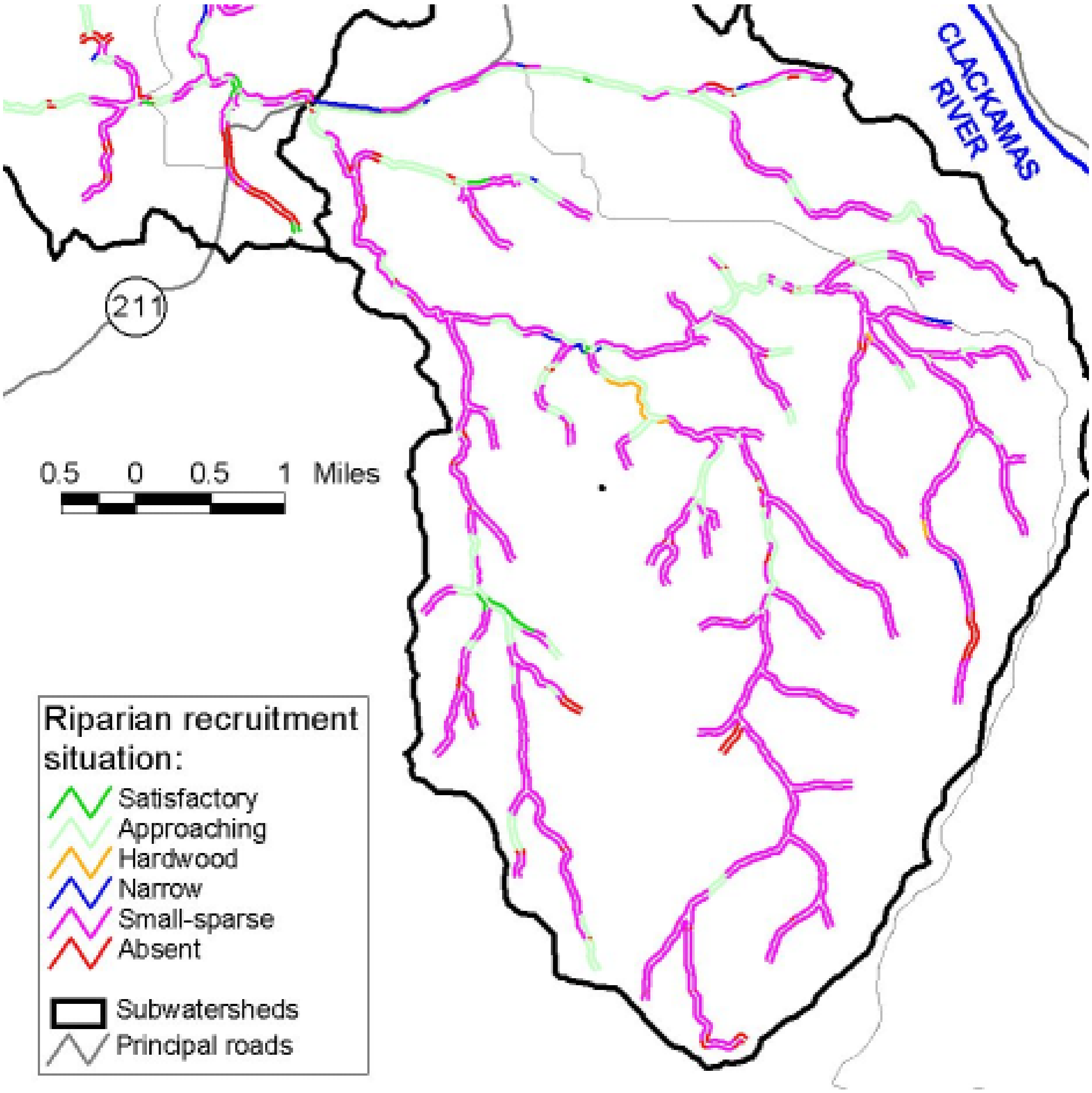

Figure 5-7. Riparian recruitment situations in the Upper Clear Creek subwatershed.

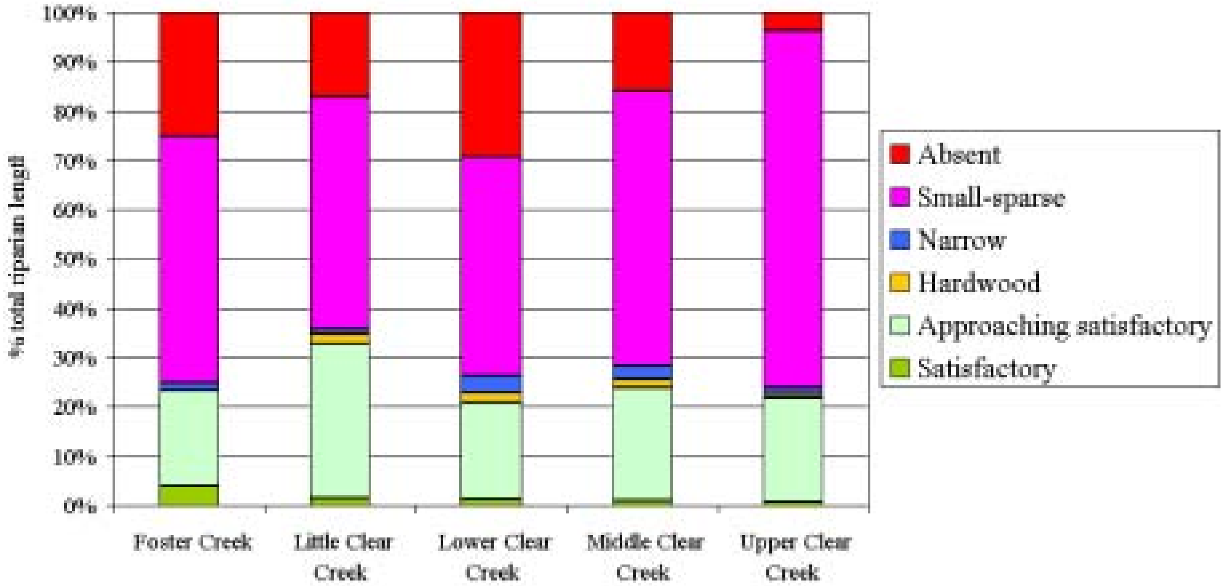

Figure 5-8. Summary of current riparian recruitment situations by subwatershed. Categories are percent of total riparian length for each subbasin.

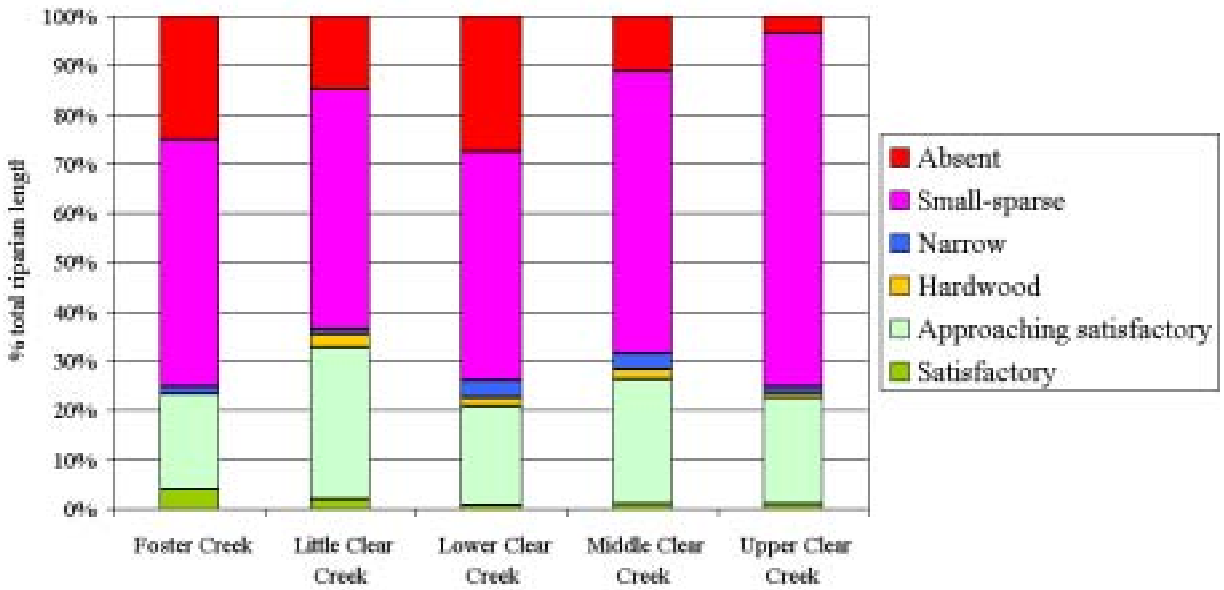

Figure 5-9. Summary of current riparian recruitment situations by subwatershed <u>for fish-bearing streams only</u>. Categories are percent of total riparian length for each subbasin.

The results presented for all streams (Figure 5-8) and for fish-bearing streams only (Figure 5-9) are very similar in appearance. This is because most of the streams in the watersheds are estimated to be fish-bearing. Out of the total stream length of 142 miles, 118 miles (83%) are estimated to be fish-bearing.

Only a very small proportion of the total length of stream within the subwatersheds are estimated to currently have "satisfactory" riparian recruitment potential (Figure 5-8, Figure 5-9). Current riparian recruitment potential is rated as satisfactory along only 1% of the total stream length in the Lower, Middle, and Upper Clear Creek subwatersheds; 2% of the total stream length in the Little Clear Creek subwatershed, and 4% of the total stream length in the Foster Creek subwatershed. As discussed in Section 5.3.1.3 above, disturbence from natural sources (e.g., fire and floods) would result in riparian conditions being in an earlier seral stage in approximately 1/3 of the total riparian area in any given year. In other words, at the watershed scale we might only expect to find approximately 2/3 of the total length of riparian areas rated as "satisfactory" in any given year. The small proportion of riparian length that is currently rated as "satisfactory" in the Clear and Foster Creek Watersheds indicates that current conditions within the watersheds are far below potential conditions, even when natural variability is accounted for.

A much larger proportion of the total stream length currently has riparian recruitment potential that is rated as "approaching satisfactory" (Figure 5-8, Figure 5-9). Current riparian recruitment potential is rated as approaching satisfactory along approximately 20% of the total stream length in all subwatersheds with the exception of the Little Clear Creek subwatershed, where approximately 30% of the total stream length is rated as approaching satisfactory.

Both the "hardwood" and "narrow buffers" categories of current riparian recruitment potential make up only a very small proportion of total stream length within all subwatersheds (Figure 5-8, Figure 5-9). The hardwood category is not present at all in the Foster Creek subwatershed, and comprises only 1% of the total length within the Upper Clear Creek subwatershed, and 2% of the total length within the Little, Lower, and Middle Clear Creek subwatersheds. The "narrow buffers" category makes up only 1% of the total length in the Little and Upper Clear Creek subwatersheds, 2% of the total length in the Foster Creek subwatershed, and 3% of the total length in the Lower and Middle Clear Creek subwatersheds.

The largest grouping of riparian areas within all subwatersheds is the "small-sparse" category (Figure 5-8, Figure 5-9). Percent of total riparian length within the "small-sparse" category ranges from 44% in the Lower Clear Creek subwatershed to 73% in the Upper Clear Creek subwatershed. The high proportion of small-sparse stands in the Upper Clear Creek subwatershed is primarly due to reforestation of past timber harvest areas that were harvested prior to the more stringent Oregon Forest Practices rules and USFS/BLM harvest policies that are currently in effect.

The grouping of riparian areas shown as "absent", in Figure 5-8 and Figure 5-9, includes those riparian areas that are devoid of tree-type vegetation. This grouping makes up a significant proportion of the total riparian length in most subwatersheds. Percent of total riparian length within the "absent" category is 4% within the Upper Clear Creek subwatershed, 16% and 17% in the Middle and Little Clear Creek subwatersheds respectively, and 25% and 29% in the Foster Creek and Lower Clear Creek subwatersheds.

The summary of riparian recruitment situations given above are for all streams and all fish-bearing streams within the subwatersheds. One possible way to look closer at those streams that are most important, with respect to fish, is to look at the distribution of riparian recruitment situations by channels that are most responsive to inputs of large woody material (LWM). The channels that are most responsive to LWM are the most likely to develop favorable fish habitat characteristics if recruitment is adequate, and conversely, are the most likely to be degraded if LWM recruitment is impaired. Within the Clear and Foster Creek watersheds, the channels that are most likely to respond to LWM are the "low gradient floodplain" (FP1, FP2, and FP3) channel habitat types (CHTs)[18]. Together, streams within these two CHT types make up only 17% of the total length of streams included in the assessment; however, these are probably the most responsive to LWM recruitment. A breakdown of the percent length of riparian areas by Riparian Recruitment Situation among these most responsive CHTs is given in Figure 5-10.

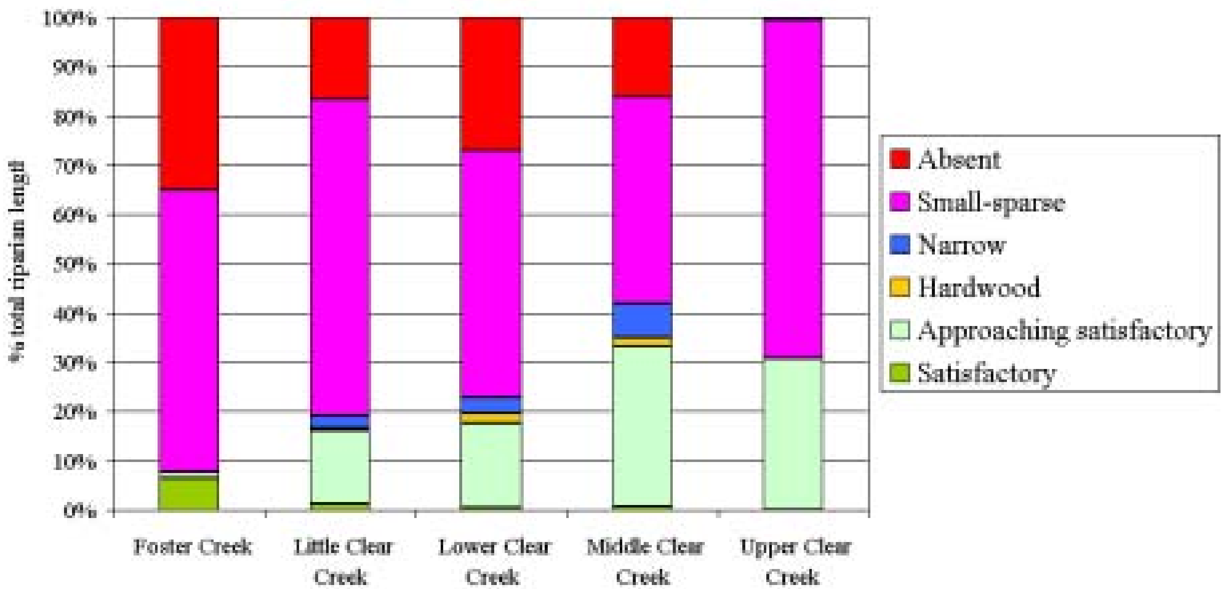

Figure 5-10. Summary of current riparian recruitment situations by subwatershed <u>for the most responsive streams only</u>. Categories are percent of total riparian length for each subbasin.

[18] Differences in gradient, confinement, and bed morphology suggest that different channel types are more or less responsive to adjustment in channel pattern, location, width, depth, sediment storage, and bed roughness (WPN, 1999). Unconfined or moderately confined channels display visible changes in channel characteristics (and subsequent alterations of aquatic habitat conditions) when the supply of roughness elements such as large woody material (LWM) are altered. These areas are commonly referred to as response reaches, and usually possess an active floodplain.

Current riparian recruitment potential is generally, although not in all cases, worse along these most responsive reaches (Figure 5-10) than for all streams overall (Figure 5-8, Figure 5-9). Current riparian recruitment potential is rated as "satisfactory" or "approaching satisfactory" along only 8% of the most responsive reaches in the Foster Creek subwatershed (as compared to 23% for all streams), 16% of the most responsive reaches in the Little Clear Creek subwatershed (as compared to 33% for all streams), and 18% of the most responsive reaches in the Lower Clear Creek subwatershed (as compared to 21% for all streams). On the other hand, 33% of the most responsive reaches in the Middle Clear Creek subwatershed are rated as having "satisfactory" or "approaching satisfactory" current riparian recruitment potential (as compared to 24% for all streams), as do 31% of the most responsive reaches in the Upper Clear Creek subwatershed (as compared to 22% for all streams).

The primary sources of limitation to riparian forest development, as estimated from aerial photographs, are shown in Figure 5-11. The primary sources of limitation vary by subwatershed, primarily in response to land use. Agricultural practices are the primary sources of limitation within Foster Creek and Lower Clear Creek subwatersheds, while past logging[19] is the primary source in the Little and Upper Clear Creek subwatersheds. The infrastructure (primarily roads and power lines) impact from 5% - 8% of the total riparian length in all subwatersheds.

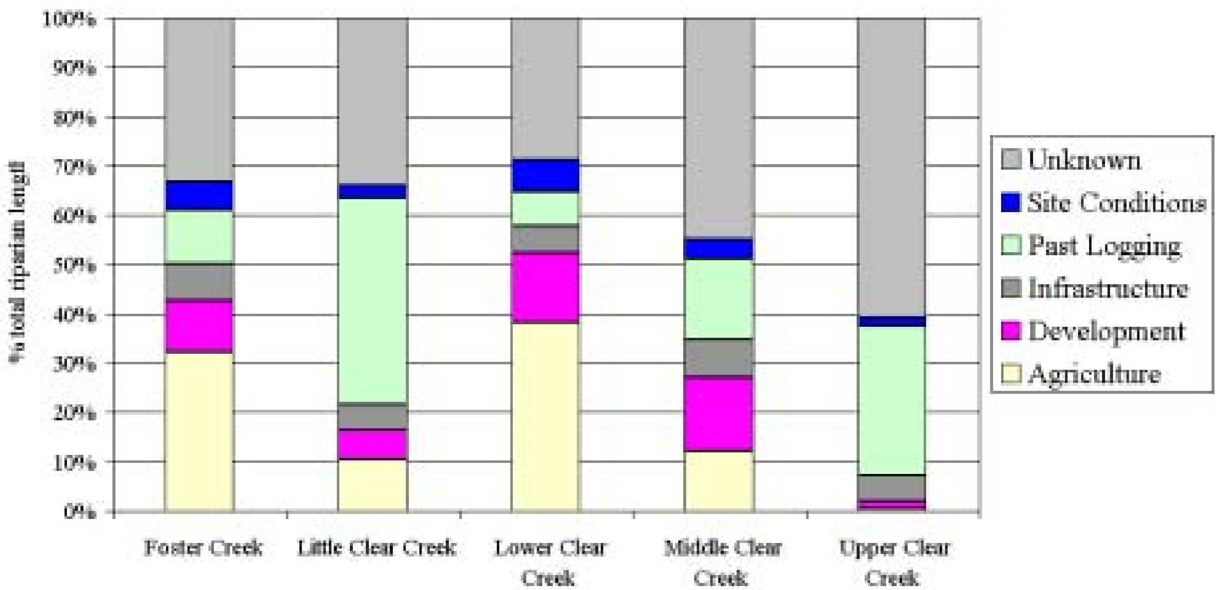

Figure 5-11. Percent of total riparian length grouped by primary sources of limitation to riparian forest development.

[19] It is important to note that the current conditions for most of the riparian stands in this category are due to legacy conditions from past forest harvest; current state forest practice regulations and USFS / BLM policy would prohibit much of the degradation that occurred under past practices

5.4.3 Riparian shade

Current riparian shade levels within the Clear and Foster watersheds are shown in Figure 5-12, Figure 5-13, and Figure 5-14; and summarized in Figure 5-15 and *Map 15: Riparian Shade Levels*. Streams are in general well-shaded, with current shade levels proportional to basin position (i.e., the headwater areas are generally more well-shaded then areas near the mouth of the basin; Figure 5-15. It is difficult to assess if current shade levels are below potential levels, and if so, to what extent. The Oregon Watershed Assessment Manual (WPN, 1999) does not include a methodology for estimating potential shade levels. The degree to which riparian areas within the watershed are deficient in terms of recruitment potential (as discussed in section 5.4.2 above), are not necessarily reflected in riparian shade levels, because small trees, shrubs, and even dense non-woody vegetation can provide high levels of shade. The degree to which other factors which control water temperature (such as riparian micro-climate) are affected by a change in vegetation composition are not known.

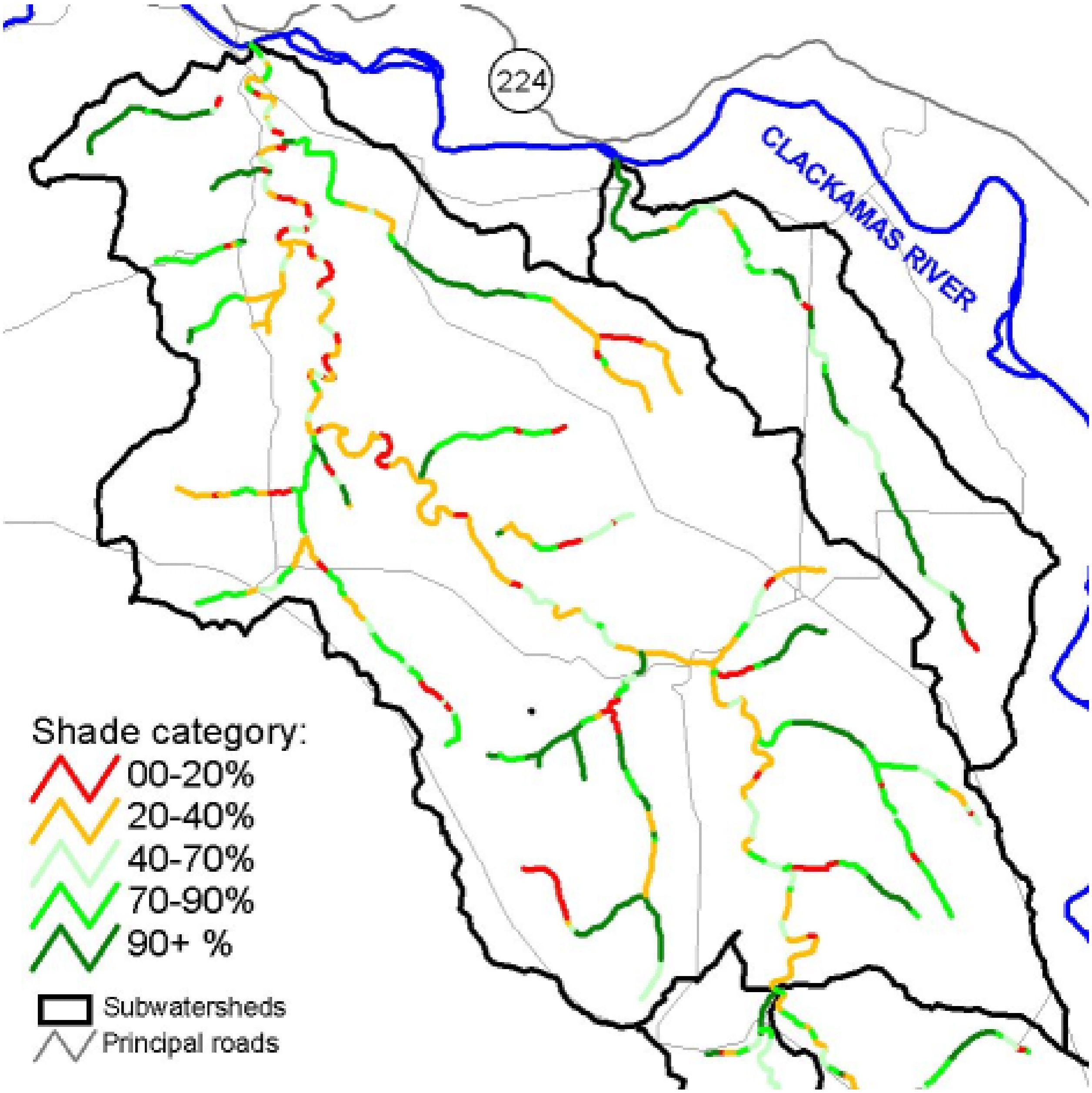

Figure 5-12. Current riparian shade levels in the Foster Creek and Lower Clear Creek subwatersheds.

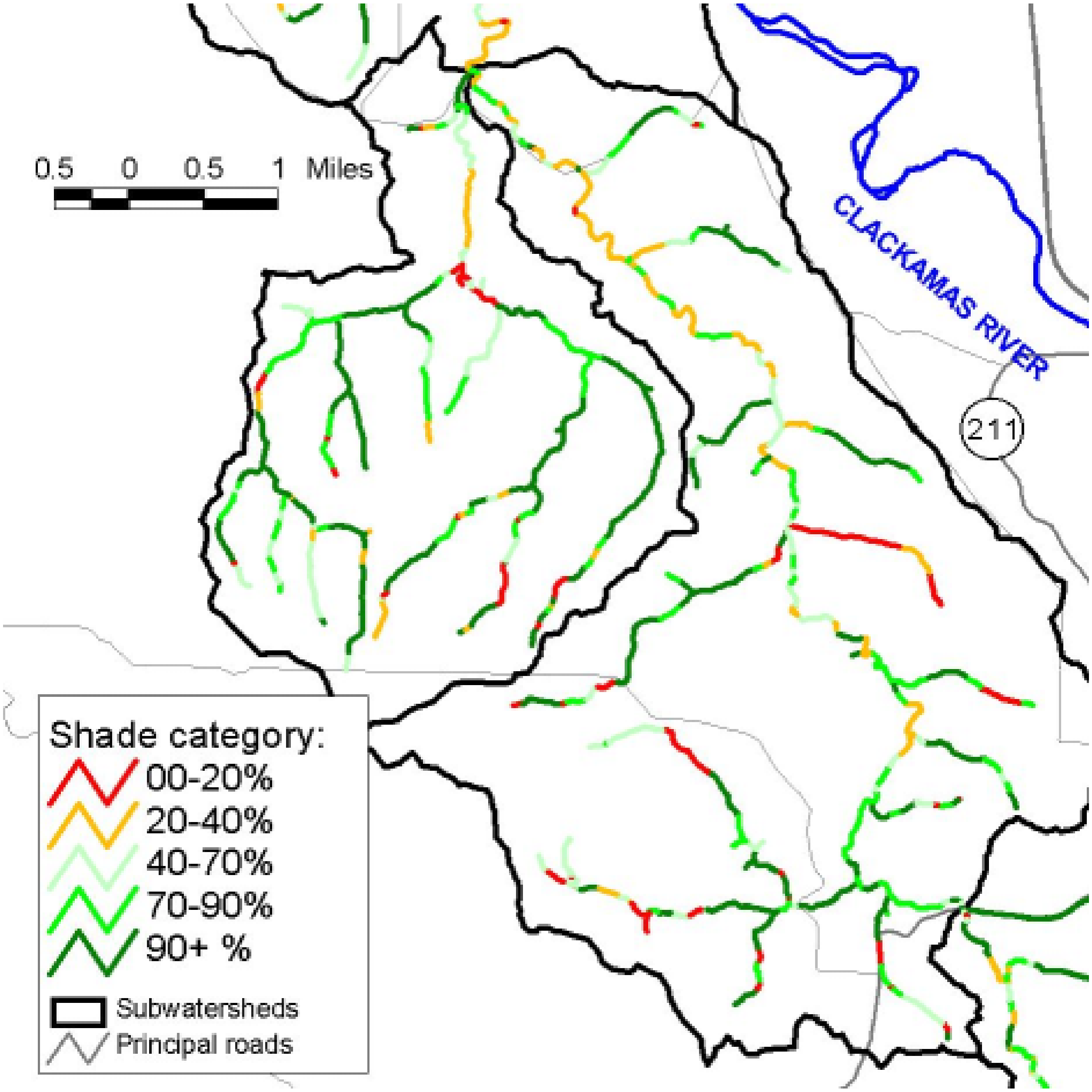

Figure 5-13. Current riparian shade levels in the Middle and Little Clear Creek subwatersheds.

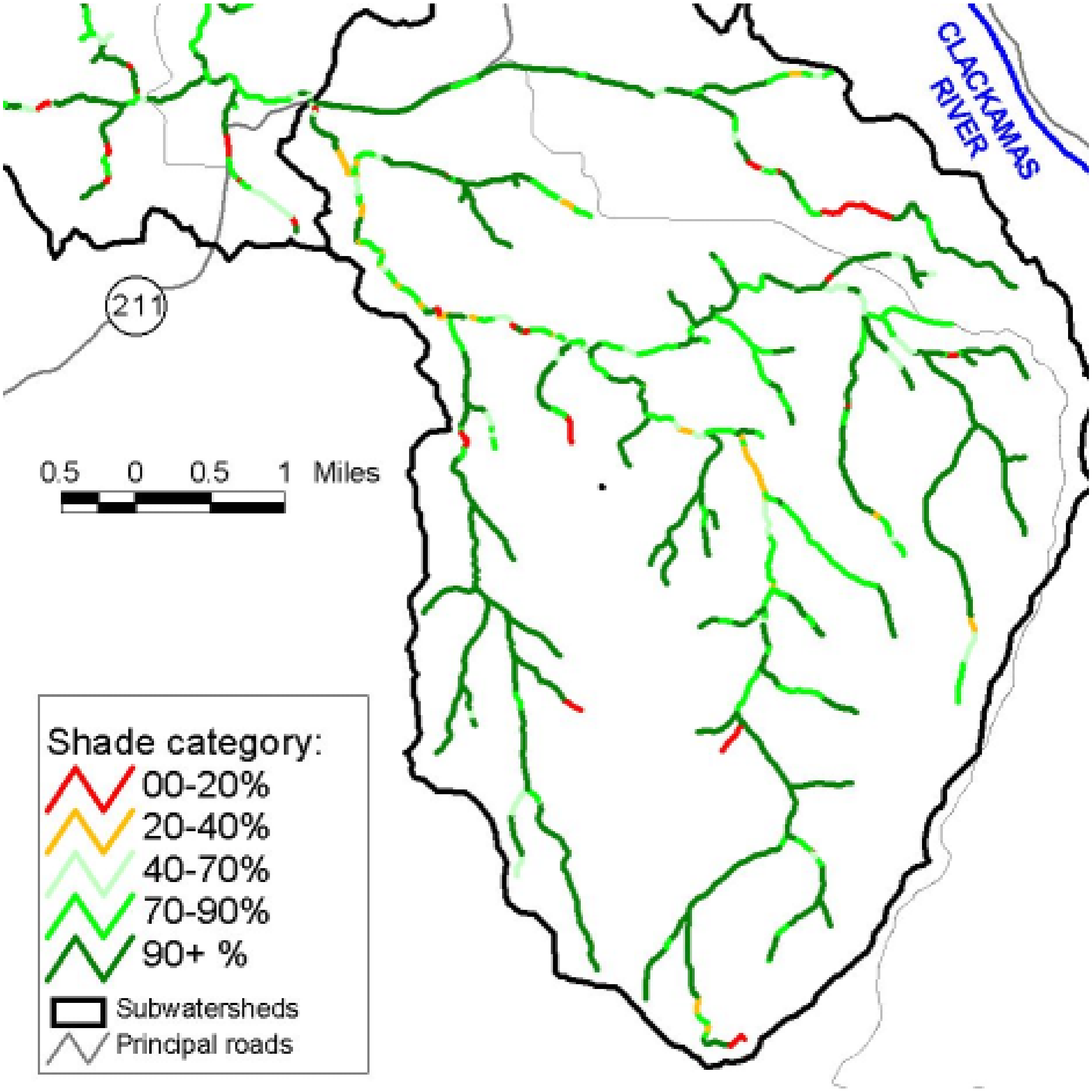

Figure 5-14. Current riparian shade levels in the Upper Clear Creek subwatershed.

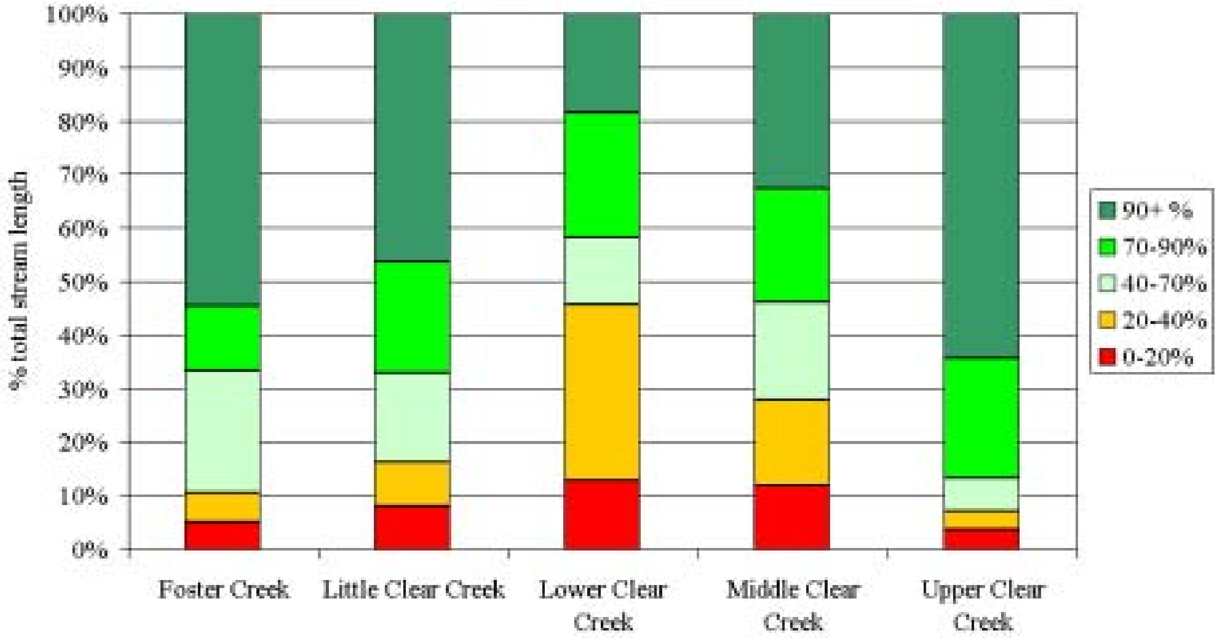

Figure 5-15. Summary of current riparian shade levels by subbasin. Categories are percent of total stream length by shade category.

5.4.4 Wetlands

Critical Question: Where are the wetlands in this watershed?

Critical Question: What are the general characteristics of wetlands within the watershed?

Critical Question: What opportunities exist to restore wetlands in the watershed?

A total of 157 wetlands covering 188 acres were identified by the NWI in the Clear and Foster Creek watersheds (Figure 5-16, Figure 5-17, Figure 5-18; summarized in Figure 5-19). Wetland density (area occupied by wetlands/area of subbasin) ranged from 0.1% of the Upper Clear Creek subwatershed to 0.7% of the Foster Creek subwatershed, and was 0.4% of the assessment area overall.

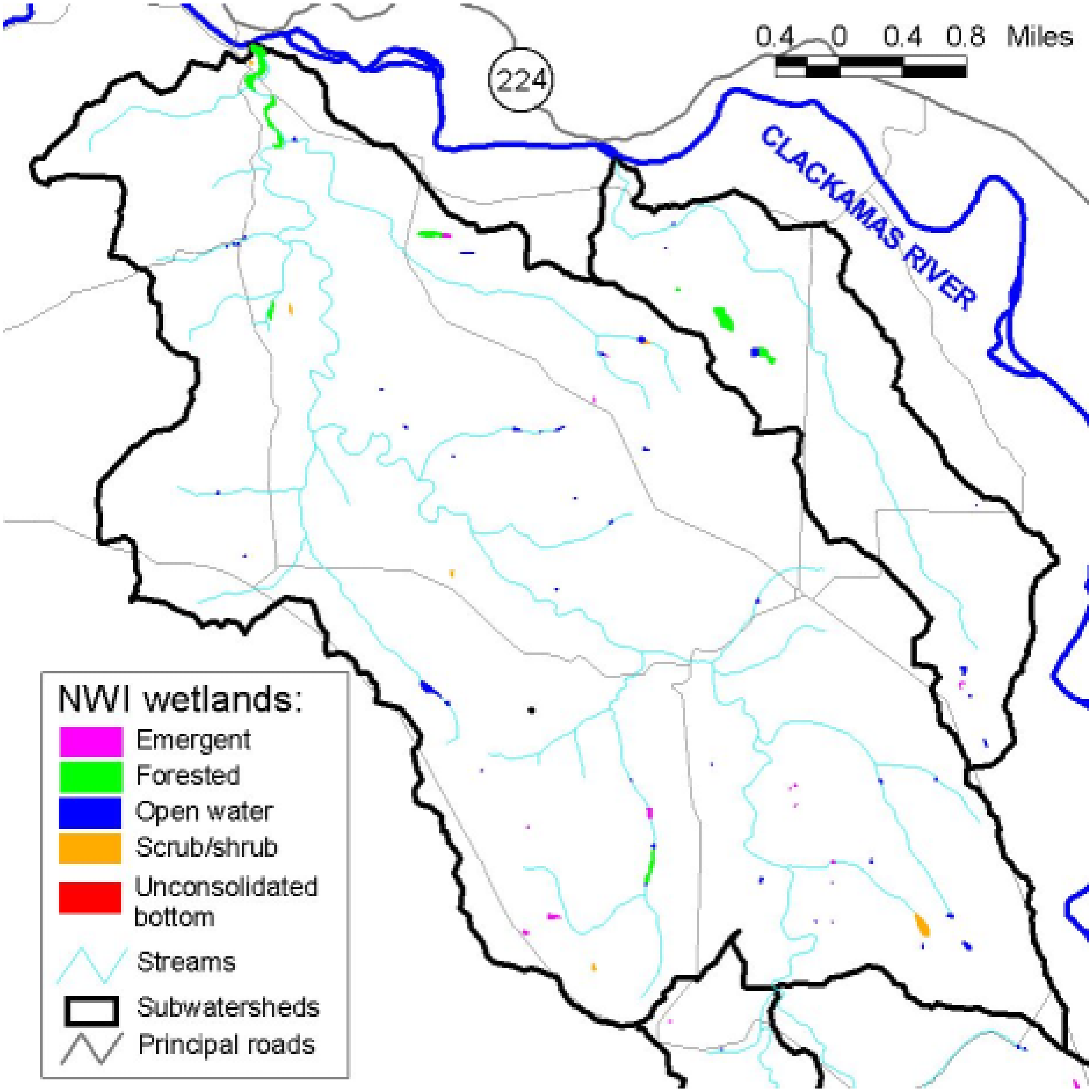

Figure 5-16. Wetlands identified in the NWI in the Foster Creek and Lower Clear Creek subwatersheds.

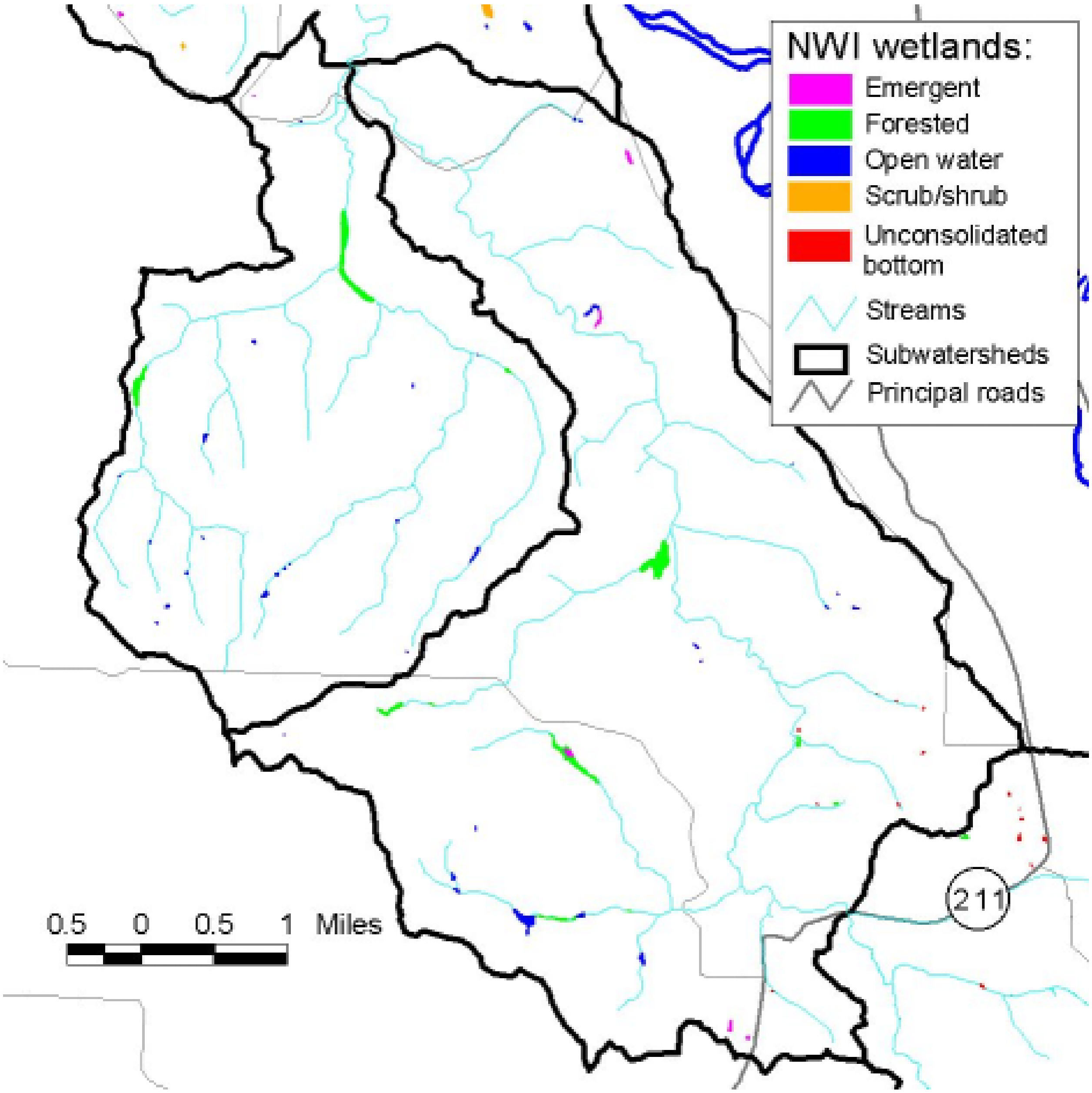

Figure 5-17. Wetlands identified in the NWI in the Middle and Little Clear Creek subwatersheds.

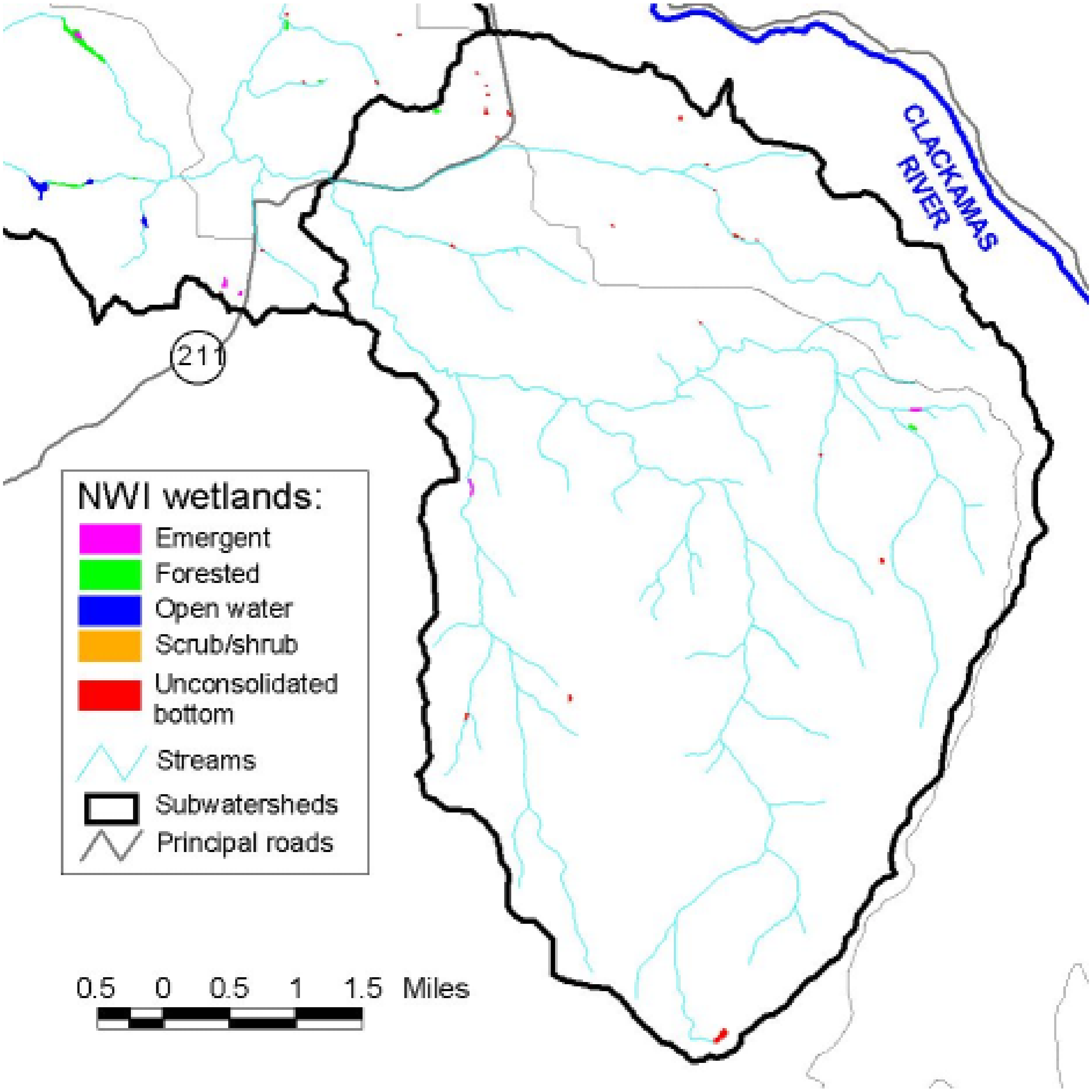

Figure 5-18. Wetlands identified in the NWI in the Upper Clear Creek subwatershed.

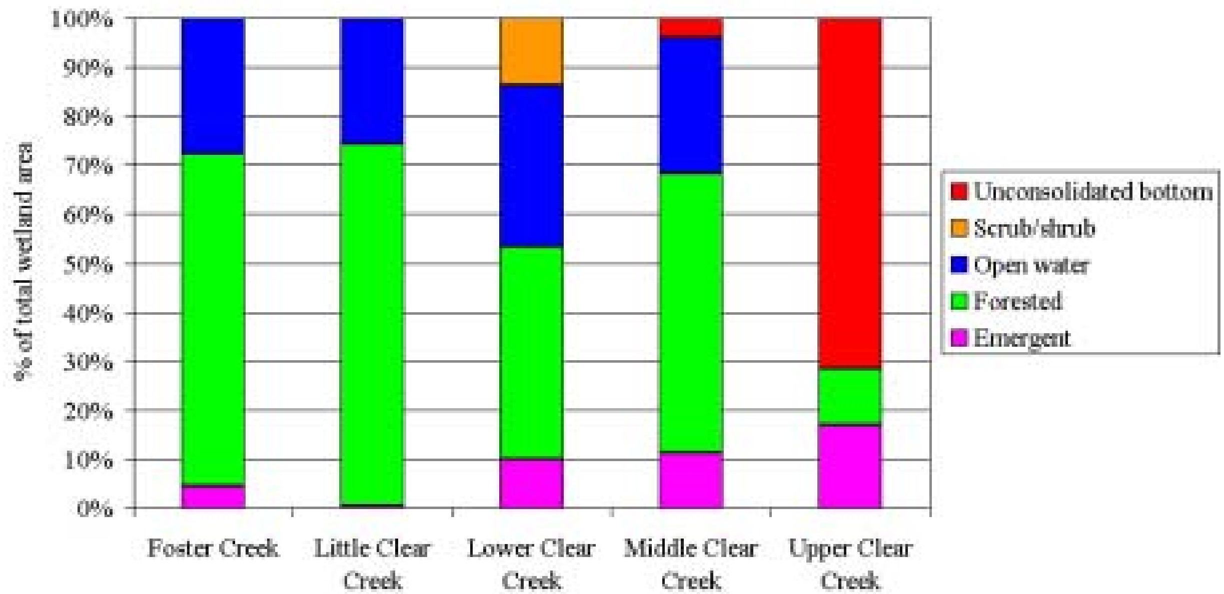

Figure 5-19. Distribution of total wetland area within subwatersheds.

Palustrine emergent wetlands are wetlands dominated by rooted herbaceous plants, such as cattails and grass. Palustrine emergent wetlands are found within all subwatersheds, and range from less than one percent of the total wetland area in the Little Clear Creek subwatershed to 17% of the total wetland area in the Upper Clear Creek subwatershed (Figure 5-19).

Palustrine forested wetlands are defined as wetlands dominated by trees taller than 20 feet. Palustrine forested wetlands are found in all subwatersheds (Figure 5-19), making up the largest single grouping of wetlands in all subwatersheds (43% - 74% of total wetland area) except Upper Clear Creek (11% of total wetland area).

Palustrine open water wetlands (lakes and ponds) are found in all subwatersheds with the exception of Upper Clear Creek (Figure 5-19). Palustrine open water wetlands make up from 26% (Little Clear Creek subwatershed) to 33% (Lower Clear Creek subwatershed) of the total wetland area within the subwatersheds where they are found.

Palustrine scrub-shrub wetlands are defined as wetlands that are dominated by shrubs and saplings less than 20 feet tall. Palustrine scrub-shrub wetlands are only found in the Lower Clear Creek subwatershed (Figure 5-19), where they make up 14% of the total wetland area.

Palustrine unconsolidated bottom wetlands are those wetlands whose substrate is primarily mud or exposed soils, and have less than 30% vegetative cover. Palustrine unconsolidated bottom wetlands are only found in the Middle and Upper Clear Creek subwatersheds (Figure 5-19), where they make up 4% and 72% of the total wetland area respectively.

Many wetlands have been created, modified or destroyed through the intentional or unintentional actions of humans. The NWI attempted to identify these modifications where possible. Three of these "special modifiers" (Table 5-4) were noted for wetlands within the Clear and Foster Creek watersheds:

- Excavated wetlands: Wetlands that lie within a basin or channel excavated by humans.
- Diked/Impounded wetlands: Diked wetlands are created or modified by a human-made barrier or dike designed to obstruct the inflow of water. Impounded wetlands are created or modified by a barrier or dam which purposefully or unintentionally obstructs the outflow of water.
- Partially drained/ditched: The water level in these wetlands has been artificially lowered, but soil moisture is still sufficient to support wetland vegetation.

Partially drained/ditched wetland modifications were only noted in one wetland in the Middle Clear Creek subwatershed, and in 3 wetlands in the Lower Clear Creek subwatershed, where the area impacted represented 3% and 1% of the total wetland area respectively (Figure 5-20). Wetland modifications due to dikes and impoundments were identified in all subwatersheds (Figure 5-20), impacting from 3% (Foster Creek) to 64% (Upper Clear Creek) of the total wetland area in the subwatershed (Figure 5-20). Wetland modified by excavation were also identified in all subwatersheds (Figure 5-20), impacting from 1% (Middle Clear Creek) to 24% (Foster Creek) of the total wetland area in the subwatershed (Figure 5-20).

A discussion of possible wetland loss not captured by the NWI is included in section 4.4.3.2.3 of this report.

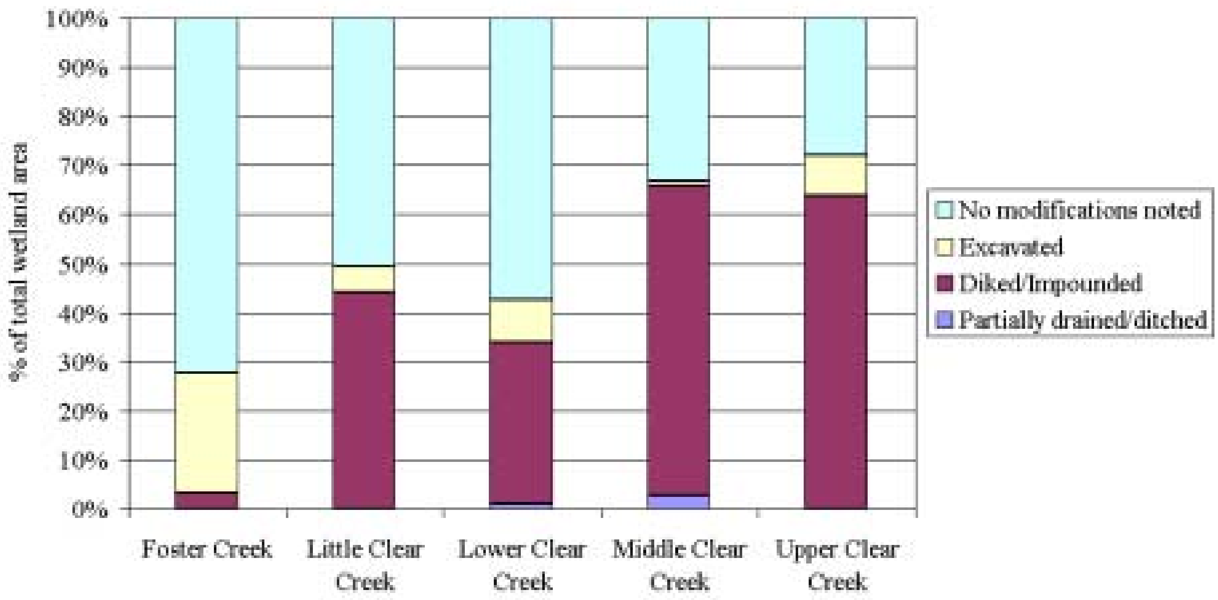

Figure 5-20. Proportion of wetland area identified by the NWI to have been modified.

5.5 INFORMATION GAPS AND MONITORING NEEDS

The information generated for this report was sufficient to characterize current riparian conditions within the Clear and Foster Creek watershed; consequently, few information gaps are identified here pertaining to riparian conditions. The following are recommendations that address the most significant information gaps affecting the assessment presented above:

- Quantify current large woody material (LWM) loadings within streams.

Prioritization of riparian enhancement activities should take into consideration current levels of LWM loadings within streams so as to identify those reaches where enhancement or recruitment potential is most critical. Few data currently exist to describe current LWM loadings. A monitoring program should be established to increase our knowledge of LWM loadings. In addition, while quantifying LWM loadings, further ground-truthing of riparian vegetation types and shade levels should be conducted.

- Investigate historical extent of wetlands within the watershed.

The current wetland density within the watershed is very low (approximately 0.4% of the watershed area is in wetlands). A comparison of current wetland area to watershed area containing hydric soils (Section 4.4.3.2.3) indicates that wetlands may have historically occupied a much larger area within the watershed than they currently do. Further analysis is needed to define the historic extent of wetland area within the watershed.

- Perform functional assessment of wetlands within the watershed.

More information on wetland condition and function is needed in order to identify and prioritize wetland enhancement efforts. It is recommended that a comprehensive wetland inventory and functional assessment be conducted for the watershed. Over 45 wetland inventories have been completed by communities in Oregon. Examples of these inventories, and assistance in developing an inventory for the watershed, can be obtained from the Oregon Division of State Lands. Among the items to be considered in developing an inventory/functional assessment are:

  - What functional assessment technique will be used? Among the methods that should be considered are the Hydrogeomorphic Approach for Oregon (Adamus, 2001), the Oregon Freshwater Assessment Methodology (Roth and others, 1996), the Indicator Value Approach (Hruby et al., 1995), and the Wetland Evaluation Technique (Adamus and others, 1991).

  - What materials are available (e.g., aerial photographs, soil surveys, vegetation surveys, etc.), what additional materials will be needed?

  - What expertise is available in-house? Are there opportunities to use volunteers or college interns? What expertise will need to be contracted?

5.6 RECOMMENDATIONS AND POSSIBLE COUNCIL ACTIONS

- Protect and enhance riparian areas watershed-wide

The following protection/enhancement recommendations are grouped by the six riparian recruitment situations described in section 5.3.1.3 above. Prioritization of protection/enhancement actions should favor those streams 1) that currently have (or have the potential for) fish usage, 2) having channel characteristics that are most responsive to inputs of large woody material, and 3) that are limited with respect to stream shading:

Satisfactory: Current riparian recruitment potential is satisfactory as compared with potential conditions for the ecoregion. No enhancement needed to achieve the potential conditions for the portion of the watershed where these RCUs occurs. RCUs included in this grouping generally consist of dense stands of large-sized conifers within RA2. Protect these areas.

Approaching satisfactory: Trees within the RCUs that are included in this classification are smaller than the potential size for the ecoregion; however, the trees are of an adequate size to currently provide adequate LWM recruitment and shade. These stands are not as productive (in terms of riparian function) as they can be. However, if protected, these stands will attain potential conditions over time. RCUs included in this grouping generally consist of dense stands of medium-sized conifers and mixed conifer/hardwood within RA2. No active enhancement actions are recomended for the majority of these stands. Protect these areas.

Hardwood: Trees within these stands are generally approaching a size that is large enough to provide satisfactory recruitment potential, but are dominated by hardwoods where the potential vegetation is conifer or mixed stands. RCUs included in this grouping generally consist of dense stands of medium-sized hardwood trees within RA1 and/or RA2. Appropriate enhancement techniques may include conversion of some of these areas over time to conifer stands. However, many of these stands have some recruitment potential at present, and any conversion should be considered in light of other considerations (e.g., wildlife and aesthetic concerns). Among the hardwood-dominated stands, only areas that consist primarily of alder (which is short-lived and usually converts to salmonberry over time) should be considered for active restoration. Given that the following categories (i.e., Narrow Buffers, Small-Sparse, and Absent) represent conditions where significantly less riparian recruitment potential currently exists, the hardwood dominated stands should be the lowest priority for active enhancement activities.

Narrow buffers: RCUs included in this classification generally have trees in the near-stream area that are of a size (generally medium-sized , with a few areas of large-sized trees) and species (conifer or mixed conifer/hardwood) approaching satisfactory relative to potential conditions. However, these areas are very narrow. The source of limitation is split approximately evenly between agricultural operations, residential development, infrastructure (roads, power lines, etc.), and past logging. The outer (farthest from the stream) portions of these stands consist of a variety of vegetation types and sizes. Within areas of forestry land use the stands generally consist of regeneration-sized (<4 inch average DBH) and small-sized (4-12 inch average DBH) conifers and mixed conifer/hardwoods. Tree and shrub vegetation is absent in many areas of agricultural and residential land use. Some areas would benefit from active enhancement techniques such as releasing the conifer component (if present) in hardwood-dominated portions of the stands, converting hardwood-dominated stands to conifer, under-planting sparse stands, or density management (commercial thinning) to accelerate structural development in conifer stands.

Small-sparse: This grouping of RCUs includes both stands of small- or regeneration-sized trees, and sparse stands of medium- and large-sized trees. In both cases current recruitment potential is far removed from potential conditions, however (unlike the following grouping), these stands are forested. Active enhancement would greatly benefit many of these stands. Appropriate enhancement techniques may include releasing the conifer component in small mixed-species stands, converting the hardwood-dominated stands to conifer, under-planting sparse stands, or density management (commercial thinning) to accelerate structural development in conifer stands.

Absent: This grouping includes RCUs that are devoid of riparian tree vegetation. Vegetation within the RCUs included in this grouping consists primarily of riparian grass species, brush species, and non-riparian vegetation (cropland, pasture, and some areas of non-native vegetation). In most cases these would be the highest priority areas for enhancement. Appropriate restoration/enhancement techniques would include riparian plantings.

Due to the generally poor recruitment potential at this time, active enhancement through density management (i.e., commercial thinning) is recommended for many of the RCUs summarized above. Density management can accelerate not only LWM potential, but provide landscape diversity and wildlife connectivity. The following recommendations are for implementing density management/thinnings are adapted from BLM (2001)

General Criteria for Density Management/Thinnings:

Timber harvest within riparian areas should emphasize enhancement and restoration, and should be implemented to develop and maintain late seral forest stand characteristics. Desirable stand characteristics include larger trees for a large green tree component and recruitment of large standing dead/down LWM in future stands, multi-layered stands with well developed understories, and multiple species that include hardwoods and other minor species. Density Management would be used primarily in mid-seral stands to encourage the development of late seral conditions.

Stand modeling indicates that there is a large range of tree sizes attainable in the 30 to 80 year age range. Typical tree sizes without previous stocking control can range from 7" dbh and 56 feet tall at age 30 to 15.1" dbh and 128 feet tall at age 80. With one thinning at age 15, tree sizes can average 8.6" dbh and 56 feet tall at age 30 to 17.6 inches dbh and 128 feet tall at age 80. With thinnings at ages 15, 40, and 60 years of age at densities maximizing stand growth, the average tree sizes could be expected to reach 20" dbh and 130 feet tall at age 80. These tree sizes can be further increased by density management treatments that maximize individual tree growth rather than stand growth. Objectives in all stands would be to develop and maintain late seral forest conditions for aquatic and terrestrial species.

Density management treatments should be done cautiously if at all in stands experiencing moderate infestations of Swiss needle cast (SNC) or areas where there is a high incidence of this disease. Caution is advised in SNC infected areas because similar treatments in the Coast Range have resulted in accelerated SNC development. SNC infections can reduce diameter and height growth because of decreased photosynthetic ability with the loss of older needles. Severe SNC infestations may result in near cessation of Douglas-fir growth, or mortality from competition by non-susceptible species, pathogens or insects and sometimes directly from the disease itself. Initial indications in the Coast Range are that stocking levels greater than 60 trees per acre may allow stand development with minimal growth reductions.

Additional Criteria for Density Management/Thinnings:

In young stands less than 30 years of age generally having less than commercial diameters, additional criteria for identifying and implementing projects include:

a. Use a range of residual tree densities. Consider creating small isolated openings, less than 1/4-acre in size, over less than 5 percent of the area, and leaving 10 percent unthinned .

b. Stocking control: Highest priority are overstocked even-aged stands in excess of 250 dominant/co-dominant trees per acre or 20 percent over target levels of 200-250 trees per acre.

c. Species composition control: favor minor species including hardwoods by increasing growing space around them.

d. Retain developing understories that do not interfere with the development of dominant and co-dominant trees in the stand.

e. Standing dead/down LWM recruitment: retain enough green tree capital for recruitment in future stands.

f. Identify stands for treatment through GIS queries, aerial photo interpretation, stand exams, riparian surveys and/or stocking surveys.

In 30 to 80 year old aged stands where dominant trees are generally less than 20" dbh. These age classes generally provide the greatest opportunities for acceleration of tree diameter growth and understory development through density management. Criteria for identifying projects include:

a. Maintain average 40 to 50 percent crown closures. Use a wide range of residual tree densities. Density management leaving 30 to 60 trees per acre residual stocking should occur over 5 to 15 percent of the area. Consider creating small isolated openings, less than 1 acre in size, over 5 to 15 percent of the area, and leaving 10 percent unthinned.

b. Stocking control: Highest priority are overstocked even-aged stands of over 40 Relative Density. Relative Density is a measure that estimates stocking density of stands using stand basal area and tree diameters.

c. Species composition control: maintain minor species in treatment areas including hardwoods.

d. Enhance developing understories where present by reducing overstory stocking to allow for their growth.

e. Understories can be developed by natural regeneration, planting in openings or beneath density management treatments.

f. Standing dead/down LWM recruitment: retain enough green tree capital for recruitment in future stands.

g. Lightly stocked areas and openings created by *Phellinus weirii* infections can be treated where canopy closure is less than 40 percent. Timber harvesting followed by site preparation may occur. Native disease resistant conifer and/or hardwood species can be planted.

h. Identify stands for treatment through GIS queries, aerial photo interpretation, stand exams, riparian surveys and/or stocking surveys.

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6.0 SEDIMENT SOURCES

6.1 INTRODUCTION

The production, movement, and deposition of sediment are natural processes that occur in every watershed. In humid regions such as the western Pacific Northwest, physical and chemical weathering processes reduce rock into fragmental and dissolved constituents; surface and mass erosion processes deliver them to flowing waters; and streams transport them to depositional sites (short- or long-term) in channels and floodplains, and eventually out of the basin.

However, when human activities cause significant changes of any of these processes, problems can result. Accelerated surface erosion can strip usable soil from farm and forest lands; landslides can damage structures on or below them. If changes occur in sediment source areas or mechanisms, increased amounts of sediment introduced into streams can cause turbidity and depositional problems that may damage aquatic habitat and water quality.

Although the relief of the study area is not extreme, even in the highlands, some areas are susceptible to slope movement. On the Goat Mountain uplands, Clear Creek and its tributaries have cut into the volcanic rocks and created some steep slopes that can be unstable. But even in the middle and lower elevations, landslides are found along incised channels and terrace scarps, particularly where the nature and arrangement of rock and soil units create adverse strength or hydrologic conditions. Although some are more susceptible than others, erosion of surface materials by running water is possible almost anywhere that soils are exposed (by natural processes or land-use activities) on slopes.

6.2 CRITICAL QUESTIONS

The purpose of this module is to assess the locations and significance of sediment sources in the Clear Creek and Foster Creek basins, including both natural processes (and the physical conditions that control them) and those produced or aggravated by land use. The assessment of sediment sources is usually divided into separate evaluations of mass wasting (i.e., landslides and debris flows) and of surface erosion (from roads and other lands). Since an important part of this module is the determination of relative significance, it is desirable to integrate the mass-wasting and surface-erosion elements sufficiently to rank the various sources and processes together.

The critical questions are:

Question 6-1: At present, what are the important sediment sources in the watershed?

Question 6-2: In the future, what will be the important sources of sediment in the basin?

Question 6-3: Where are severe erosion problems that are manageable, so as to be assigned a high priority for remediation techniques or projects?

6.3 METHODS

6.3.1 General Approach

This study of the erosion potential and sediment sources of the Clear and Foster basins included procedures to evaluate mass movement and surface erosion. The scope of analysis was limited to screening using existing information, aerial photography, and GIS-derived maps. This level of analysis provides a picture of the locations and kinds of sediment sources, but no quantitative estimates of their magnitudes (such as would be produced by more detailed assessments, such as the Washington watershed analysis and Oregon watershed assessment procedures [WFPB, 1997; OWEB, 1999]). However, these methods are adequate for identifying the relative risks of erosion from various land types in the basins.

6.3.2 Background Information

The assessment of erosion conditions and potential began with the collection of existing information. The most useful study is the Oregon DOGAMI report on *Geology and Geologic Hazards of Northwestern Clackamas County* (Schlicker and Finlayson, 1979), which includes descriptions of geologic materials and processes. The accompanying geologic and hazards maps (1:24,000 scale) of the Gladstone, Damascus, Oregon City, Redland, and Estacada quads show large (generally >500 ft on a side) slump/earthflows, mudflow/debris flows, generalized landslide topography, and slope classes. The limitations of this study are its age, that it did not cover the south half of the basin (Colton, Elwood, or Bedford Point quads), and that many features, especially smaller ones (e.g., road wash-outs) were not mapped. Some large landslides are also mapped in other studies of limited parts of the basin (the Damascus quad in Madin, 1994; part of the south end in Hampton, 1972). The upper Clear Creek watershed was analyzed in the early 1990s (USBLM, 1995). None of these studies included the effects of the February 1996 storm; Hofmeister's (2000) summary inventory of 1996-97 storm damage included 17 features in the Clear and Foster basins (and many others in the vicinity), most of them associated with public roads.

The main source of soils information is the soil survey of Clackamas County (Gerig, 1985). It covers almost the entire project area, with mapping on air-photo base (1:20,000 scale), and descriptions and data (including those relevant to soil erosion) for the soil units. The BLM's watershed analysis contains estimates of road-related surface erosion (0.03-0.05 t/ac/yr), but no similar quantitative estimates of hillslope erosion (or mass wasting) with which they can be compared.

The only publication found that included ratings for erosion potential is Metro's (1997) atlas of the Clackamas River watershed. The atlas includes very small-scale (about 1:185,000) maps of relative susceptibility to mass wasting and relative surface erosion potential, based on combinations of slope gradient and geologic or soil properties. These ratings show about 8% of the Clear Creek basin with high susceptibility to mass wasting, and about 5% with high surface-erosion potential. (The Foster Creek basin was not summarized separately from the Lower Clackamas.)

6.3.3 Mass Wasting

Our approach to evaluating mass movement as a sediment source involved two main phases.

The first step was an inventory of landslide features visible in aerial photographs. For the upper end of the basin (roughly south of Redland and Logan), we used the BLM's 1998 color photos (O-98-SAL, scale about 1:12,000); for the lower (northern) part, we looked at the Spencer B. Gross 1998 color photos (SBG-M98-047, scale 1:10,200). While viewing the air-photos, along with the geologic maps (particularly the landslide maps of Schlicker and Finlayson, 1979), any apparent landslide-related landforms were mapped onto 1:24,000-scale topographic maps, and labeled with identification numbers coded to geographic location (township, range, section, subsection). Information on each feature was entered onto an inventory sheet, based on air-photo interpretation (landslide type, vegetation, land use), topographic maps (dimensions, elevation, gradient), and other supplementary maps (rock and soil types).

Very little time was available for field-checking of these features. We spent parts of four days in the field, and visited a sampling of sites through the basins. Therefore, many of the landslide data, and most of the interpretation of causes, remain tentative.

Nevertheless, as the second step, we utilized the information from the air-photo inventory (and the surface-erosion evaluation, described below) to develop ten landslide-related landform units (similar to the mass-wasting map units of watershed analysis; WFPB, 1997). These units are shown in *Map 5:Terrain Unit Map* and described in Appendix 3, they incorporate our judgments about the general geologic and geomorphic characteristics of the terrain, and particularly the relative susceptibility to mass-wasting processes. With due respect for the uncertainties inherent in this process, we include some interpretations of the possible effects of various land uses on slope stability.

6.3.4 Surface Erosion

In lieu of a detailed analysis, we developed a simple index for use in coarse screening for surface erosion. We adapted the formula used in the Metro atlas into a more precise index, based on three factors:

1. Slope gradient: mapped from available 10-m DEMs grid cells, calculated in degrees (*Map 4: Surface Slope*).

2. Soil-erosion factor, for the soil series in the basins (available as GIS coverage from the Clackamas County soil survey): the K factors have numeric values, ranging in this area from 0.05 to 0.55, simple numerical average of values for the top two horizons.

3. Simple indicator of current land use/land cover (in GIS): on a scale of 0 to 5 points (in 0.5-point increments), with 5 for the most intensive soil-disturbing practices (bare ground, agriculture), 1 for the least erosive lands (mature forest), and 0 for open water and wetlands. The 25 classes present in the basins are not as precise as would be desirable; for example,

there seems to be no distinction made within "agriculture" between row crops, Christmas trees, or pasture. Also, it would be good to explicitly include the extent and performance of unpaved roads in each land-use type into the index, but this was not possible at this stage. This is a subjective rating, and could be modified later.

For a straightforward index, the numerical components should be of the same magnitude, so that none affects the outcome too heavily. Thus, slope is divided by 10 (giving a range of 0.0 to 9.0, although maximum slopes are probably no more than 70°, giving a maximum of about 7.0); the K factor is multiplied by 10 (giving a range of 0.69 to 5.23); and the land-use factor remains 0 to 5. (In practice, multiplying one factor by 10 and dividing another by 10 cancel each other out.) The component parts of the index remain transparent and recoverable, because it can be important whether a high erosion rating for a particular area is due to natural (material and slope) or human-influenced (land use) factors.

The product of the three factors are shown in *Map 3: Surface Erosion Potential*, in a range of colors visually indicating surface-erosion potential due to the combination of slope, soil properties, and land use (blue/low to red/high). This is still not a physically-based forecast of erosion potential (i.e., in tons/acre/year) that could be compared quantitatively with other predictions of road erosion or mass wasting; but that is not the purpose at the screening stage. Rather, the index reveals the geographic extent of areas currently most susceptible to surface erosion, and allows some comparison with the areas where landsliding may be a problem.

6.4 RESULTS

6.4.1 Geology: Rocks, Soils, Landforms

The geologic history of the lower Clackamas region, spanning about 15 million years (15 Ma), has been characterized by the interaction of volcanic and depositional processes along the border between the Cascade Range and the Portland Basin (part of the Willamette structural trough). The materials include volcanic and sedimentary rocks, poorly-indurated to unconsolidated fluvial and mudflow deposits, and the soils formed on them. We briefly introduce the major units here; more information is available in Trimble (1963), Peck and others (1964), Hampton (1972), Schlicker and Finlayson (1979), Madin (1994), and the references cited therein.

6.4.1.1 Sardine (Rhododendron) Formation

The Goat Mountain highlands are built of the oldest rocks in the study region, Western Cascade volcanic rocks named the Sardine Formation or Rhododendron Formation by various workers. Andesitic lava flows erupted from vents at Goat Mountain, Soosap Peak, and other sites east and south of the study area, about 15-5 Ma. Along with associated flow breccias, the lavas built thick volcanic piles around the vents; mudflows carried some of the material north and west, where it was deposited in the lowlands (and is exposed in the bottom of Clear Creek almost to Viola). All of these rocks are now well cemented.

6.4.1.2 Troutdale Formation, Sandy River Mudstone

As the Cascade Range rose (after about 4 Ma), the ancestral Columbia River and streams flowing off the growing mountains deposited sediments in the trough to the west. These fluvial conglomerates, sandstones, and siltstones form one of the thickest layers of materials in the Portland Basin. In the study area, they lap onto the Goat Mountain highlands near Dodge and Elwood, and thicken northwestward; as much as 500 ft is exposed in the canyon of Clear Creek.

The fine-grained lower unit, the Sandy River Mudstone (or mudstone and siltstone member of the Troutdale), is mostly well-cemented, thin-bedded siltstone and fine sandstone. The Troutdale Formation (or conglomerate member of the Troutdale) consists mostly of gravel and sand, also well indurated, typically exposed above the mudstone units. In reality, these names denote fluvial facies related to channel deposits (Troutdale gravels and cobbles) and overbank or floodplain deposits (Sandy River fine sands, silts, organic material), and are probably interbedded in most areas.

6.4.1.3 7.4.1.3 Boring Lava

High Cascade-like volcanic activity extended across the Portland Basin in the late Pliocene and Pleistocene (about 3.2-0.5 Ma). Named for the Boring Hills, these basaltic flows and associated agglomerates and tuff-breccias erupted intermittently from dozens of vents in the region, forming cinder cones, shield volcanoes, and some extensive lava plateaus. In the Clear-Foster area, the main sources were in the Outlook buttes (3.15 Ma, among the oldest Boring Lavas yet dated), in the hills between Redland and Four Corners, and at Highland Butte. The Clackamas River, Clear Creek, and their tributaries later eroded into and broke up the nearly-continuous surface of Boring Lavas and cones that probably once stretched from Oregon City to the Cascade foothills.

The Boring materials include dense lava rocks, more porous lavas, breccias, and mudflow deposits. Particularly where not covered by later deposits, these rocks can be deeply weathered, in many cases leaving only scattered boulders in clay saprolite.

6.4.1.4 Alluvial Deposits: Terraces and Floodplains

Erosion and deposition processes continued throughout occasional eruption of the Boring Lavas. There are some breccias that were probably formed by mudflows coming off the volcanoes; meanwhile, streams continued to bring sediment down from the Cascades. The highest surface in the study area, called the Springwater surface, is mantled with fluvial conglomerate (with lesser sands, silts, and debris flows), deposited over Troutdale sediments and interbedded with Boring Lavas. The Springwater is thickest next to the Cascades near Dodge, and thins westward toward Logan, where it laps against the Boring volcanic plateau; it probably once formed a near-continuous piedmont or bajada surface at the foot of the Cascades. Now about 2 Ma old, it is commonly highly weathered to about 75 ft depth.

A large river – probably the Clackamas – seems to have been mainly responsible for cutting the lower terrace surfaces in the Clear—Foster region, abetted by large tributaries such as Clear

Creek. This incision has exposed up to several hundred feet of Boring, Troutdale and Sandy River rocks; broadly meandering streams then placed relatively thin deposits of gravels and sands on them. (The reasons for the fluctuations of the Clackamas have not been worked out. The causes may include some combination of glacial oscillations in the Cascades; regional base-level changes in the lower Clackamas and Willamette; and/or back-up behind the constriction at Carver.)

The higher strath terraces are older and more weathered, and they get younger and fresher toward the active river channels. Thus, after the Springwater surface (highest), the terrace occupied by Logan (about 350-550 ft elevation) is next in age and depth of weathering (about 25-30 ft). The surface containing most of the Foster Creek basin (about 250-450 ft) is next youngest, with about 10 ft of weathering. The surface between lower Clear Creek and the mouth of Foster Creek (about 150-250 ft) is younger and relatively unweathered; and the valley bottoms of Clear Creek and the Clackamas are the youngest, experiencing active channel and floodplain processes.

6.4.1.5 Soils

Soils are formed by the combination of weathering of parent materials (rocks and sediments) and organic processes, as influenced by climatic and terrain conditions, acting over time. The various kinds of soils in the Clear Creek and Foster Creek basins reflect these factors (Gerig, 1985). The character and thickness of soils depends to some degree on the relative rates of weathering and erosion processes. Rapid weathering (as in a humid, temperate climate) on relatively flat surfaces over a long time commonly produces thick clay-rich soils, such as those on the Boring Lava plateaus and the older terraces. As mentioned above, the depth of intense weathering is roughly proportional to the age of the surface, so weathered zones are thinner stepping down toward the active floodplains.

In steeper areas, rapid erosion may strip debris almost as fast as it is produced, leaving shallow, coarse colluvial soils. The Goat Mountain highlands are mostly mantled with well-drained soils formed on volcanic rocks and ash in a cool environment. But in the inner gorges of Goat Mountain and the Clear Creek canyon, relatively active stream erosion and landsliding reset the pedogenic clock more often, by either exposure of bedrock or deposition of large piles of debris.

6.4.1.6 Landforms and Processes

The Clear and Foster Creek basins cover terrain that includes moderately steep mountains built of volcanic rocks of the Cascade Range; younger volcanic buttes and plateaus extending from the edge of the Cascades northeast to the Overlook area; and a series of flat to rolling terraces formed by the Clackamas River and its tributaries. Major streams, particularly Clear Creek and its larger branches, have eroded into the upland hills and terraces, forming ravines, canyons, and terrace scarps.

Not surprisingly, most mass wasting occurs in these steeper landforms. More detail will be provided in the sections below, but it is possible to list the principal landforms susceptible to landsliding in the study basins:

1. In the valleys and ravines cut by Clear Creek and its major tributaries, especially along the edges of the Boring volcanic highlands, roughly from Dodge-Elwood to Fischer's Mill (terrain units IVvw and IVr, shown on *Map 5: Terrain Unit Map*). Stream incision has exposed strata of varying material properties: typically denser and stronger Boring Lavas near the top, and commonly weaker Troutdale and Sandy River sediments below. Gravity and active stream erosion have acted on the different materials in the canyons to produce almost continuous bands of landslides, of varying ages (old/dormant to recently active) and sizes (a few cubic yards to hundreds of acres).

2. In the deeper gorges eroded into the Sardine/Rhododendron rocks of Goat Mountain (terrain unit GMr). Stream erosion by Clear Creek, (southern) Little Clear Creek, and their tributaries into these hills has created steep slopes with thin soils over bedrock, where shallow-rapid debris sliding can occur.

3. Along terrace scarps lower in the basin: along Clear Creek (below Fischer's Mill), lower Foster Creek, other northern streams, and on the scarps flanking flights of terraces (terrain units TSs and TSg). Sliding typically happens where stream erosion is active at the base or across the slope, maintaining oversteepened gradients, but also occurs in scarps away from active streams, as they seek lower and more stable slopes.

4. In a few areas on Goat Mountain, landslides have occurred in bedrock, probably where erosion has removed the reinforcement on dipping rock layers (terrain unit GMs).

6.4.2 Landslide Inventory

6.4.2.1 Other Landslide Studies

Schlicker and Finlayson (1979) mapped landslide features (slumps, earthflows, debris flows) and suggestive topography in the northern half of the study area (north of North Highland and Springwater). Although their mapping and discussion of slope hazards was a useful starting point, it seems from our air-photo work that they underestimated the extent of landsliding in the area. However, we consulted their maps constantly as we examined the newer photos.

In their watershed analysis of the upper Clear Creek subwatershed, the BLM (1995, their Map 11) found that erosion in that basin is concentrated in incised canyons of the main stem and upper Little Clear Creek. Some of that was associated with forest roads, although for the most part the road network seems to be in good shape on the 1998 air-photos. In addition, the 1998 photos show some features that suggest soil damage and/or shallow sliding associated with past harvest in the steeper gorges.

Hofmeister's (2000) data summary and GIS maps of slides caused by large storms in 1996-97 (especially February 1996) contains only 17 features in the Clear and Foster Creek basins. The majority of these (13) are along state and county roads (especially Oregon 211), where reports and repairs were necessary. This is almost certainly a gross underestimate of the true effects of that storm in the area, which is more reasonably evaluated from the large numbers of slides in the Metro region or in Mt. Hood National Forest, where more detailed studies were carried out (e.g., Burns and others, 1998). In particular, a large number of slides occurred in the Abernethy Creek and Newell Creek canyons, near Oregon City, in geologic and topographic situations very similar to those in the Clear Creek canyon.

6.4.2.2 Inventory

Our landslide inventory identified more than 200 features in the Clear and Foster Creek basins. Table 6-1 shows the distribution (based on preliminary counts) of these landslide features, by type and subwatershed. Note that the sizes of these features vary tremendously, from small soil slips to landslide complexes hundreds of acres in area.

Table 6-1. Preliminary Count of Landslide Features

Subwatershed	Number of landslide features:				
	Deep *	**Shallow ****	**Debris flows**	**Other *****	**Acreage**
Upper Clear	27	22	6	3	610
Middle Clear	59	5	0	0	2430
Little Clear	35	0?	0	0	1560
Lower Clear	37	11+	0	3	1380
Foster	9	0	0	0	320

Notes: # Includes all features mapped from air-photos, whether certain/probable/questionable

* Deep-seated landslides include large-persistent and small-sporadic kinds

** Shallow-rapid/debris slides are underrepresented due to small size and canopy concealment

*** Includes rock slides, rockfall/bluffs, unclassified

As mentioned above, most of the unstable areas are located in a few landform types: along the valley walls of Clear Creek and its major tributaries; in the deep ravines on the slopes of Goat Mountain; along terrace scarps; and in a few bedrock slides on Goat Mountain. Most of these landslides are prehistoric, and due chiefly to natural forces. Human activities probably had a role in triggering some, particularly the small shallow slides, but we are unable to ascribe precise causes for most, based on this air-photo survey with limited field checking. However, even old natural landslides can affect human structures and land uses, or be reactivated by significant changes in slope geometry and drainage patterns.

6.4.3 Surface Erosion

In general, soils containing a larger fraction of silt and fine sand tend to be more susceptible to surface erosion, because the small particles can be more easily moved entrained by running water. Clay-rich soils have cohesion that resists entrainment; large particles in rocky soils are less likely to be washed away by small overland flows. Fine grain sizes can be present in parent materials (e.g., the fine-grained Sandy River mudstones), produced by weathering of volcanic rocks (e.g., clays in weathered Boring Lavas), or deposited on top of soils by floodwaters or winds. In addition, soils having low natural porosity, or susceptible to compaction during disturbance (e.g., by cultivation, traffic, animal trampling, etc.), are more likely to inhibit infiltration and create surface runoff.

As a result of these natural factors, the most easily eroded soils in the project area seem to be those in the northern part of the basins ((based on soil K factors; Gerig, 1985). In particular, most of the Foster Creek basin is covered by the most erodible soils; the alluvial terraces of the lower and middle Clear Creek subwatersheds (including the Springwater surface) seem to be moderately erodible. Most of the Boring Lava plateaus and the Goat Mountain highlands have soils that are less susceptible to surface erosion.

The values we assigned to land use/vegetation cover are based on assumptions about relative sensitivity to surface erosion. We rated bare ground, agricultural fields, and pastures as highly sensitive; and mature forests as least sensitive. In the medium categories, we placed medium and low-density (including hobby farms) residential areas, shrub and scrub lands, transportation corridors (and their cuts and fills), and immature forests (more recent logging). Consequently, the land use/cover index map reflects these assumptions and the current patterns: high values (erosion potential) are concentrated in the north end (more residences) and on the terraces (more farmland).

When these factors are combined with slope gradient in the product index for surface erosion pontential (*Map 3: Surface Erosion Potential*), slope somewhat dominates the result. The areas highlighted as most susceptible to surface erosion are along the terrace scarps and valley walls, especially where vegetation has been cleared for farming, houses, or timber harvest.

Even so, the soil-erosion index values for most of the study area are quite low, as can be seen in Table 6-2. Almost 95% of the area has an index value <10. The lower Clear Creek subwatershed contains the highest proportion of relatively erosion-susceptible areas, with about 39% of its area with a value >5. The other subbasins have smaller proportions, chiefly concentrated along inner gorges, valley walls, and terrace scarps.

Table 6-2. Soil erosion index values

Subwatershed	**Acreage and % having erosion index values:**											
	< 1		1 – 2		2 – 3		3 – 5		5 – 10		> 10	
Upper Clear	2867	16.9	4068	24.0	3253	19.2	3860	22.8	2545	15.0	339	2.0
Middle Clear	2435	22.1	2350	21.3	1736	15.7	2439	22.1	1632	14.8	428	3.9
Little Clear	858	14.8	1482	25.6	1170	20.2	1455	25.1	718	12.4	117	2.0
Lower Clear	2697	21.8	1086	8.8	1371	11.1	2403	19.4	3181	25.7	1636	13.2
Foster	1095	48.6	124	5.5	188	8.4	238	10.6	432	19.2	177	7.9
Totals	9952	20.6	9109	18.8	7718	16.0	10395	21.5	8508	17.6	2696	5.6

Notes: No soil data (and thus no index) for the east edge of Upper Clear Creek basin (within Bedford Point quadrangle).

(An alternative index, created by the sum of the three factors instead of the product, better reveals the effects of soil properties and land use, by emphasizing the farms and residential areas on the terraces. But by adding instead of multiplying the slope factor, extremely flat surfaces where erosion is unlikely are not as well discounted as in the product index.)

This general screening procedure points out regional tendencies, but could not pick out the local, small-scale sources of surface erosion in the basin. In general, agricultural, forestry, and development practices have been appropriate and properly applied; the condition of the basins' streams is fairly good, as indicated by the satisfactory turbidity levels.

The air-photos do not show many obvious surface-erosion features (rills, deposits of eroded soil), but most of those would be too small to show up. We saw a couple of apparent depositional areas on the photos, where small streams and ditches happened to be in the open (e.g., North Highland), indicating sediment sources upstream. None of the large farm fields that were recently plowed in the photos appeared to be obviously eroding, but the photos were taken in May and July. However, in the photos and in the field, we have observed places where preventable surface erosion is occurring. In several areas, rural-residential and hobby-farm lots seemed to have many bare/unpaved tracks (driveways, stock trails, etc.); where these areas are on moderate to steeper hillsides, they may experience surface erosion in the rainy season. Likewise, there were a few recently cleared forest lots on which the ground seemed to have been scarified after logging, and these might also be susceptible to surface erosion before the ground is revegetated or converted. Some unpaved roads showed signs of erosion, commonly due to neglect of drainage control (culverts, water-bars). This may not be a great issue on some little-used tracks, but on roads that still support traffic, fine sediment is constantly created, to be washed off by the next rains. An example is Benzinger Road, which has inadequate culverts, surface rilling, and fairly direct flow into the southern Little Clear Creek.

6.4.4 Terrain Units

In order to provide a mappable tool to discriminate areas with varying erosion processes, we divided the Clear Creek and Foster Creek watersheds into four major terrain groups, having collectively 10 subunits. These terrain units (similar to mass-wasting map units) are based on generalizations of the dominant geologic materials, landforms, and landslide processes across the region. These are shown on *Map 5: Terrain Unit Map*, and the details regarding each terrain unit are contained in a series of descriptive tables in *Appendix 3: Terrain Unit Descriptions*. These will be expanded as summary and synthesis continues.

Table 6-3 shows our summary evaluation of the relative erosion potential of the terrain units. The positions of the units is based on our appraisal of their relative susceptibility to both mass and surface erosion, although we weight mass movement and landsliding as somewhat more significant.

Table 6-3. Relative Erosion Potential of Terrain Units

Terrain groups	Relative erosion potential				
	Low (flat)				High (steep)
Goat Mountain highlands		GMc	GMs		GMr
Highland-Outlook uplands		HObp			
Valley walls and ravines				IVr	IVvw
Terraces and scarps	TFy	To	TSg		TSs

6.4.5 Summary: Critical Questions

To repeat the critical questions:

1. At present, what are the important sediment sources in the watershed?

2. In the future, what will be the important sources of sediment in the basin?

3. Where are severe erosion problems that are manageable, so as to be assigned a high priority for remediation techniques or projects?

We address these questions in a summary of our preliminary findings regarding the probable current sediment sources, susceptible terrain units (generally in descending order of sensitivity), conceivable trends into the future, and likely linkages with land-use activities. Most of this list is in the form of apparent or probable sediment sources. So far, none of them seems to be tremendously active, so future assessment work should consider whether any of them are significant sources of sediment in the streams, and to what extent land-use practices aggravate them in particular sites. These are subjects for discussion within the BRAG and future, more detailed and local assessments.

<u>Forest/upland zone: Mass wasting</u>

1) Forest roads
Terrain types: GMr, IVvw > GMs, IVr, TSs > GMc, HObp, TSg
Causal linkages: fill and sidecast failures due to improper construction, decay of strength, or drainage problems; some roads located in inappropriate terrain or sites (e.g., in ravines and on landslides).
Status: fair to good, even after stormy/wet winters of late 1990s; some road-related slides observed.
Trend: probably good, with improving techniques and little new construction; depends partly on storms.

2) Harvest and yarding on forest hillslopes, especially in steep gorges and ravines
Terrain types: GMr, IVvw, IVr, TSs > GMs > GMc, HObp
Causal linkages: loss of root strength on slopes after harvest, concentration of subsurface flow, soil damage during yarding.

Status: fair to good, even after stormy/wet winters of late 1990s; some scars in inner gorges.
Trend: depends on harvest location, rate, practices, and storms.

3) Deep-seated landslides
Terrain types: IVvw > GMs, IVr, TSs > TSg
Causal linkages: large slump-earthflows – changes in groundwater recharge?; small subsidiary debris slides – as in 1 and 2 above.
Status: large bodies rarely move, but local small slides within them (especially on streamside bluffs) more likely during storms and wet winters.
Trend: probably good; depends on storms, and rate/techniques of new road construction and large-scale harvest.

Forest/upland zone: Surface erosion

1) Forest roads
Terrain types: GMr, IVvw, IVr, TSs > GMs, TSg > GMc, HObp, To
Causal linkages: misdirected drainage (blocked ditches, culverts) causing rilling of unprotected running surfaces (especially with sediment generated by traffic), cuts, fills, ditches.
Status: undetermined from air-photos; some erosion of inactive roads seen in field.
Trend: spot problems could improve with inspection, maintenance, simple erosion-control techniques.

2) Harvest on steep slopes
Terrain types: GMr, TSs > IVr, IVvw
Causal linkages: erosion of yarding scars, other bare spots; usually short-term, unless concentration of flow onto damaged areas becomes chronic.
Status: some evidence of yarding damage in inner gorges.
Trend: depends on harvest rate, yarding practices, reforestation, storms.

3) Post-harvest site preparation (scarification, burning) on moderate to steep slopes
Terrain types: GMr, IVvw, IVr, TSs > GMr, GMc, HObp > TSg, To
Causal linkages: exposure of soil over large areas; decline of soil-mass strength from loss of roots.
Status: noted at some locations in air-photos, but generally rare.
Trend: depends on rate of harvest and site-prep techniques; usually unnecessary, and can be avoided or controlled, especially on steep slopes near streams.

Rural-agricultural-residential/lowland zone: Mass wasting

1) Activities in/near deep-seated slides in canyons, ravines
Terrain types: IVvw > IVr, TSs, GMs > TSg, HObp
Causal linkages: excavation, fill, drainage alterations causing groundwater changes; damage to buildings and roads has occurred in the region (especially around small subsidiary slides).
Status: little movement in large bodies (?); occasional local/small slides within (especially streamside bluffs).
Trend: depends on storms, rate and techniques of new road or building construction.

2) Activities in/near ravines, terrace scarps
Terrain types: GMr, IVvw, IVr, TSs > TSg
Causal linkages: excavation, fill, drainage alterations causing groundwater changes.
Status: occasional local/small slides, especially where erosion by streams or seepage.
Trend: depends on storms, rate and techniques of new road or building construction.

<u>Rural-agricultural-residential/lowland zone: Surface erosion</u>

1) Farm fields, pastures
Terrain types: GMr, IVvw, IVr, TSs > TSg, HObp, To, GMc, GMs > TFy
Causal linkages: exposure of soil in cultivation, trampling by stock, tracks, with runoff to streams.
Status: undetermined from air-photos; noted in places in the field.
Trend: probable decrease with shift from seasonal crops to Christmas trees; can be controlled by erosion-control practices, especially on slopes near streams; better surfacing and drainage on farm tracks.

2) Residential developments, rural-residential/hobby farms
Terrain types: GMr, IVvw, IVr, TSs > TSg, HObp, To, GMc, GMs > TFy
Causal linkages: exposure of soil during excavation, unpaved rural roads, drainage/runoff changes, stock trampling in small fields.
Status: noted at some locations in air-photos and the field.
Trend: can be controlled by erosion-control practices, especially on steep slopes near streams; better surfacing and drainage on rural roads.

With this level of analysis, it is not possible to quantitatively determine the relative magnitudes of sediment delivery from mass wasting and surface erosion, or the amounts from specific sites. We believe that certain landform types are more susceptible to mass movement (Table 7-3): those in the valley walls and ravines (IVvw, IVr, GMr), terrace scarps (TSs, TSg), and perhaps some old rock slides (GMs). Human activities have probably had a role in causing some landslides and much of the soil erosion, but we are unable to assign specific causes for most cases based on this limited survey. In general, all of the subwatersheds are liable to erosion problems related to land-management activities (agriculture and forestry), but especially in the steeper landforms. Problems associated with suburban development are more likely in the Lower Clear basin, and other scattered areas with development pressure.

Our preliminary appraisal, based on experience here and elsewhere, is that surface erosion (along with other chronic processes, such as soil creep) is a greater source of sediment than landsliding for most years. But in extremely wet and stormy winters, such as 1995-96 and 1996-97, even a few middling to large landslides can provide many years' worth of "average annual" sediment flux to streams, as well as damage to structures and roads.

In summary, we find that current conditions of erosion and sediment transport in the Clear and Foster Creek basins are mostly fair to good. This assessment is based on features that are visible in air-photos, a limited amount of field work, and the low to moderate levels of turbidity measured in water samples. This status is probably due more to the current low population density and land-use intensity in the basins, and not to their inherent resistance to erosion.

Trends into the future will depend on the uses and activities that are allowed or encouraged, and especially where and how they take place. More intensive suburban development, agriculture or forestry could cause an increase in the amount of sediment reaching the streams, if conducted in the wrong places (erodible landforms), in the wrong manner (without regard to erosion processes), and when inevitably struck by wet winters and big storms. On the other hand, if the erodible areas are avoided to the extent possible, and good management and development practices employed, the Clear and Foster basins could continue to enjoy low erosion rates.

6.5 INFORMATION GAPS AND MONITORING NEEDS

Landslide mapping from air-photos is a useful but imperfect technique. Any such mapping can miss some features, especially the smallest ones and those concealed by tree canopy or shadows. Photos from any given year show a biased sample of the most recent events, above all for small slides that can be quickly repaired or revegetated. Field checking is required to fully confirm the existence, dimensions, causes, activity levels, etc. of features recognized on air-photos.

From the limited amount of field work that has been done so far we cannot completely determine the extent to which human activities contribute to mass movement in the area. Although we can draw many inferences from similar situations in the region that have been more thoroughly studied (Schlicker and Finlayson, 1979; Burns and others, 1998; Hofmeister, 2000), further work would be necessary to suggest the major ways (misplaced culverts? poorly placed or built roads? improper drainage from residential areas? other?) that mass erosion can be aggravated in this particular study area.

The working maps produced in this project, showing the locations of the largest landslides, most of the landslide-susceptible terrain, many of the small mass-erosion features that occurred within the past few years, and the areas most vulnerable to surface erosion, constitute a continuation of a process of information-gathering and interpretation. More extensive field experience is necessary to confirm the information generated here; in particular, surveys of landslides and erosion damage would be most useful immediately after major storms (as occurred in February 1996) and very wet winters (as in 1996-97).

6.6 RECOMMENDATIONS AND POSSIBLE COUNCIL ACTIONS

As the state of erosion in the study basins is generally fair to good, we do not make any radical recommendations to deal with sediment sources. Most of the actions listed below utilize existing rules and procedures, well-known management practices, and voluntary cooperative measures to address specific problems. Various of these actions can be applied throughout all of the sub-watersheds.

1. Information/assessment:

a. In cooperation with Oregon DOGAMI and Clackamas County Project Impact, continue studies of mass movement in Clear and Foster Creek basins (and nearby rural Clackamas County), with field work devoted to confirming, measuring, and determining the contributory causes of slides in the region. (Such investigations can inform all other steps.)

b. In cooperation with the County, Soil and Water Conservation District, and local land-owners, conduct an inventory of unpaved roads (location, condition, drainage, etc), to evaluate the need for erosion control and remediation. This would especially involve forest roads in the Upper, Middle, and Little Clear Creek subwatersheds; and multi-home private roads in all subwatersheds.

2. Avoidance (regulatory and zoning measures):

Utilize existing land-use planning tools to ensure proper consideration of potential stability problems in the siting and construction of new structures and roads. Most of these are already in place, such as and rules regarding earth movement hazard areas and development standards for protection of natural features (including hillsides and stream corridors; see Clackamas County Zoning and Development Ordinance).

3. Prevention/protection:

a. Ensure better geotechnical evaluation of proposed structures, roads, forest practices, etc. in slide-susceptible areas (mainly by enforcement of existing rules).

b. Employ erosion-prevention measures in farm fields, pastures, hobby farms to avoid exposure of bare soil, especially on slopes, especially before/during the wet season.

4. Restoration:

Encourage and organize voluntary measures to encourage some of the above. In particular, organize appropriate neighborhood and land-owner groups to provide adequate surfacing and surface-erosion control of private rural roads; and planting, fencing, or other means of protecting waterways from compaction and erosion by livestock, off-road vehicles, etc.

6.7 REFERENCES

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7.0 WATER QUALITY

7.1 INTRODUCTION

This section of the watershed analysis report presents the results of the water quality assessment. The water quality assessment uses existing information to summarize what is known about water quality patterns in the Clear Creek Watershed. The results are followed by recommendations regarding recommendations on future monitoring needs to fill data gaps and steps that can be taken to improve water quality conditions. There was no specific water quality data for Foster Creek, but general recommendations based on observations in the Clear Creek watershed should apply.

Water quality – the biological, chemical, and physical properties of water – is an important indicator of the health of the watershed. Biological characteristics of water quality include factors such as bacterial indicators, the composition and abundance of algae, and the status of populations of aquatic insects and other organisms (macroinvertebrates). Physical and chemical characteristics of water quality include factors such as nutrients, sedimentation, temperature, dissolved oxygen, and introduced chemical contaminants.

7.2 CRITICAL QUESTIONS

In order to guide the assessment, a number of critical questions were developed during the project scoping.

Question 7-1: What are the designated beneficial uses for streams in the watershed?

Question 7-2: What are the water quality criteria that apply to streams in the watershed?

Question 7-3: Are there stream reaches identified as water quality limited on the State's 303(d) list?

Question 7-4: What do water quality studies, existing data sets, or other summary documents indicate about water quality conditions?

Question 7-5: What are the key data/information gaps in water quality information?

The critical questions were discussed at meetings with the Clackamas Basin Research and Advisory Group and with the Clackamas River Basin Council. The outcome of the meetings was a clarification on water quality issues of concern in the basin. These issues include:

a. Nutrient sources may include commercial businesses, such as golf courses, in addition to urban, agricultural and forest lands.

b. Source and fate of organic contaminants should address pesticides, herbicides, and TOC.

c. Protection of drinking water supply sources. Pay special attention to DEQ Source Water Assessment.

d. Stream temperature for protection of anadromous and resident salmonid species. Emphasis should be placed on maintaining or reducing temperature for beneficial uses.

e. Identification and prioritization of high quality stream segments. Identify potential demonstration projects.

7.3 METHODS

The purpose of the water quality section is to summarize existing information sources, identify data gaps that may require further study, and identify opportunities for water quality improvement. The Oregon Department of Environmental Quality (DEQ) provided information on beneficial uses to be protected, the criteria for their protection, and the list of "water quality limited" streams segments. Where appropriate, water quality characteristics are described in terms of the existing State of Oregon water quality standards.

Existing water quality information was obtained from cooperators of the CRBC, and from online databases (DEQ, Environmental Protection Agency, and U.S. Geological Survey), and agency websites. Relevant sources of water quality information are listed in Table 7-1. The table indicates the format of the information - paper copy reports, electronic databases, or online information. Existing reports were reviewed and pertinent results summarized and listed in this report. Where data was provided, the information was reviewed for applicability to project objectives, and evaluated in the Results section of this report.

Numerous water quality studies have been completed at the Willamette River Basin scale, for example the series of studies completed by the USGS NAWQA program. These studies generally do not provide specific information on Clear Creek, but do provide information on expected pollutants, sources, and issues at the river basin scale. The most pertinent of these reports include: Anderson, C.W., Rinella, F.A., Rounds, S.A. 1996 – trace metals and organics; Anderson, C. W., Wood, T. M., and Morace, J. L. 1997 – pesticides; Hinkle, S. R. and Polette, D. J. 1998 – arsenic in ground water; Orzol, L. L., Wozniak, K. C., Meissner, T.R., and Lee, D. B. 1999 – ground water chemistry; Rinella, F. A. and Janet, M. J. 1997 – nutrients and pesticides; Uhrich, M. A. and Wentz, D. A. 1997 – environmental setting of the Willamette Basin; Wood, T. M. 2001 – herbicide use in roadside management.

Table 7-1: Water Quality Data and Information for Clear and Foster Creeks.

	Applicable Water Quality Reports & Data Sets in Clear Creek
Clackamas County SWCD, 2001	**Report Title**: Tributaries of the Clackamas River Watershed. ***Topic: Nutrients, turbidity, bacteria*** Four monitoring sites in Clear Creek, sampled monthly in 2001. *A primary source of data for the watershed assessment.*
GE, 2002	**Report Title:** To be published as a Clackamas River Project Fish and Aquatics Work Group report. ***Topic: Nutrients, Physical chemistry, TDS, TSS, Temperature*** Preliminary data provided in excel spreadsheets Clear Creek at mouth, 04/2000-09/2001, approximately twice/month. Chemistry - 23 obs. Temperature continuous: 04/2000- 10-2001. *Provides chemistry and temperature data for Clear Cr. at the mouth in 2000 and 2001.*
Student Academy, 2001	**Report Title**: No report, on-line database. **Topic: Nutrients, Physical chemistry, Bacteria** Approx. 18 observations, three stations on Clear Creek. Metzler Park, RM 19, 2 obs. 1998-2000 Willsada Resort, RM 1.5, 4 obs., 1992-1994 Carver Bridge, RM 0.25, 12 obs., 1992-2001, ~ twice per year. *Misc. measurements are of limited value to the watershed assessment.*
Carpenter, K. 2002	**Report Title:** To be included in USGS reports, release date expected 2002. ***Topic: Pesticides and Algae*** *Clackamas River basinwide assessment planned USGS report.* *Information provided as Excel spreadsheet.* Limited observations (3-5) in Clear Creek.
ODEQ, 2001a.	**Report Title**: No report, on-line data base **Topic: Nutrients, Physical chemistry, Bacteria** Water chemistry data on the Laboratory Analytical Storage and Retrieval Database. Two stations on Clear Cr., 1969 to 1973, 5-9 samples per site. *Limited value to the watershed assessment.*

Applicable Water Quality Reports & Data Sets in Clear Creek	
Shibahara, T. 1998	**Report Title**: Lower Clackamas River and tributaries temperature monitoring program. **Topic: Temperature** *Useful in evaluating temperature in Clear Creek, 1997 & 1998.*
Shibahara, T. 1999	**Report Title:** Clackamas River basin temperature monitoring study **Topic: Temperature** *Useful in evaluating temperature in Clear Creek, 1997 & 1998.*
SFS, 2001.	**Report Title:** No report. Molt trap data in excel spreadsheet. **Topic: Temperature** *Temperature data collected with operation of smolt trap. Temperature collected May 30 – Jun 21, 2001. Shows similar temperature pattern as PGE data. Duplicates the PGE data, but covers a shorter period, so not further used in this report.*

7.3.1 Background on Water Quality Regulations

The key terms – *beneficial uses, water quality standards, water quality criteria, water quality limited*, etc. – have unique meaning in the federal Clean Water Act and Oregon water quality regulations. The purpose of this section is to help define these terms and then describe their application to the Clear and Foster Creek watershed.

Water Quality Standards include the list of beneficial uses of the stream, the criteria designed to protect those uses, and policies to implement the standards. *Beneficial uses* refer to a list of specific uses for which water is to be protected, such as livestock watering, fisheries, and recreation. Table 7-2 describes the beneficial uses designated for the Clackamas River Basin, including Clear and Foster Creek Watershed.

In a broad sense the term, water quality, includes the water column, the stream channel, and the associated riparian areas that influence the stream. The goal of the federal Clean Water Act, "*to protect and maintain the chemical, physical, and biological integrity of the nation's waters*", identifies the importance of assessing both water chemistry and the habitat required for maintaining fish and other aquatic organisms. In Oregon, this goal is incorporated into the state Water Quality Standards and the associated regulations.

Oregon *Water Quality Standards* include the list of beneficial uses of the stream, the criteria designed to protect those uses, and policies to implement the standards. *Beneficial uses* refer to a list of specific uses for which water is to be protected, such as drinking water supplies, fisheries, and recreation. *Water quality criteria* are defined to protect these beneficial uses of water.

Water quality criteria are comprised of narrative statements and numeric criteria. Numeric criteria are established when it is feasible to identify specific limits that protect these uses across the basin. Narrative criteria are used when it is infeasible to set specific targets at a regional or statewide level. Information from the scientific literature is then used on case-by-case basis to interpret the narrative criteria and apply it to the specific watershed. For example, water quality criteria are specified that limit the suspended solids and bacteria that can be present in drinking water. To protect trout in streams, the criteria provide specific numeric limits for temperature, dissolved oxygen, and contaminants. However, nutrients and sedimentation are only covered by narrative standards.

The beneficial uses and criteria identified in the Water Quality Standards provide the basis for a TMDL, the Total Maximum Daily Load, for a stream segment. The federal Clean Water Act requires states to maintain a list of streams, considered "*water quality limited*", because they do not meet particular water quality standards. The 303(d) list of water quality limited segments refers to the section of the Clean Water Act that identifies the requirement. Streams on the list may be studied further to determine if the listing was appropriate in the first place; if not, the stream segment can be delisted. If the 303(d) listing is warranted, data are collected to develop the TMDL. The TMDL is based on identifying the maximum pollutant load that can be supported and still meet water quality criteria. Pollutant loads, above the level that meet water quality criteria, are required to be reduced over time using pollution control technology for point sources, such as wastewater treatment plants, and using BMPs, best management practices, for non-point sources.

The beneficial uses of water, water quality criteria, and 303(d) listed streams in the Clear Creek are identified in the Results section.

7.4 RESULTS

7.4.1 Designated Beneficial Uses

Key Question: What are the designated beneficial uses for streams in the watershed?

Protected beneficial uses in Clear Creek encompass human needs of water such as drinking water supply and irrigation, as well as the needs of fish, wildlife, and aesthetics. The protected uses are actually designated at the river basin level in the State of Oregon water quality rules as indicated in Table 7-2. In the Clear Creek assessment, the emphasis is on protection of fisheries resources, salmon and resident trout species, affiliated aquatic biological life, and protection of drinking water supplies, both in Clear Creek, and downstream in the Clackamas River. These two beneficial uses (aquatic life and drinking water supply) are the most sensitive to pollution, so assessing these uses also provides a sufficient assessment for other uses as well.

Table 7-2: Beneficial uses of water protected in the Clackamas River Basin.

Beneficial Uses: Clackamas River Basin (OAR 340-41-442)	
Public Domestic Water Supply*	Salmonid Fish Spawning
Private Domestic Water Supply*	Resident Fish & Aquatic Life
Industrial Water Supply	Wildlife & Hunting
Irrigation	Fishing
Livestock Watering	Boating
Anadromous Fish Passage	Water Contact Recreation
Salmonid Fish Rearing	Aesthetic Quality
	Hydro Power
* With adequate pretreatment (filtration and disinfection) and natural quality that meets drinking water standards. (ODEQ 2001b).	

7.4.2 Water quality criteria.

Key Question: What are the water quality criteria that apply to streams in the watershed?

Water quality criteria are defined to protect the beneficial uses of water, and are comprised of numeric criteria and narrative criteria Table 7-3. Numeric criteria are established when it is feasible to identify specific limits that protect these uses across the basin; for example the maximum water temperature criteria of 64 Fahrenheit to protect salmonid rearing. In other cases, it is not feasible to identify numeric values for criteria until site-specific evaluations are completed, and therefore narrative criteria provide general guidance on protecting the beneficial use.

Criteria applicable to issues identified in Clear Creek are listed in Table 7-3. This includes numeric criteria from the state regulations for dissolved oxygen, pH, total dissolved solids, water temperature, bacteria, and toxic substances. Evaluation criteria, based on the literature, are listed where feasible to provide guidance in interpreting the narrative standards.

Table 7-3: Abbreviated summary of applicable water quality criteria.

Parameter (Beneficial Use)	Criteria Type/ Measurement	Criteria *
Dissolved Oxygen (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric Criteria Dissolved oxygen (mg/L)	Salmonid Spawning: Greater than 11.0 mg/L Cold Water Aquatic Life: Greater than 8.0 mg/L. (Several conditions apply, refer to State standards for details.)
pH and TDS (Resident fish and aquatic life, water contact recreation)	Numeric Criteria (pH) (Total Dissolved Solids)	pH: 6.5 – 8.5 TDS: 100 mg/L
Nutrients (Aesthetics)	Narrative Criteria (phosphorus, nitrates)	No State numeric criteria. Recommended criteria (EPA 2001) Total Phosphorus 0.04 mg/L Nitrates 0.15 mg/L
Temperature (Resident fish and aquatic life, salmonid spawning and rearing)	Numeric Criteria (temperature)	Salmonid fish rearing: 64 ° F (17.8° C) Salmonid spawning, egg incubation, and fry emergence: 55 ° F.
Turbidity (Resident fish and aquatic life, water supply, aesthetics)	Narrative Criteria (turbidity (NTU))	Not greater than 10% increase over natural stream turbidity (ODEQ 2001b). Screening criteria for aquatic life– 50 NTU (WPN 1999) Screening criteria for slow sand filter (National Drinking Water Clearinghouse 2000)
Bacteria (Water contact recreation)	Numeric Criteria *Escherichia coli*	126 colonies/100 ml. (30 day log mean) 406/100 ml. (Single sample)
Toxics (Resident fish and aquatic life)	Numeric Criteria	Numeric criteria are identified for 120 organic and inorganic toxic substances in Table 20 in the Oregon Water Quality Standards (ODEQ 2001b).
Biological Criteria (Resident fish and aquatic life)	Narrative Criteria (measured using macroinvertebrates)	Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.
Sedimentation (Resident fish and aquatic life, salmonid spawning and rearing)	Narrative Criteria	Formation of bottom deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry are not allowed.
* This description of criteria is abbreviated. Most criteria have associated conditions and exceptions that apply. The full text of the regulations should be used for a specific application (ODEQ 2001b).		

7.4.3 Stream reaches on the State's 303(d) list

Key Question: Are there stream reaches in the watershed identified as water quality limited on the State's 303(d) list?

The federal Clean Water Act requires states to maintain a list of "*water quality limited streams*" that do not meet water quality standards. Streams on the list – called the "303(d) list" for the section of the Clean Water Act – may be studied further to determine if the listing was appropriate in the first place. If there is sufficient information, then a stream segment can be "delisted". For example, some stream segments in Oregon have been taken off the 303(d) list when new information on water temperature patterns demonstrated that a stream, or sections of the stream, meets water quality criteria.

Clear Creek is not specifically listed on the 303(d) list (ODEQ 1998). The lower Clackamas River, from River Mill Dam to the mouth, is listed in the 1998 303(d) list for temperature as listed in Table 7-4. The temperature TMDL for the Clackamas River basin is in progress, and should be completed by the end of 2002 according to information on the ODEQ website. There may be some implication for management in Clear Creek arising from the Clackamas River TMDL. However, generally, the recommendations from the Clear Creek assessment developed here should be compatible with the TMDL recommendations, and can be expected to work toward common goals.

Table 7-4: 303(d) listed waters in the Clackamas River Basin (ODEQ 1998).

Stream Segment (Description)	Parameter/ Criteria	Supporting Data or Information
Clackamas River Mouth to River Mill Dam	**Temperature** Rearing 64° F (17.8 C) Season: Summer	DEQ Data (Site 402913; RM 1.2): 76% (39 of 51) Summer values exceeded temperature standard (64) with exceedances each year and a maximum of 75.2 in WY 1986 - 1995; 7 day average of daily maximum of 70.4 exceeded standard (64) in 1995.

7.4.4 Water Quality Conditions

7.4.4.1 Background

Information was available on a number of water quality parameters. Some of this data is more relevant to the issues identified by the CRBC than others, and therefore this report will focus on those most relevant pieces of information. The information will be evaluated in the following order: nutrients, bacteria, turbidity, water temperature, pesticides, and biological indicators.

Nutrient concentrations and water temperature are fundamental measures of ecological health, and directly relate to support of fish and aquatic communities. Turbidity, an indirect measure of suspended sediment concentrations, and bacteria are evaluated in relation to protection of domestic water supplies. There is very little information regarding contaminants or biological indicators in Clear Creek, so this report will only briefly touch on the relevance of these parameters and their effects on aquatic health and domestic water supplies.

Variation in water quality is often controlled by streamflow, which in turn depends on climatic factors that influence the yearly flow pattern and fluctuations in flow over longer time scales. Variability in flows is the first place to look for explanation of seasonal or annual changes in water quality. To examine how flows may have affected water quality data presented in this report, weather and streamflow patterns will be discussed briefly in relation to the five-year time frame in which water quality or temperature data were available.

7.4.4.2 Flow and Climatic Patterns

Seasonal and annual patterns in precipitation, air temperature, and streamflow exert an overriding effect on water quality conditions. Annual climatic conditions directly influence runoff and streamflows, which in turn, influence water quality conditions through natural processes such as erosion and transport of suspended solids or by dilution of chemical constituents. In many cases, the variation in water quality can be explained by these natural conditions, so it is important to consider variation in these climatic factors.

Climate stations (Oregon Climate Service 2002) at Estacada and Oregon City were the closest weather stations to the water quality monitoring sites on Clear Creek. Estacada is close to the middle of the watershed, and the Oregon City station is closest to the lower end of the watershed. Precipitation data from Estacada was used because there were many missing records at the Oregon City station.

The years 1997 through 1999 were average precipitation years (Table 7-5), and were followed by dry years in 2000 and 2001. Year 2001, when the most complete water quality data set was collected, was a particularly dry year. During the low flow period during the summer, water chemistry will be more influenced by groundwater conditions; and chemical constituents are expected to be more concentrated compared to normal years. From a data evaluation perspective, the low rainfall year should help identify zones of human influence associated with continuous sources such as septic systems, better than high rainfall years when these sources are diluted by surface runoff.

Summer air temperatures were warmer (or similar) in 1997 and 1998 than in 2000 and 2001 (**Error! Reference source not found.**). If water temperature is primarily influenced by weather patterns, one might expect higher water temperatures in 1997-1998 compared to the period 2000-2001. Air temperature measured at Oregon City was noticeably higher during the summer than at Estacada. If this station is a good indicator of air temperature near Clear Creek, then one might expect higher water temperature near the mouth of Clear Creek. However, the station at Oregon City may be influenced by the more urban environment (warmer) and may not be a particularly good surrogate for Clear Creek.

Table 7-5: Precipitation at Estacada climate station for 1997 to 2001 (Oregon Climate Service 2002).

	Total Precipitation (inches)				
Year	**Jun**	**Jul**	**Aug**	**Sep**	**Yearly Total**
1997	1.8	1.4	1.38	4.26	62.6
1998	1.92	0.17	0.12	1.91	65.8
1999	2.97	0.4	1.55	0.19	58.1
2000	2.42	0.55	0.12	1.34	49.2
2001	4.28	1.03	1.27	0.76	41.7

Table 7-6: Average maximum air temperature at Estacada and Oregon City climate stations (Oregon Climate Service 2002).

	Monthly Average Maximum Temperature (deg. C)			
Year	**Jun**	**Jul**	**Aug**	**Sep**
	Estacada			
1997	69.4	76.5	80.4	72.8
1998	71.8	79.7	80.9	78.2
1999	68.4	77.7	78.0	79.1
2000	75.0	76.7	79.4	73.6
2001	69.1	75.8	79.4	75.8
Mean*	72.3	78.7	78.8	73.2
	Oregon City			
1997	74.7	83.3	86.5	78.5
1998	77.1	86.0	85.4	81.3
1999	72.4			82.4
2000	80.1	83.0	82.8	
2001		80.5	82.7	78.4
Mean*	75.9	82.2	82.4	77.2
Note:	** Mean for 40 year period of record.*			

Flow patterns are primarily influenced by precipitation, with highest rainfall occurring in the fall and winter (Figure 7-1). The figure shows the expected average flows (the 50 percent exceedance bars), and low flow levels (80 percent exceedance) (Oregon Department of Water Resources (OWRD), 2002). Low flows during the summer period, July through September, combined with warmer temperatures create potentially unfavorable water quality conditions for fish and macroinvertebrates. During this period, the combination of high water temperatures and associated low concentrations of dissolved oxygen may be harmful to aquatic organisms. Years with normal or near-normal precipitation, 1997-1999, may be represented by the flow pattern as shown for the 50 % exceedance graph and by the 80 % exceedance graph for the low precipitation years of 2000 –2001.

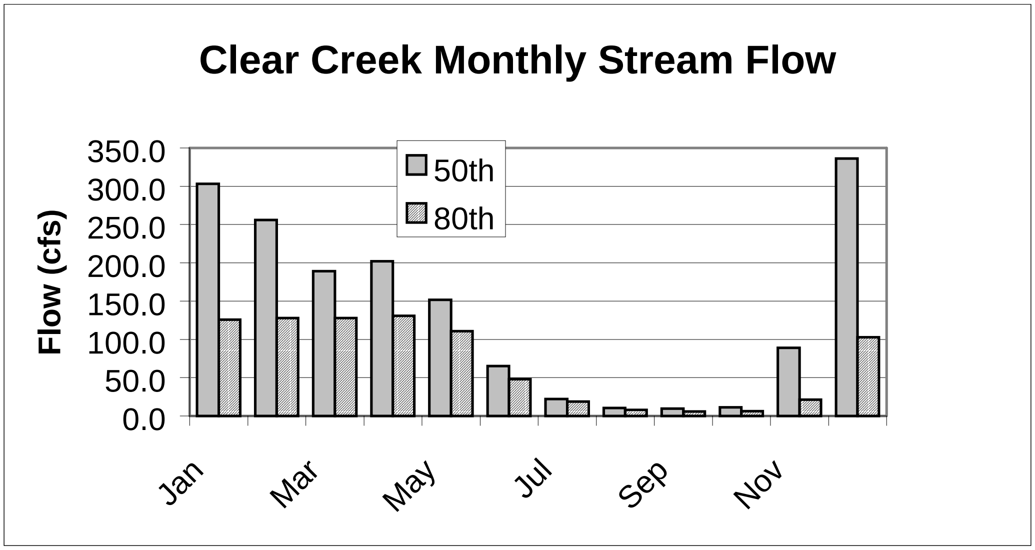

Figure 7-1: Estimated monthly streamflow at 50 percent and 80 percent exceedance levels (OWRD 2002).

7.4.4.3 Water Quality Data Evaluated

The primary sources of water chemistry data were the Clackamas County SWCD study in 2001(Clackamas County SWCD, 2001), and samples collected by Pacific Gas and Electric (PGE) in 2000 and 2001 at Clear Creek at the mouth (PGE, 2002). The five stations sampled by Clackamas County SWCD are listed in downstream order below and the location is shown in (Figure 7-2):

1. Clear Cr. @Metzler Park (#105), RM 20

2. Clear Creek @ Fishers Mill Rd (#103), RM 8.0

3. Bargfeld Creek @ Fishers Mill Rd. (#104), at RM 7.5

4. Hattan Fork @Hattan Road(#102), at RM 4.3

5. Clear Cr. @ Carver Park(#101), RM 0.3

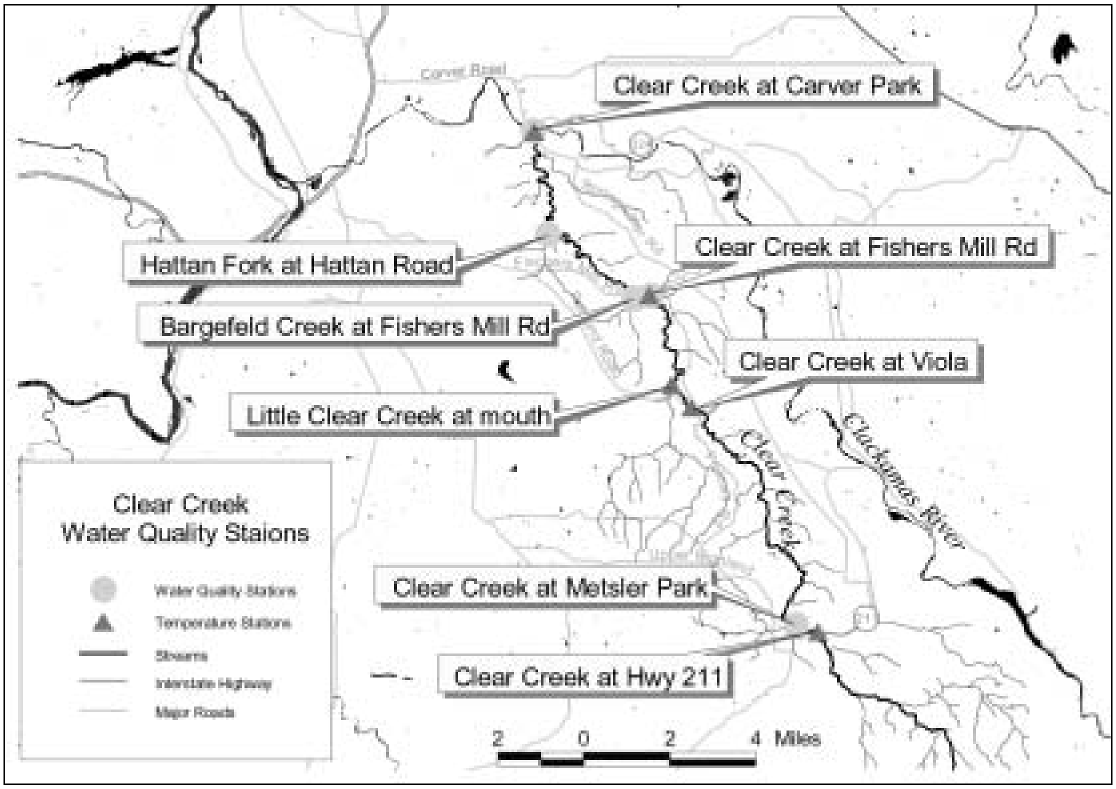

Figure 7-2: Water quality and temperature monitoring stations on Clear Creek.

The PGE samples were collected at the mouth of Clear Creek within the same vicinity as the station measured by the SWCD.

7.4.4.4 Nutrients

Nitrogen and phosphorus are the primary cause of eutrophication (eutrophication refers to the excessive enrichment of streams and lakes). Symptoms of eutrophication include excessive growth of algae, low dissolved oxygen, turbid water, changes in macroinvertebrate communities, and in extreme cases, fish kills. In addition, the increase in algae and turbidity may increase the need to chlorinate water for domestic supplies. This, in turn, may leads to higher levels of disinfection by-products that have been shown to increase the risk of cancer (EPA, 2001).

Oregon water quality standards do not specify numeric criteria for nutrients. Nutrient levels vary depending on local factors including geology, climate and soil types, in addition to human-caused sources, so targets for nitrogen and phosphorus need to be established at the watershed scale. Watershed-scale criteria have not been established for Clear Creek, but EPA has recently developed suggested criteria at the ecoregion scale (EPA, 2001). The Clear Creek watershed falls into a transition zone between the Cascades ecoregion and the Willamette Valley ecoregion. Since most of the water quality stations that were sampled are located in lower Clear Creek, the criteria developed for the Willamette Valley ecoregion will be used for this evaluation. The criteria were based on a statistical sampling of streams selected to represent reference condition or least impacted streams within the ecoregion, and so provide a useful way to screen for possible adverse conditions. The recommended criteria for streams in the Willamette valley is 0.04 mg/L for total phosphorus, and 0.15 mg/L for nitrates (often reported by water quality laboratories as the combination of $NO_2 + NO_3$).

Because of the high variability of water quality at a site, box-and-whisker plots were used to display the water chemistry data. The box plots are advantageous because they show the central tendency and range of data. The box in a box-and-whisker plot encompasses the middle fifty percent of the data (the 25^{th} to 75^{th} percentile), the whiskers show the 10^{th} and 90^{th} percentiles, and the dots show the outliers (the 5^{th} and 95^{th} percentile). Water quality may exceed criteria for a short period of time in any stream (pristine or developed), but when much of the data is above the criteria line then human sources of pollution are likely causes.

Total phosphorus and nitrate concentrations show a similar pattern from upstream to downstream (left to right on the graph) along Clear Creek (Figure 7-3 and Figure 7-4); inputs from tributaries are high in nutrients, but these inputs have little residual effect on the concentration of nutrients in Clear Creek. The apparent recovery in Clear Creek may be attributed to several possible factors – simple dilution from the higher flows in Clear Creek, groundwater inflows, or recovery as stream biota (algae and bacteria) use up the available nutrients. At Clear Creek near the mouth (RM 0.3), concentrations have decreased back to levels observed upstream at Metzler Park, 20 miles upstream.

Bargfeld Creek, coming in at 7.5 miles from the mouth of Clear Creek, shows the potential influence of livestock, agricultural practices, and increasing urbanization. Hattan Fork, at 4.3 miles from the mouth, exhibits higher levels of nutrients, which may be associated with the increased density of human activities compared to Bargfeld Creek. The PGE data shown on the right-hand side of the figures provides comparable data for Clear Creek at the mouth for 2000 and 2001. This provides some independent confirmation for the concentrations observed in the SWCD study.

The dashed line in the graphs (Figure 7-3 and Figure 7-4) indicates the EPA suggested criteria. The phosphorus criteria are exceeded at Fisher Mill Rd. (RM 8.0) and in the two tributaries, but the phosphorus concentration returns to below the criteria near the mouth in Clear Creek. Nitrate concentrations exceed the EPA criteria in Hattan Fork, but less so at the other stations. Nitrate concentrations near the mouth of Clear Creek are similar to that observed at Metzler Park. The exceedences above suggested criteria, do not specifically translate into an eutrophication problem, but the pattern of nutrient enrichment does provide a signal that such problems may be an issue in the future if nutrient concentrations continue to increase from land use activities.

Observation of water chemistry by itself is not sufficient to indicate adverse effects. The effect of excessive nutrients is observed by observation of changes to aquatic communities or through changes to 24-hour dissolved oxygen measurements. (Limited data on biological communities and dissolved oxygen is presented in Section 7.4.4.9.)

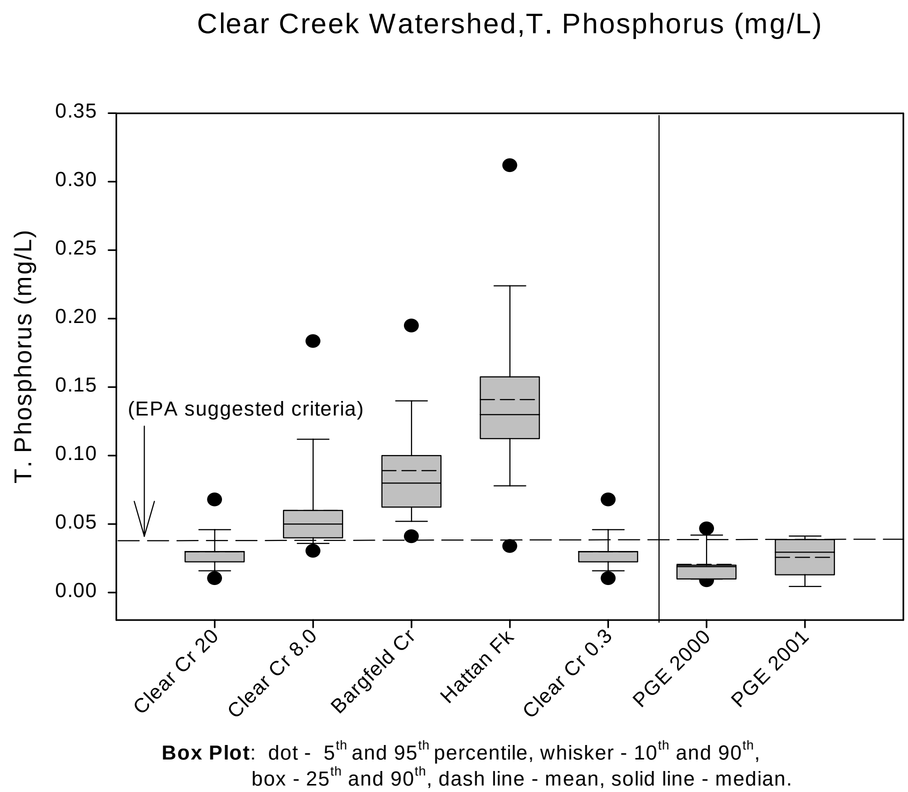

Figure 7-3: Total Phosphorus in Clear Creek. 2000 and 2001.

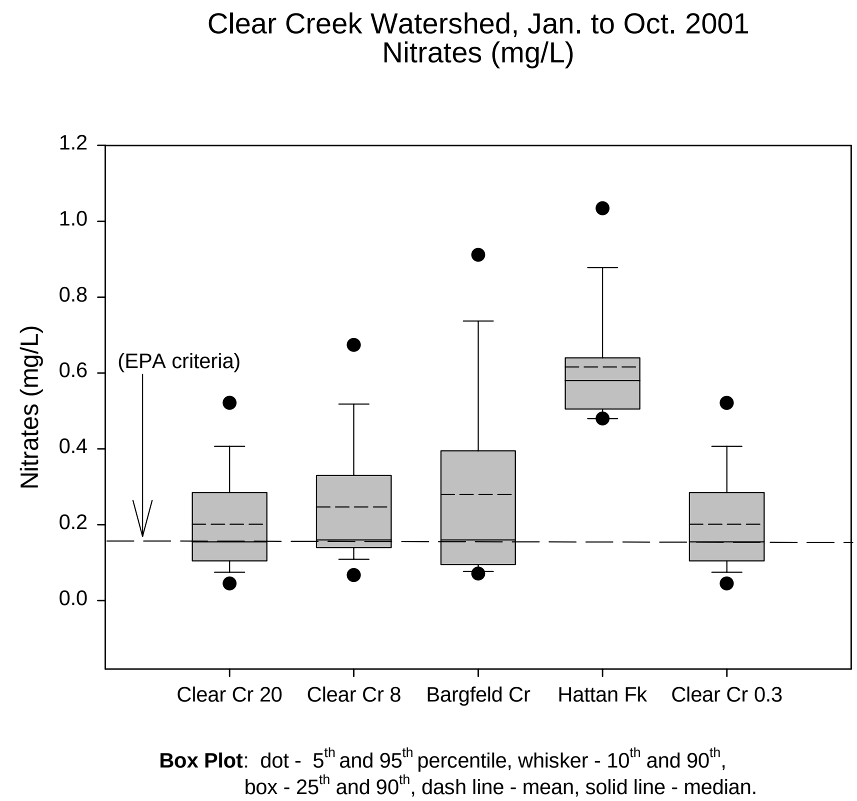

Figure 7-4: Nitrates measured in Clear Creek, 2000 and 2001.

Nitrate concentrations decrease fairly dramatically seasonally, from spring to fall (Figure 7-5). Concentrations peaked in the spring, possibly related to runoff from storm events and/or to application of fertilizer in the spring. Hattan Fork shows an interesting pattern that deviates from the other stations. Nitrate concentrations remain high throughout the low-flow period at Hattan Fork indicating a constant source of nitrates. A possible explanation is that the nitrate pattern is due to septic systems (a continuous source) associated with the increased housing in this section of the watershed. (However, other explanations are also plausible; algal growth and therefore nitrogen uptake is suppressed by stream shading, or groundwater is naturally higher in this section of the watershed.)

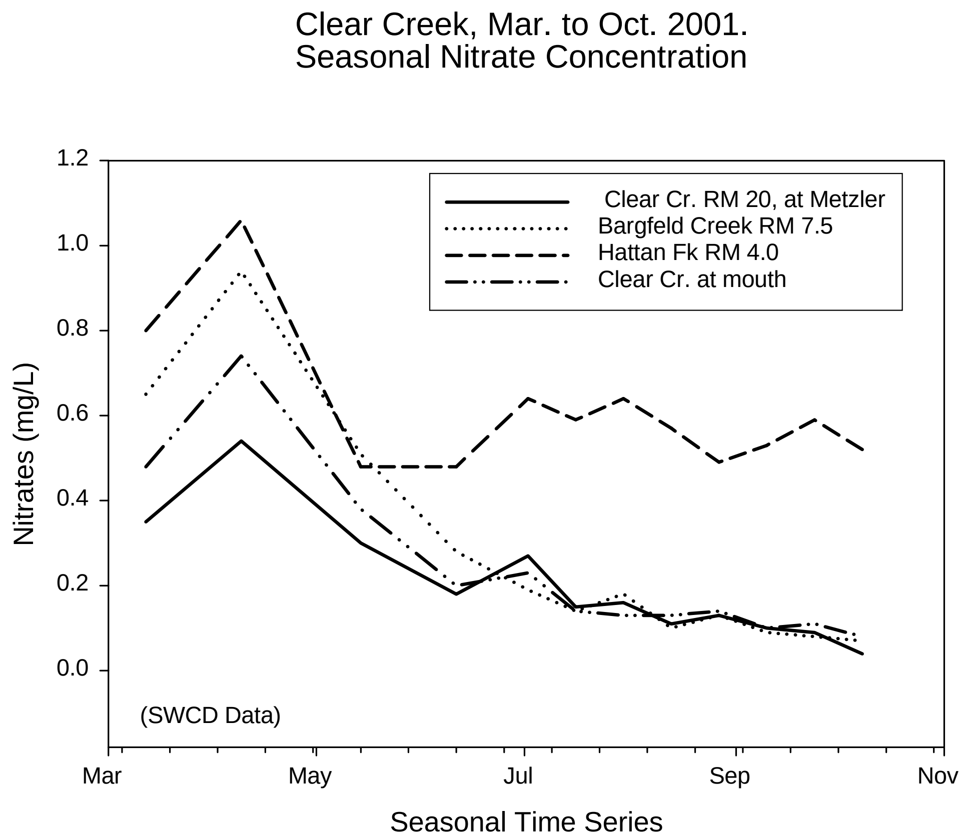

Figure 7-5: Nitrate concentrations in Clear Creek, spring to fall in 2001.

7.4.4.5 Bacteria and Specific Conductance

E. coli (*Escherichia coli*) is a type of fecal coliform bacteria commonly found in the intestines of warm blooded animals and humans. The presence of *E. coli* in water is an indication of recent sewage or animal waste contamination, and a possible indication that other pathogens may also be present. The Oregon water quality criteria value of 126 colonies/100 ml provides a useful target for screening surface water quality; however the regulatory use of the criteria depends on sample frequency.

Specific conductance is a measure of the ability of water to conduct an electrical current, which increases with the amount of dissolved salts that the water contains, and therefore provides a measure of total dissolved solids (TDS). TDS is presented along with bacteria because increases in TDS can serve as an indication of contamination from sewage, but could also be attributed to other sources such as use of road salt and fertilizers.

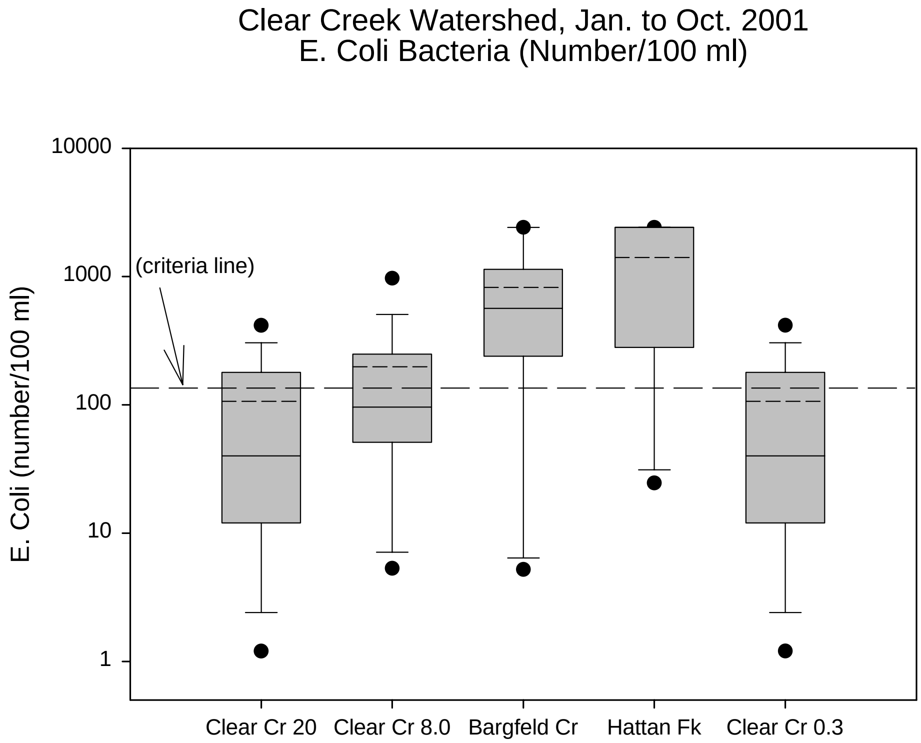

Figure 7-6: Indicator bacteria in Clear Creek, 2001.

The graphs for E. coli bacteria and specific conductance show a similar pattern with increases in both Bargfeld and Hattan Fork Creek. The concomitant increase in bacteria and TDS in Hattan Fork Creek may be an indication that septic systems in this small subwatershed are reducing water quality.

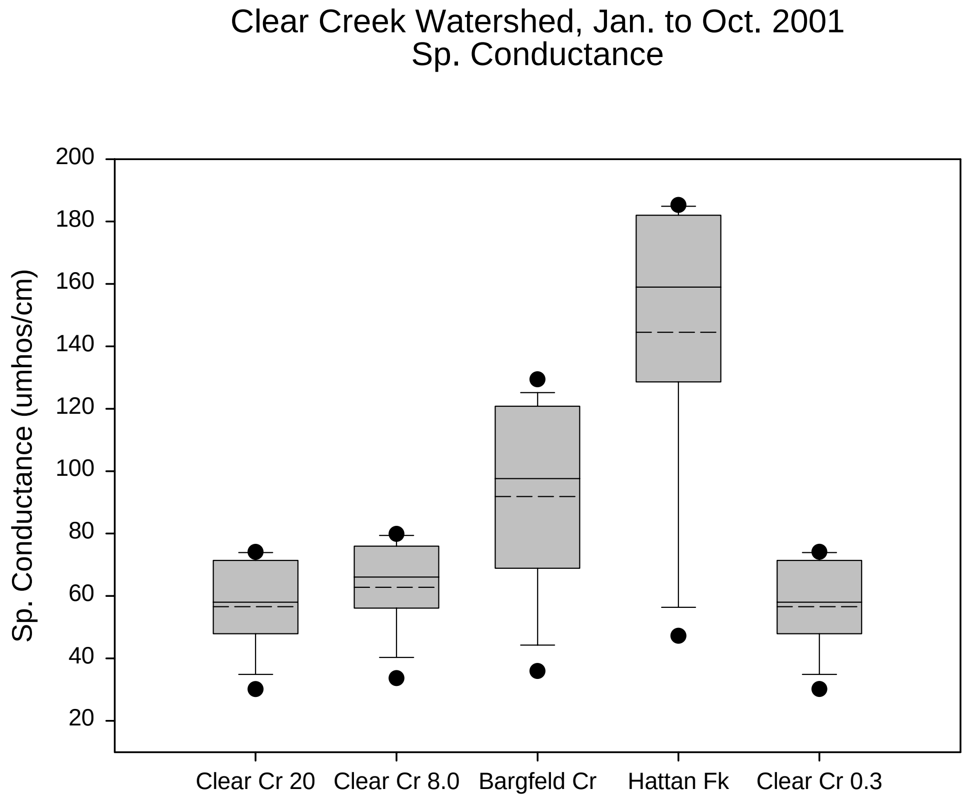

Figure 7-7: Specific conductance in Clear Creek, 2001

7.4.4.6 Turbidity

Turbidity is a measure of water clarity, and is measured in units called Nephelometric Turbidity Units (NTU). The lower the turbidity value, the clearer is the water. Suspended sediment and organic matter are the primary causes of turbidity in streams. There is no numeric standard for turbidity, but a level above 50 ntu is thought to affect salmon and trout by reducing their sight-feeding ability (Lloyd et al., 1987). Suspended solids directly impact water treatment facilities by clogging the fine sand in slow sand filters. Source water having turbidity less than 10 ntu is recommended for these systems (National Drinking Water Clearinghouse 2000).

Turbidity in Clear Creek shows a similar pattern to that observed for nutrients. Turbidity is higher in Bargfeld and Hattan Fork Creek than in Clear Creek, although the magnitude of increase in Hattan Fork is small. Generally, it appears that Clear Creek lives up to its name; water stays fairly clear throughout its length (given this data set). The increase in turbidity at the two tributaries, however, shows a source of suspended material that has the possibility of acting as the carrier for other pollutants.

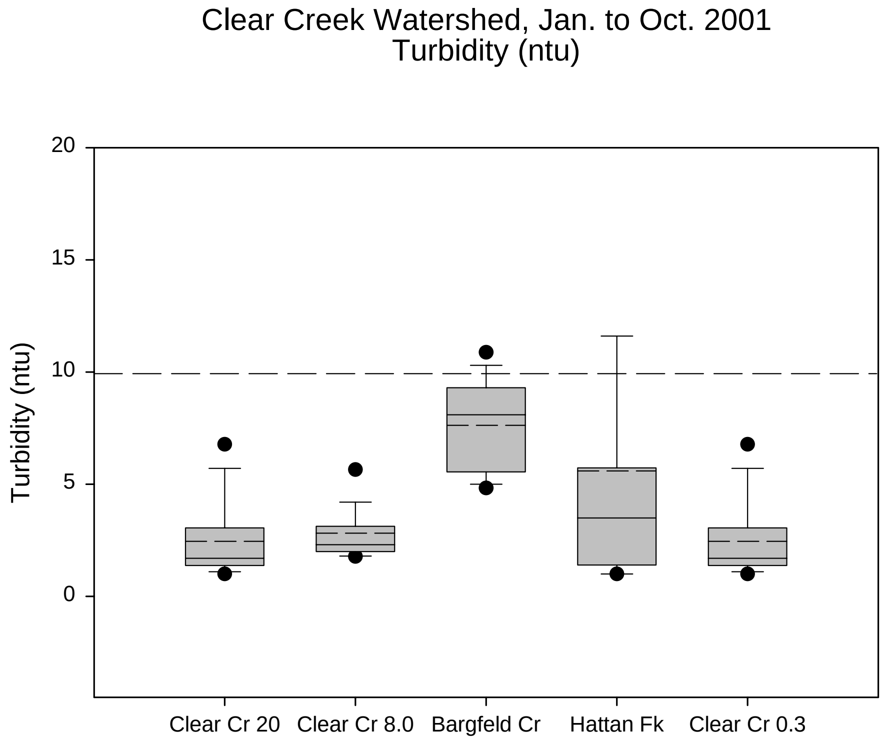

Figure 7-8: Turbidity (NTU) measured in Clear Creek, 2001.

7.4.4.7 Temperature

Water temperature data used in this analysis were provided primarily by PGE in cooperation with the Clackamas River Fisheries Working Group. Water temperature data for 1997, 1998, and 1999 were evaluated in written reports for the working group as referenced below. Data for Year 2000 and 2001 were provided as Excel spreadsheets. The raw data was evaluated in a manner similar to the working group reports to provide consistency in presentation and interpretation. Temperature is compared to the DEQ temperature criteria for salmonid rearing by calculating the *7-day moving average of the maximum daily temperatures*, and the number of days the 7-day average exceeds the criteria of 17.8º Celcius (C) or 64º Fahrenheit. (Note: the water temperature criteria for salmonid rearing is used for consistency with existing reports, however, the temperature criteria of 55º F for native salmonid spawning, egg incubation, and fry emergence may also technically apply to selected species, such as winter steelhead emergence in June/July, and fall chinook spawning in late August/September.)

Existing Water Temperature Reports

***Shibahara, T. 1998. Lower Clackamas River and tributaries temperature monitoring program*.**

The following information is summarized from Shibahara (1998). Three stations were monitored for temperature in 1997, and one in 1998 during the period July 1 through September 28, 1997. Although standard temperature data loggers were used, the report notes that the quality assurance procedures for calibrating temperature sensors recommended by DEQ were not utilized.

Three sites were measured in 1997 (Figure 7-2): *Clear Creek at Highway 211* (RM 20.5), *Little Clear Creek at the mouth* (Clear Creek at RM 11.2), and *Clear Creek at Fishers Mill* (RM 8.0) Clear *Creek near mouth* (RM 0.3) was measured in 1998 since the temperature sensor was lost in 1997. (*Note: River miles as measured by the GIS analyst for this watershed assessment differ significantly from the river mile locations reported in Shibahara 1998. For consistency, we refer to the river mile locations as generated by the GIS analyst.)*

Table 7-7: Water temperatures in Clear Creek and selected tributaries, 1997 and 1998. (data from Shibahara 1998).

Year	Monitoring Site	River Miles	# Days Sampled	Summer Average (ºC)	Summer Average Maximum (ºC)	Days over Temperature Criteria (17.8 ºC)
1997	Clear Cr. at Hwy 211	20.5	92	14.1	15.5	0
1997	Little Clear Cr. at Mouth	11.2	89	16.2	17.3	33
1997	Clear Cr. at Fishers Mill	8.0	89	17.3	18.4	64
1998	Clear Cr. near Mouth	.03	88	17.9	19.6	64

There is a general pattern of increasing water temperature from the upper watershed at Highway 211 to the mouth. Although temperature was measured during two different years, it appears that the pattern of increased temperatures at Fishers Mill in 1997, RM 8.0, is retained at Clear Creek near the mouth. Without further data, it is reasonable to assume that the temperature pattern between these two stations (at Fishers Mill and at the mouth) is similar, that is that water temperature exceeds criteria along the lower eight miles of Clear Creek. The temperature conditions at Little Clear Creek (with fewer days exceeding the criteria, 33 versus 64 days) indicate potentially better shade or channel conditions than the main channel.

Water temperatures exceed the salmonid rearing criteria for a large percentage of time during the summer, 70 % of the monitored period in lower Clear Creek. The time frame, July to September, is a critical period for salmonid rearing (and spawning in some species), and therefore a potential issue to consider for watershed improvement.

Shibahara (1998) made a comparison between the temperatures measured near the mouth in 1998 to historical temperature measurements made in 1952 by the Oregon Fish Commission. The seasonal temperature pattern measured in 1997/1998 was very similar to the pattern observed in 1952, with similar excursions above the current temperature criteria. The 1952 Oregon Fish Commission survey (as referenced in Shibahara 1998) noted that the basin was *"primarily cutover timber land with major log jams removed from over 14 miles of Clear Creek and its tributary, Soap Creek, by the OFC Engineering Division with funds from the Columbia River Fishery Development Program prior to 1954*". Using the 1952 temperature information as pre-development, therefore, would not be an accurate contrast since stream shading in 1998 could be more or less than stream shading in 1952.

Shibahara, T. 1999. Clackamas River basin temperature monitoring study.

Three of the four stations monitored in 1997/1998 were again measured in 1999. A fourth station, *Clear Creek at Viola* (RM 12) was added in 1999. These stations were monitored from approximately June 01 to August 31 (note: monitoring period inferred from figure in the report). The data were collected following DEQ monitoring protocols for quality assurance.

Table 7-8: Water temperature monitoring in Clear Creek, 1999. (in Shibahara 1999).

Year	Monitoring Site	Clear Cr. Miles	Warmest 7 days (period)	Warmest 7-day Average of Maximums (ºC)	Highest Recorded Maximum (ºC)	Days over Temperature Criteria (17.8 ºC)
1999	Clear Cr. at Hwy 211	20.5	7/28-8/3	16.8	17.5	0
1999	Clear Cr. at Viola	12	7/28-8/3	19.1	20.1	31*
1999	Clear Cr. at Fishers Mill	8.0	7/28-8/3	20.4	21.4	50*
1999	Clear Cr. near Mouth	.03	7/28-8/3	21.7	22.6	54*
Note	*Data set incomplete, ending early during the summer. Additional days exceeding criteria are likely.					

Temperature in 1999 shows a similar pattern as observed in 1998. The temperature is low in Clear Creek at Highway 211, and then increases downstream. Measuring temperature at Viola (RM 12) provides a better indication of the onset of temperature increase along the creek. Temperature in Clear Creek at Viola indicates that water is being warmed further up the creek than previously indicated by the 1998 data. This data shows that Clear Creek is exceeding the recommended temperature for salmonid rearing along the lower 12 miles.

In general, Clear Creek shows temperature patterns similar to other stations measured in the lower Clackamas River basin. The lower Clackamas River refers to the 23-mile reach below River Mill dam. The tributaries, Deep Creek and Eagle Creek, show a similar number of days that exceed the temperature criteria as the Clear Creek data. On the Clackamas River, water temperature was below the salmonid rearing criteria at McIver Park, and then warmed above temperature criteria at Barton County Park and also at the mouth. In contrast, temperatures measured in the upper basin generally did not exceed the temperature criteria or show excursions above the criteria for much shorter duration (Observations summarized from Shibahara 1999).

Water Temperature Data (PGE)

Additional water temperature data for Clear Creek was collected by PGE in 2000 and 2001 (PGE, 2002). Water temperature exceeds the DEQ temperature criteria for fish rearing for most of July and August, and for two weeks in both June and September (Table 7-9.) The seasonal pattern for the two years is quite similar as shown in Figure 7-9. Although there are annual variations in water temperatures from year to year, the data show a consistent pattern of water temperature that is outside the range to support salmonid rearing near the mouth of Clear Creek.

Table 7-9: Water temperature in Clear Creek near the mouth in 2000 and 2001 (PGE data).

Year	Month	Warmest 7-day Average of Maximums (ºC)	Highest Recorded Maximum (ºC)	Days over Temperature Criteria (17.8 ºC)
2000	May	17.0	18.33	2
2000	June	21.8	23.62	17
2000	July	23.4	25.34	28
2000	August	24.4	24.65	30
2000	September	19.5	20.77	12
2000	October	15.2	16.11	0
2001	May	18.7	19.96	6
2001	June	18.9	21.59	9
2001	July	22.4	23.28	26
2001	August	23.7	24.31	29
2001	September	20.7	20.12	14
2001	October	14.9	14.99	0

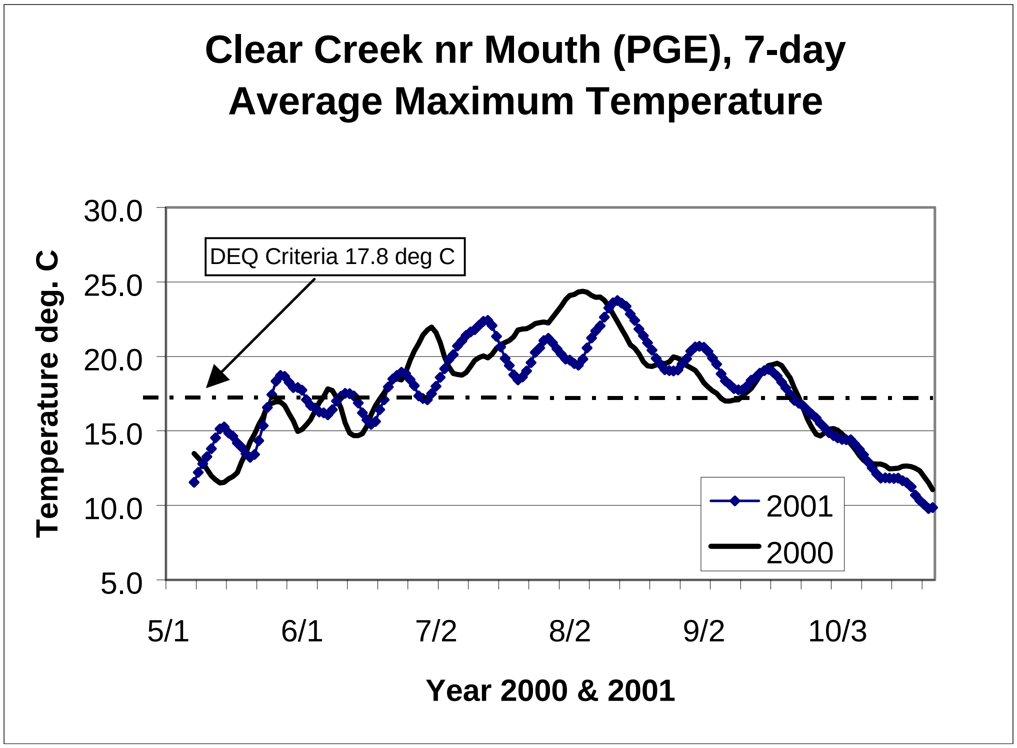

Figure 7-9. Seasonal pattern of 7-day average maximum temperature in lower Clear Creek (data from PGE, 2002).

7.4.4.8 Pesticides

Although there are a number of studies on pesticides in the Willamette River Basin the information on pesticides in Clear Creek is fairly minimal. Completed USGS studies of pesticides and nutrients in the Willamette River Basin are listed in the reference section (Anderson, C.W., Rinella, F.A., Rounds, S.A. 1996; Anderson, C. W., Wood, T. M., and Morace, J. L. 1997; Rinella, F. A. and Janet, M. J. 1997) and USGS is in the process of completing a report that focuses on the Clackamas River Basin (Carpenter 2002, in progress).

The USGS studies in the Willamette River Basin document the occurrence of a number of pesticides in basin streams (29 herbicides and 7 insecticides) and related their occurrence to land uses in the basin, primarily agricultural and urban land uses. The five most frequently detected compounds in the basin streams (not specifically Clear Creek) were the herbicides atrazine (99% of samples), desethylatrazine (93%), simazine (85%), metochlor (85%), and diuron (73%). The pesticides, lindane, dieldrin, and DDT or its metabolites, were also regularly detected.

Clear Creek Pesticide Samples

Clear Creek was sampled twice for pesticides in 2000 by USGS (Carpenter, 2002 in progress). Atrazine and desethylatrazine (a metabolic breakdown product of atrazine) were detected at low concentrations. Three other pesticides; metolachlor, pendimethalin, and triclopyr; were also detected, but were below quantification limits. The limited data does not provide sufficient information to identify the environmental hazard associated with these contaminants in Clear Creek, but their detection alone indicates the need to be aware of their use and potential for biological effects in the watershed.

Characteristics of Pesticides Detected in Clear Creek

The information provided below identifies general environmental concerns with the pesticides detected in Clear Creek samples. The summary is not intended to indicate adverse effects associated with the concentrations detected in Clear Creek, it is provided only for the reason of increasing awareness in regards to possible environmental effects.

Atrazine is a selective triazine herbicide used to control broadleaf and grassy weeds in crops including Christmas trees and conifer reforestation plantings (Ecotoxnet, 2002). It is also used as a nonselective herbicide on non-cropped industrial lands and on fallow lands. Atrazine is described in Ecotox as slightly toxic to fish and other aquatic life; however recent studies found that atrazine caused endocrine disruption in frogs at low concentrations (0.1 ug/L) , resulting in hemaphrodism, among other effects (Hayes et al., 2002). Although atrazine has a low level of bioaccumulation in fish, it is highly persistent in soil, having a half-life of 60 to >100 days (or longer than 1 year under dry or cold conditions). Atrazine is moderately soluble in water yet has a high potential for leaching into groundwater, being moderately-to-highly mobile in soils with low clay or organic matter content. Atrazine and its metabolic breakdown product desethylatrazine were the two most commonly detected pesticides found during a 1993 USGS study of shallow ground water in the Willamette Basin (Hinkle, 1997).

EPA is currently reviewing re-registration of atrazine as an herbicide, given the widespread detection of atrazine and its breakdown products in the environment. EPA's preliminary ecological risk assessment for atrazine indicates that risks exceed levels of concern for chronic effects on mammals, birds, fish, aquatic invertebrates, and nontarget plants at maximum and in some cases typical use rates (EPA, 2002).

Metolachlor is usually applied to crops before plants emerge from the soil, and is used to control certain broadleaf and annual grassy weeds in crops including highway rights-of-way and woody ornamentals (Ecotoxnet, 2002). Metolachlor is moderately toxic to both cold- and warmwater fish, including rainbow trout, carp, and bluegill sunfish. Studies on algae and fish exposed to metolachlor in water indicate that very little is accumulated and that any accumulated material is excreted rapidly when the organisms are placed in clean water. Metolachlor is moderately persistent in the soil environment. Half-lives of 15 to 70 days in different soils have been observed. Metolachlor is highly persistent in water over a wide range of water acidity. Its half-life at 20º C is more than 200 days in highly acid waters, and is 97 days in highly basic waters. Metolachlor is also relatively stable in water under natural sunlight.

Pendimethalin is a selective herbicide used to control most annual grasses and certain broadleaf weeds (Ecotoxnet, 2002). It is used both pre-emergence, that is before weed seeds have sprouted, and early post-emergence. Pendimethalin is highly toxic to fish and aquatic invertebrates and has a moderate potential to accumulate in aquatic organisms. Pendimethalin is moderately persistent in soils, with a field half-life of approximately 40 days. Pendimethalin is stable to hydrolysis, but may be degraded by sunlight in aquatic systems. Pendimethalin may also be removed from the water column by binding to suspended sediment and organic matter. It is rapidly degraded under anaerobic conditions once precipitated to sediment.

Triclopyr, a pyridine, is a selective systemic herbicide used for control of woody and broadleaf plants along rights-of-way, in forests, on industrial lands, grasslands and parklands (Ecotoxnet, 2002). The parent compound and amine salt are practically nontoxic to fish. The compound has little if any potential to accumulate in aquatic organisms. In natural soil and in aquatic environments, the ester and amine salt formulations rapidly convert to the acid, which in turn is neutralized to a relatively nontoxic salt. It is effectively degraded by soil microorganisms and has a moderate persistence in soil environments. Reported half-lives in water are 2.8 to 14.1 hours, depending on season and depth of water.

7.4.4.9 Biological Indicators and other Water Quality Data

Macroinvertebrate Indicators

Jeff Adams, a biologist currently with the Xerxes Society, Portland, Oregon, included Clear Creek in a study of the Clackamas Basin in 1997. He collected samples at three sites in the Clear Creek basin - Mosier Creek, Foster Creek, and Upper Clear Creek. The samples were evaluated using a scoring procedure that compares the data to reference conditions defined for the Clackamas Lowland Basin. A score of 50 is the ideal based on characteristics of the biota in streams with the least amount of human influence in the watershed (Adams, 2002). Jeff Adams provided an evaluation of the results that are summarized below.

The macroinvertebrate assemblage collected from Mosier Creek (score of 44) is quite similar to the reference condition. In fact, a difference between two sites of 6 points or less is considered statistically the same. Thus, Mosier Creek, upstream of the Port Blakely Tree Farm, is very close to reference conditions for Clackamas Lowland Streams. In a truly healthy stream, we would expect another couple mayfly, and caddisfly taxa; lower dominance by the three most abundant taxa (in this case snails and limpets, midges, and saddle case caddisflies), and fewer generally tolerant taxa.

Foster Creek (score of 34) falls into the moderately degraded category. The biota is clearly depressed compared to reference conditions. Community composition could certainly be worse, but mayflies, stoneflies, and particularly caddisflies are all less diverse than would be expected in a healthy stream. Also, very few taxa were found that are generally intolerant to human disturbance, indicating there are pressures present that were limiting the macroinvertebrate community.

The scoring criteria used in the study was set up for slightly smaller streams than Clear Creek itself, but the final value for Upper Clear Creek (score of 32) indicates the macroinvertebrate community is moderately depressed in comparison to reference conditions. The assemblage collected in Clear Creek is very similar to that of Foster Creek and exhibits a similar lower diversity than expected.

USGS Clackamas Basin Study

The USGS Clackamas River basin study collected one sample of periphyton near the mouth of Clear Creek (Carpenter, personal communication, 2002). Periphyton refers to the attached benthic algae (the green slippery film on the stream bottom) that form the base of the food chain in streams. Kurt Carpenter provided preliminary interpretation of this information. Chlorophyll a, the one measure of biomass, was 235 mg/square meter in Clear Creek, which exceeds the proposed biomass indicative of "nuisance" conditions (150-200 mg/square meter) (Dodds and Welch, 2000). The species composition was primarily diatoms, with no filimentous green algae. The presence of diatoms compared to filimentous green algae is generally an indicator of a healthy stream, but the biomass is indicative of a level close to that considered to be reaching a nuisance stage.

The observations on the periphyton community support the pattern observed in the nutrient data. The decrease in nutrients in Clear Creek near the mouth should be accompanied by a corresponding uptake of nutrients and growth of attached algae. However, these observations of cause-and-effect are highly speculative, given that these two sets of data were not collected in the same time frame. What this data indicates, in combination with the nutrient and macroinvertebrate data, is that Clear Creek is likely in a transitional trophic condition, neither in an obviously excellent condition or an obviously poor condition. When other conditions are favorable, such as high water flows and cool temperatures, trophic conditions would tend to toward higher quality conditions, and when these conditions turn unfavorable seasonally or become more unfavorable over time then one might expect a trend toward increased eutrophication. Again, these observations may be considered highly speculative.

Dissolved oxygen and pH

Dissolved oxygen is routinely measured when water quality samples are collected. Adequate dissolved oxygen is critical to aquatic life, however, instantaneous samples are not particularly meaningful, and can be misleading. Dissolved oxygen fluctuates on a 24-hour pattern relative to the balance of respiration, photosynthesis and temperature in the stream. A relevant way to evaluate dissolved oxygen is to measure its concentration over a 24-hour period during the algal growing season. Dissolved oxygen reported in the databases was not measured in this manner and therefore is not particularly meaningful to the evaluation of water quality conditions.

"pH" measures the degree of the acidity or the alkalinity of a solution as measured on a scale of 0 to 14. The pH of a stream is an important factor regulating the availability of nutrients and toxic elements such as metals to plants and animals. Like dissolved oxygen, however, pH fluctuates on a daily cycle in relationship to respiration. In Clear Creek, pH is measured within a very small range (± 0.5 units) of pH 7 with little fluctuation. The pH level is what is expected for the stream, and shows no degradation.

7.5 SOURCE WATER ASSESSMENT

The 1996 federal Safe Drinking Water Act (SWDA) Amendments mandated that states conduct source water assessments for public water supplies. Source water assessments are completed by the Oregon Department of Environmental Quality and Oregon Health Division in coordination with local water providers and communities (ODEQ & OHD 2000). The source water assessments delineate the groundwater and surface water source areas, which supply public water systems, and inventory the potential sources of contamination within these areas.

The Source Water Assessment for the Clackamas River Basin was completed jointly by DEQ, CRBC, the South Fork Water Board, North Clackamas County Water Commission, Clackamas River Water, and the City of Estacada. The database generated by the survey identifies all potential contaminant sources that within a designated source area, and ranks these potential sources as contaminants as low, moderate, or high.

The assessment is intended to identify "***potential***" contaminant sources (PCS) leading to identification of needs for treatment or remediation. The data was not collected in a manner to explain cause-and-effect relationships to observed surface water quality, but does provide an indication of the possible pollutant sources in the watershed.

For the purpose of the watershed assessment, the information from the PCS database was plotted by subwatershed with the stream network within the Clear and Foster Creek watershed. (See *Map 6: Water Quality.*) The PCS location is identified in the figure with the corresponding PCS identified used in the database. The database provides descriptive information on each PCS, and provides an associated qualitative risk ranking. The database has been sorted by subwatershed, and is provided to the CRBC as a spreadsheet file.

Because the database identifies only potential sources, not sources verified through cause-and-effect monitoring, and since it contains potentially sensitive and unverified private information, it will be used here only descriptively to indicate the relative distribution and magnitude of sources. (The CRBC may choose to use this database in more detail in developing specific actions in cooperation with stakeholders.)

Table 7-10 provides a summary of the distribution of contaminant sources by subwatershed. The 205 potential sources identified in the database are described by forty-one separate pollutant-source types, so a diversity of activities occurs within the watershed. For agricultural sources, the sources described as "high risk" include animal grazing activities (high livestock density, feedlots, stables, barns), managed forest land (clearcuts, recent harvest activity), and chemical storage areas (pesticide and fertilizers). Commercial sources were a minor component in the watershed and included such activities as a farm supply store, salvage yard, and auto/junk yards. Areas classified as residential included a few high density housing areas (trailer parks), utility maintenance yard, and a landfill. Homesteads on 1-acre parcels are indicated as septic systems in the table, although this appears to be underrepresented in the database. Miscellaneous sources included primarily transportation (roads and stream crossings) and transmission lines.

Table 7-10: Summary of pollutant contaminant sources in the Clear Creek watershed.

Subwatershed	Risk	Agricultural	Commercial	Residential	Septic	Misc.	Total
Upper Clear Cr.	H	10	3	1		2	
	M	1	3				
	L	10			4		
	Subtotal	21	6	1	4	2	34
Middle Clear Cr.	H	15	1			6	
	M	4	3	1		1	
	L	15		2	3		
	Subtotal	34	4	3	3	7	51
Little Clear Cr.	H	5					
	M					1	
	L	1					
	Subtotal	6	0	0	0	1	7
Foster Cr.	H	3	4	2		4	
	M			5		1	
	L	4			4		
	Subtotal	7	4	7	4	5	27
Lower Clear Cr.	H	23	4	2	2	13	
	M	5	2	11		2	
	L	7		2	8	5	
	Subtotal	35	6	15	10	20	86
Total							205

7.6 WATER QUALITY DISCUSSION

Nutrients and associated indicators

Water quality was measured at three locations in Clear Creek: at Metzler Park, at Fisher's Mill Road and near the mouth; these locations are at river mile (RM) 20, 8, and 0.3 respectively. The concentrations of nutrients, total dissolved solids, and bacteria in Clear Creek at the upper and lowermost station indicate high water quality conditions. Water quality conditions generally meet the State of Oregon water quality standards at these locations.

The intermediate site on Clear Creek at Fisher's Mill Road, shows some effect of land uses that occur within the reach. Total phosphorus, nitrates, and bacteria are elevated slightly above concentrations detected at both upstream and downstream of this location. The two tributaries that were monitored, Bargfeld Creek, at RM 7.5, and Hattan Fork, at RM 4.3, show elevated concentrations of nutrients and bacteria that exceed recommended water quality criteria. Rather than indicate a problem within the entire reach of the tributaries, however the samples likely reflect pollutant sources within the immediate upstream vicinity of the sample sites. The degraded water quality at these locations provides an indication that land uses within the drainage are having an effect on water quality and a need for attention to current and future pollutant sources is warranted.

Based on observation of land use, it appears that water quality in Bargfeld and Hattan Fork is influenced primarily by residential development and livestock wastes. Although there is no direct cause-and-effect monitoring at these sites, the most likely explanation for elevated nutrients and bacteria are the cumulative effects of septic systems, livestock wastes, and chemical application of fertilizers that occur within a close proximity to the sample locations.

Pollutants in runoff from urban areas have been found to include sediment, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum hydrocarbons, pathogenic bacteria, and viruses (EPA, 1993). The monitoring results for nutrients and associated water quality indicators in the Clear Creek watershed are consistent with the impacts of increasing urbanization, although it is presently at a scale that limits direct impacts on Clear Creek. Increased rural residential development within the watershed may be expected to degrade water quality further if development continues to increase and the same management practices continue to be used along the creek. Residential property or livestock operations that are located close to waterways provide little opportunity for the natural buffering and filtering effects of riparian vegetation. Opportunities for improving this situation are discussed in the Recommendations section.

Water Temperature

Water temperature monitoring shows a similar pattern in Clear Creek as that observed for nutrients. Water temperature was observed to be in good condition at Highway 211, but then warmed along the lower 12 miles of stream. Monitoring at Viola (RM 12) and at Fisher's Mill Road (RM 8.0) indicate violations of the Oregon water quality criteria for protection of salmonid rearing. Some warming in temperature may be associated with natural processes, such as the increase in air temperature at lower elevations, the natural increase in stream channel width in a downstream direction or possibly in relation to groundwater inflows.

The major factors that affect temperature patterns in streams are riparian vegetation and shade, channel morphology and hydrology (IMST, 2000). Riparian vegetation directly affects stream temperature by intercepting solar radiation and reducing stream heating. Limited canopy cover can also increase the difference between the daily maximum and minimum water temperatures, contributing to higher temperatures during the day due to increased solar radiation and lower temperatures at night because the insulating canopy cover has been decreased (IMST, 2000).

Human alterations of stream channel shape (morphology) can contribute to increases in water temperatures by changing the width and depth of the active channel. Changes in channel width can modify the surface area of the stream, which determines the area exposed to the atmosphere and solar radiation. Sediment deposition and decreases in large wood in the channel (fewer deep pools) also contribute to changes in channel shape. A wide, shallow stream will increase water temperatures more rapidly than a stream of the same volume that is narrow and deep. Alteration to water quantity is the third major factor that can affect water temperatures. Streams with smaller volumes of water increase temperature faster than streams with larger volumes of water.

These factors are addressed in the sections of the watershed assessment on channel modification, fisheries habitat and riparian condition. The areas needing attention are identified in these sections and associated maps.

Pesticides

Information on contaminants in Clear Creek is fairly minimal although there are numerous studies on contaminants at the Willamette River Basin scale. The limited sampling in Clear Creek detected five commonly used herbicides: atrazine and desethylatrazine (a metabolic breakdown product of atrazine), metolachlor, pendimethalin, and triclopyr. Atrazine and desethylatrazine were the two most commonly detected pesticides found during a 1993 USGS study of shallow ground water in the Willamette Basin (Hinkle, 1997). Atrazine is currently being reviewed by EPA for re-registration as an herbicide, given the widespread detection of atrazine and its breakdown products in the environment.

The detection of these pesticides does not indicate an immediate threat to beneficial uses of water. The detections do indicate that Clear Creek is likely similar to other locations in the Willamette Basin, where a diversity of other pesticides have been detected. Continued attention to controlling contaminated runoff is a prudent step, since establishing safe levels for these pesticides in very difficult.

7.7 INFORMATION GAPS AND MONITORING NEEDS

Water quality data collected by the Clackamas County SWCD (Clackamas County SWCD 2001) and Pacific Gas and Electric (PGE, 2002) provided useful information to characterize water quality conditions in Clear Creek. This water quality information combined with the results of the other watershed assessment components leads to general recommended actions that the

CRBC and community can take to protect and restore water quality. As with any study, it also leads to further questions that the CRBC and community may wish to answer.

Nutrient Sources and Effects

Although nutrients are high in some tributaries, there is little information on the specific sources of nutrients or the effects of these nutrients in Clear Creek. Excessive algal growth stimulated by nutrients can lead to depression of dissolved oxygen and shifts in the macroinvertebrate community. These changes can have direct effects on reducing growth and survival of juvenile salmon and trout. These potential effects can best evaluated by measuring dissolved oxygen over 24-hour periods (diel monitoring) during critical periods and biological monitoring of algal and macroinvertebrate communities. Diel dissolved oxygen monitoring is fairly straightforward given access to the right monitoring equipment. Monitoring biological communities is not as straight forward. Although, samples may be easy to collect, properly analyzing and interpreting results requires professional expertise.

Identifying specific sources of nutrients through monitoring may not be necessary to recommend further action. Clean-up activities may be better addressed through programs/projects that provide information, technical assistance, and cost-sharing to homeowners and landowners. Further identifying specific sources may disenfranchise the target groups rather than gain their cooperation.

Water Temperature Monitoring

Monitoring to date indicates that water temperature exceeds recommended criteria for salmonid spawning and rearing along the lower reach (12 miles) of Clear Creek. Since the CRBC has been involved in tree-planting projects and water temperature may be a limiting factor for salmonid species it would be useful to establish a long-term water temperature monitoring program. A comparable multi-year data set would be necessary to detect any long-term changes in water temperature attributed to these projects since temperature varies over longer term periods due to climatic variation.

Pesticides

There is limited data on pesticide residues in the Clear Creek watershed. The limited data indicates the occurrence of some commonly used herbicides. Detection of herbicides is likely to increase with further monitoring. Voluntary actions to reduce runoff and contamination of pesticides should be an action regardless of any future monitoring effort.

7.8 RECOMMENDATIONS AND POSSIBLE COUNCIL ACTIONS

Prevention/Protection:

Passive restoration refers to activities that prevent or avoid degradation. Since Clear Creek is generally in good condition the CRBC may be effective in protecting water quality in the long term by coordinating protective actions with other governmental entities. Prevention may invlove such activities as Planning and Zoning that minimizes the effect of increasing population density on sensitive areas. Generally, streams, riparian areas, and wetland areas are sensitive areas where clearing, increased impermeable areas, livestock/pet wastes, and chemical application will have the greatest negative impact. Buffering these areas from increased urbanization and lower densities will help maintain the high water quality that is generally observed in Clear Creek.

A second aspect of prevention/protection is to maintain those landscapes/land uses that currently provide higher water quality. Although monitoring in the forested zone was minimal, it is apparent that the forested land use curently provides higher water quality (nutrients, bacteria and temperature) than the mixed agricultural/urban areas. Use of BMPs in forestry that protect and maintain water quality and current actions to improve riparian stands for LWD recruitment and shade should be encouraged.

Advocacy and Coordination:

There are numerous agencies that are interested in assisting the CRBC in protecting and enhancing watersheds; for example, Metro, OWEB, DEQ, ODFW, ODF,USDA NRCS, OSU Extension, and the Clackamas County SWCD. The Clackamas SWCD is a particularly suited to assist the CRBC in working with local landowners on the small acreages and hobby farms that occur in Clear Creek. The Clackamas County utilizes a "Micro Watershed" based approach to work with private landowners.

The SWCD Micro Watershed approach may be particlurly applicable to the small watersheds with current nutrient and bacteria problems:

1) Bargfeld Creek (confirmed problem)
2) Hattan Fork Creek (confirmed problem)
3) Lower Clear Creek (suspected – any concentrated rural/urban population area).

Education:

Education activities can also be closely coordinated with other agencies such as OSU – Extension and the Clackamas County SWCD. Education activities specific to water quality protection may include:

1) Livestock, manure, and nutrient management

2) Pesticide and fertilizer application

3) Backyard conservation practices to protect streamside zones and wetlands.

4) Crop, pasture and forest practices

Restoration Activities: Restoration refers to active management activities. Restoration activities for water quality should be prioritized in the denser population zones in the Lower Clear Creek subwatershed. Restoration activities may include:

1) Riparian planting programs (associated with education to maintain riparian zones).

2) Riparian fencing and livestock management to enhance vegetative coverage.

3) Livestock manure management.

4) Pond management to decrease the impact of in channel ponds on water quantity and temperature.

5) Water management to decrease flow diversions and restore/enhance wetlands.

Information/assessment:

As described above under Section 7.7 there are data gaps, but not to the extent to prevent the CRBC from moving forward on restoration activities. The following list describes some information needs and approaches for information gathering for CRBC consideration.

1) ***Septic Systems***. The data obtained in the two small tributaries, Bargfeld and Hattan Fork Creek, indicate a high potential for contamination from septic systems. This issue may be worth investigating in more detail to determine: a) if the pollutant source is indeed septic systems, b) if so, is this due to poorly designed, undersized, or failing systems, c) and whether some alternative to septic systems are called for. The CRBC should coordinate with the local health district to determine a course of action.

2) ***Filling in Spatial Coverage***: Data on other streams and sub-watersheds, specifically Middle, Little, and Foster Sub-watersheds is entirely lacking. The CRBC should consider whether further monitoring in these areas is needed, or whether applying conclusions from monitoring in similar land use areas is sufficient to move forward with restoration activities.

3) ***Hot Spots***: As identified in this assessment, there are tributaries that appear to be pollutant hot spots (Hattan Fork Creek, Bargfeld Creek, and other nearby tributaries). Continuing to monitor these locations over time may assist in understanding cause and effect as well as whether the initial results are an anomoly or a true representation of the ambient condition.

4) ***Volunteer Monitoring***: Volunteer monitoring is a good way to involve local landowners and promote ownership in the program. Volunteer monitors may be paired up with the "Micro Watershed" approach for watershed restoration described by the Clackamas County SWCD. Volunteer monitoring should be viewed as primarily an educational excercise, and not a substitute for professional level assessment.

5) ***Coordinated Monitoring and Trend Data***: As with many watersheds, monitoring in Clear Creek lacks a Monitoring Program Plan. A comprehensive monitoring program plan would assure that data is collected with sufficient rigor to answer questions in a scientifically valid manner. Currently a number of entities collect data, but the value of that data is compromised by the lack of an objective based monitoring plan that outlines minimum sample frequency, standard protocols, and quality assurance/quality control procedures.

   Trend data at a small number of selected stations will provide the most useful information over time to determine if water quality is getting better or worse in Clear Creek. Trend analysis requires a high sample frequency (number of samples/time period) over a long period of time to be effective. Monitoring programs also require continuous flow data at an associated gaging station to be effective in interpreting the data.

   A detailed Monitoring Program Plan should be developed prior to collection of any further data sets. The monitoring plan should be developed with professional assistance from an experienced water quality specialist. Refer to the OWEB Watershed Assessment Manual, Chapter 10, (WPN 1999) and Water Quality Monitoring Guide Book (Oregon Plan for Salmon and Watersheds 1999) for further guidance.

6) ***303 (d) Listing***: Several impaired reaches may qualify for listing as a water quality limited waterbody with Oregon Department of Environmental Quality. This may include:

   a. Clear Creek, from mouth to Viola, 12 RM. Temperature (64 degrees F)– Salmonid fish rearing

   b. Bargfeld Creek (7.5 RM), Hattan Fork Creek (4.3 RM)
      Total phosphorus, nitrates, E. coli bacteria.

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8.0 FISHERIES

8.1 INTRODUCTION

The purpose of the Fisheries and Aquatic Habitat assessment is to compile and evaluate available information on fish populations, in-stream habitat and migration barriers and actions that can be taken to enhance or restore those habitats. The information will be used to evaluate impacts to important areas of current fish use and prioritize potential voluntary action opportunities.

8.2 CRITICAL QUESTIONS

Question 8-1: What salmonid species are documented in the watershed, are any of these currently ESA or candidate species?

Question 8-2: What is the distribution, relative abundance and population status of salmonid species in the watershed?

Question 8-3: Which salmonid species are native to the watershed, and which have been introduced to the watershed?

Question 8-4: What are the species interactions?

Question 8-5: What is the condition of fish habitat in the watershed (by sub-basin) where habitat data has been collected?

Question 8-6: Where are there potential barriers to fish migration?

8.3 METHODS

This portion of the report relies on finding and compiling existing information to develop distribution maps for resident and anadromous fish. At the start of the project a literature search was conducted and initial contacts made with agency representatives. A database of references was completed, reviewed and compiled. Table 8-1 summarizes the existing reports and pertinent results.

Table 8-1: Summary of applicable Fisheries Reports

Applicable Fisheries Reports & Data Sets in Clear and Foster Creeks	
Murtagh et al. 1992	**Report Title:** Clackamas Subbasin Fish Management Plan **Topic:** Describes habitat and the background status, management considerations, policies, and objectives for Winter Steelhead, Summer Steelhead, Spring Chinook salmon, Fall Chinook salmon, Coho salmon, warm water fish, trout, and whitefish in the Clackamas River subbasin. *A primary source of data for the assessment.*
BLM 1995	**Report Title:** Upper Clear Creek Watershed Analysis **Topic:** Investigate and document an ecological understanding of the Upper Clear Creek Watershed. *Limited fisheries information on Clear Creek.*
Cramer, S.P. et al. 1995	**Report Title:** Status of Willamette River Spring Chinook Salmon in Regards to the Federal Endangered Species Act - **Part 1**, **Topic:** Part 1 of two reports designed to assist the NMFS in determining whether spring Chinook should be listed as threatened and endangered. Reports assemble and synthesize the best available information on spring Chinook salmon status in the Willamette River Basin. *No specific mention of Clear or Foster Creeks.*
Cramer, S.P. et al. 1996	**Report Title:** Status of Willamette River Spring Chinook Salmon in Regards to the Federal Endangered Species Act - **Part 2**, **Topic:** Assembles and synthesizes the best available information on Spring Chinook population structure, trends, and risks to persistence of spring Chinook salmon in the Willamette River Basin. This report specifically determines the extent and causes of trends in abundance and assesses the risks that threaten persistence. *No specific mention of Clear or Foster Creeks.*
Foster, C.A. 1998	**Report Title:** 1997 Willamette River Spring Chinook Salmon Run **Topic:** Describes characteristics of the spring Chinook salmon run in the Willamette River, the effects of recreational fishing on the run, and fish production and its contribution to fisheries. *No specific mention of Clear or Foster Creeks.*
Cramer, S.P., Cramer, D.P. 1994	**Report Title:** Status and Population Dynamics of Coho Salmon in the Clackamas River **Topic:** Report assembles the known information concerning the native coho population in the Clackamas River. This population is considered the last remaining viable wild coho population in the Columbia Basin. *No specific mention of Clear or Foster Creeks.*
S.P. Cramer and Associates, 1997	**Report Title:** Synthesis and Analysis of the Lower Columbia River Steelhead Initiative, S.P. Cramer and Associates. **Topic:** Describes conservation measures and analyzes their effects on wild steelhead population of the Lower Columbia River ESU. Reviews steelhead demographics, defines the problem, offers a design for a solution, and then analyzes that proposed solution. *No specific mention of Clear or Foster Creeks.*

The upper extents of fish use maps were obtained from Oregon Department of Forestry (ODF). The ODF maps were only available in a paper format. Hence the information from the ODF maps was digitized onto the base stream layer. Large portions of the stream network had not been surveyed for upper extent of fish use and the data on the ODF maps represented best guesses. As part of the Clear and Foster Creek barrier assessment barrier assessment project upper extent of fish for streams that did not have fish presence surveys done on them was re-evaluated using interim guidance. The interim guidance for this region, estimates the upper extent fish use when a stream reaches a watershed area of 100 acres or less, a consistent stream channel slope of 20% or more, or there is a marked waterfall on a map in conjunction with a small sized fish bearing stream. These points were mapped using GIS and are incorporated in *Map 7: Fish Distribution.*

The ongoing barrier assessment project is completing field surveys to document the approximate end of fish use. The end of use is marked at falls of four feet or more for resident trout (8 feet or more for salmon and steelhead) if a jump pool is present, two foot falls with absence of a jump pool that is 1.25 times the jump height, 20 feet or more of 20% gradient channel for resident trout (30 feet or more for salmon and steelhead) if pools are present, 20 feet or more of 12% gradient if no pools are present (30 feet for salmon and steelhead), or no pools approximately 12 inches or more in depth during spring spawning season over a significant length of channel. These methods were used to determine upper extent of fish use on selected streams in the Clear and Foster Creek watersheds during field work during the summer of 2002. *Map 7: Fish Distribution* shows these boundaries where they were determined at the time of this report, this information may need to be updated at the completion of the barrier assessment project..

The GIS data from the ODFW/ Streamnet site on distribution of anadromous species in the watershed was downloaded. This information was evaluated and combined to create one map showing the distributions of anadromous and resident fish in the watershed.

Natural fish passage barriers were identified by consulting the ODFW passage barrier database, review of the Upper Clear Creek Watershed Analysis (BLM 1995), and review of the Clackamas Watershed Atlas (Metro 1997).

Fish stocking data were obtained from the ODFW/ Streamnet WEB site (http://www.osu.orst.edu/dept/nrimp/). ODFW biologists were contacted about other fish enhancement programs that have occurred in Clear and Foster Creeks.

There was limited fisheries data and no existing habitat data available for Clear Creek. As a result the Watershed Council funded an effort to collect baseline habitat data in conjunction with the field verification efforts. Sampling sites were selected based on 1) presence of anadromous fish habitat, 2) representative CHTs, and, 3) access. Data was collected following habitat survey protocols outlined in Washington DNR Watershed Analysis manual (DNR 1997). A minimum of 100m (or 10 channel units in streams with bank full widths < 2m) were quantitatively surveyed.

The collected data was evaluated through compassion to selected parameters (physical barriers, substrate, large woody debris, pool frequency, pool quality, width-depth ration and streambank condition) in the National Marine Fisheries Service matrix of pathways and indicators (NMFS

1996) to evaluate properly functioning condition (Table 8-2). The data was summarized and analyzed to provide an evaluation of the current habitat conditions in these reaches.

Table 8-2. Matrix of pathways and indicators to evaluate properly functioning condition (PFC) in Clear and Foster Creeks (from NMFS 1996).

Indicators	Existing condition		
	Properly functioning (PF)	**At risk (AR)**	**Not properly functioning (NPF)**
Substrate	Dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%	Gravel and cobble is subdominant, or if dominant, embeddedness 20-30%	Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%
Width/depth ratio	<10	10-12	>12
Large woody debris	>80 pieces/mile >24" diameter >50 ft length; and adequate sources of woody debris recruitment in riparian areas	Currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	Does not meet standards for properly functioning and lacks potential large woody debris recruitment
Streambank condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding	80-90% stable	<80% stable
Off-channel habitat	Backwaters with cover, and low energy off-channel areas (ponds)	Some backwaters and high energy side channels	Few or no backwaters, no off-channel ponds
Floodplain connectivity	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly
Pool frequency: Channel width / No. pls/mi 5 ft 184 10 ft 96 15 ft 70 20 ft 56 25 ft 47 50 ft 26 75 ft 23 100 ft 18	Meets pool frequency standards and large woody debris recruitment standards for properly functioning habitat	Meets pool frequency standards but large woody debris recruitment is inadequate to maintain pools over time	Does not meet pool frequency standards
Pool quality	Pools >1 meter deep (holding pools) with good cover and cool water, minor reduction of pool volume by fine sediment	Few deeper pools (>1 m) present or inadequate cover/temperature, moderate reduction of pool volume by fine sediment	No deep pools (>1 m) and inadequate cover/temperature, major reduction of pool volume by fine sediment

8.4 RESULTS

8.4.1 Fish Species, Distribution and Relative Abundance

- *What salmonid species are documented in the watershed, are any of these currently ESA or candidate species?*
- *What is the distribution, relative abundance and population status of salmonid species in the watershed?*

Anadromous fish occurring in the Clackamas basin include: spring and fall chinook, coho salmon, winter steelhead, summer steelhead (non-native), migratory cutthroat trout and pacific lamprey (Cramer xx). Clear and Foster Creeks are utilized by fall chinook, winter steelhead and coho salmon. The distribution of anadromous fish is limited by 15' to 20' falls on both Upper Clear Creek and the North Fork of Clear Creek (D. Roberts BLM, personal comm., BLM 1995), (*Map 7: Fish Distribution*)

Resident salmonids potentially occurring in Clear and Foster Creeks include, cutthroat trout, rainbow trout and mountain whitefish. The last confirmed sighting of a bull trout in the Clackamas River was in the early 1970's, bull trout are thought to have been eliminated from the basin (Cramer xx). Other resident fish potentially occurring in Clear and Foster Creeks include, sculpin, longnose dace, speckled dace, shiners, brook lamprey, suckers and northern pikeminnow.

8.4.1.1 Fall Chinook

Fall Chinook are federally listed as Threatened. They utilize the lower portion of Clear Creek (*Map 1: Base Map*) for spawning and rearing. Current run probably originates from 'tule' stock released in the Clackamas River from 1952 to 1981, or may be remnants of the historic native stock (Murtagh et al. 1992, Cramer xx). Hatchery produced fall chinook have not been released in the Clackamas basin since 1981 (Murtagh et al.1992, Cramer xx). There is limited information on the historic and current distribution and abundance of fall chinook, this is partially because of the difficulty in distinguishing them from spring chinook (run timing overlaps and at spawning they look similar)(Cramer xx). However the average annual returns of fall chinook to the Clackamas basin from 1981 to 1991 is estimated to be 840 fish, which may include some spring chinook (Cramer xx). The Clackamas fall chinook have not been popular with anglers due to their dark color, early spawning time and poor flesh quality (Murtagh et al. 1992)

The timing of fall chinook in Clear Creek is summarized in Table 2. Fall chinook only spawn in the lower reaches of Clear Creek and have not been documented using Foster Creek. Spawning occurs in late August and September with the peak in mid-September (Murtagh et al. 1992). Smolts out migrate at age zero+ starting in April and peaking in June.

8.4.1.2 Winter Steelhead

Winter Steelhead stocks in the Clackamas basin are federally ESA listed as Threatened. The winter steelhead population consists of fish from Eagle Creek Hatchery stock, Big Creek Hatchery stock and native wild population. Winter steelhead use a wider variety of habitat types than spring chinook and coho and will use all accessible stream reaches (Cramer xx). There have been recent increases in hatchery returns and declines in wild steelhead returns have raised concerns that hatchery fish may be mixing with wild fish (Cramer xx). The timing of wild winter steelhead in Clear Creek is summarized in Table 8-3. Migration occurs from November through June and spawning occurs from late April through June (Cramer xx, Murtagh 1992). Juvenile steelhead rear for 1 year or more and then outmigrate on high spring flows (Murtagh 1992). The Eagle Creek Hatchery stock and Big Creek stock were released in the Clackamas to improve angling opportunities in December and January. Returns of these fish are earlier (January – April) than the wild steelhead returns.

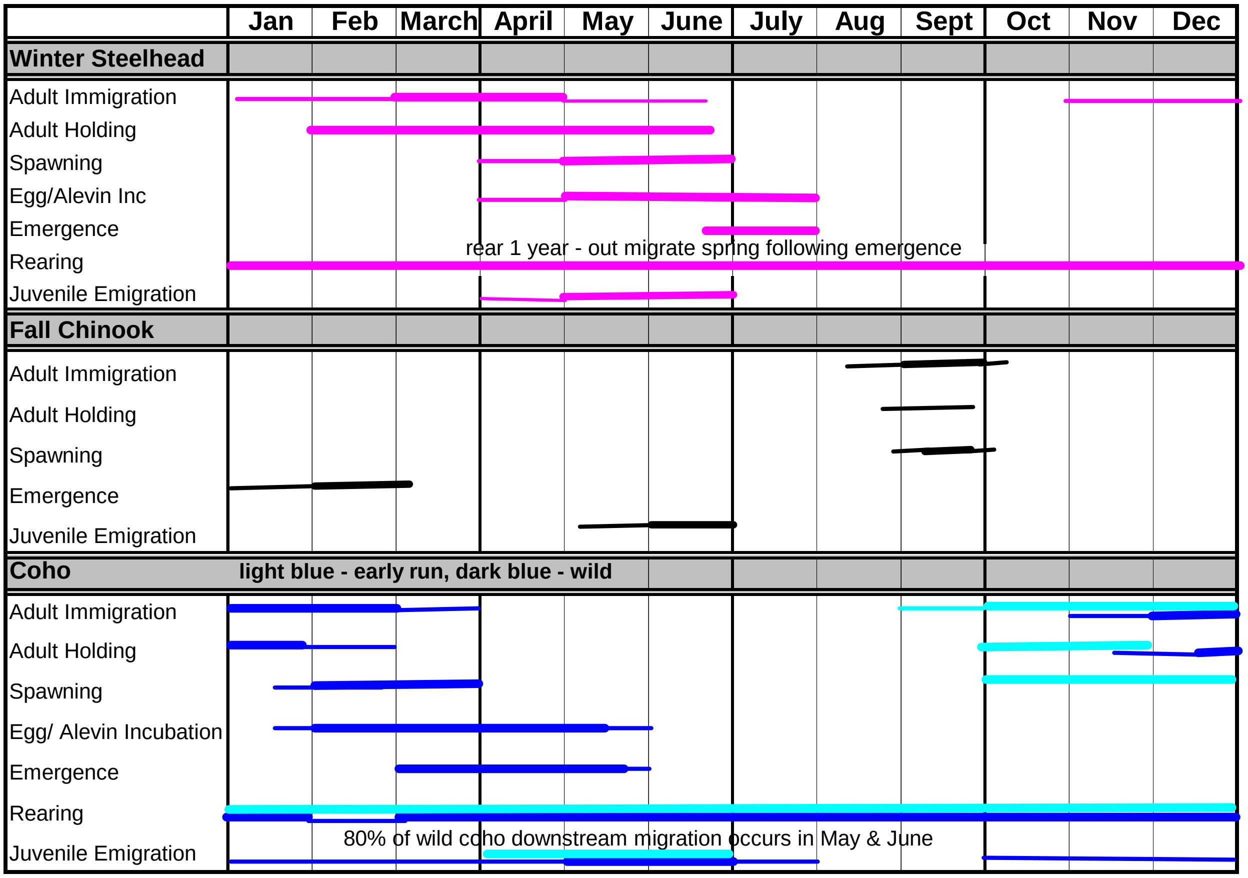
8.4.1.3 Coho Salmon

The wild coho salmon stock in the Clackamas basin is a candidate species for federal ESA listing and is state-listed as Endangered. There are both wild and hatchery stocks of coho salmon occurring in the Clackamas basin. The hatchery stock (called early run) is produced at Eagle Creek National Fish Hatchery and stocked in the basin.

There is also a self sustaining population which is thought to have originated from fish from Eagle Creek hatchery but which reproduces naturally throughout the basin (Cramer xx). The early run fish were introduced to provide a recreational fishery and to provide coho for harvest in downstream and ocean fisheries (Murtagh et al. 1992). The wild population (late run) is considered the last remaining wild coho stock with a substantial run in the entire Columbia River Basin (Murtagh et al. 1992).

The late wild run generally spawn above the North Fork Reservoir, on the mainstem Clackamas (Cramer xx). The self-sustaining early run fish spawn primarily in the Clackamas River above the Collawash and in Clackamas River tributaries such as Deep, Eagle and Clear Creeks. (Cramer xx). There have been no stocking for about 5 years or egg boxes for coho supplementation for the last 3 or 4 years (D. Caldwell ODFW pers comm. 5-24-2002) in Clear or Foster Creeks. It is likely the coho in Clear and Foster Creeks Creek are a combination of self-sustaining stock from the Eagle Creek Hatchery and possibly some wild coho stock.

Table 8-3: Summary of the timing of anadromous fish life history stages in Clear and Foster Creeks (based on Murtagh 1992, Cramer xx).



8.4.2 Fish Stocking

- *Which salmonid species are native to the watershed, and which have been introduced to the watershed?*
- *What are the species interactions?*

The fish species stocked in Clear and Foster Creeks are summarized in Table 8-4 (Hatchery release data downloaded from: www.osu.orst.edu/dept/nrimp/information/index.htm). Data available on the WEB site only listed releases until 1991 and did not include egg boxes that were placed in streams as part of ODFW's STEP program. Dick Caldwell of ODFW was contacted and he stated that due to endangered species concerns release of hatchery raised fish had been discontinued for at least 5 years and that the egg box enhancement programs in Clear and Foster Creeks had also been discontinued at least 3 to 4 years ago (Dick Caldwell ODFW 5-23-02 pers. comm.).

There are no references to brook trout currently occurring in either Clear or Foster Creeks. It is likely these stocking efforts were unsuccessful.

The only identified species interaction is increases in hatchery returns of winter steelhead and declines in wild steelhead returns have raised concerns that hatchery fish may be interbreeding with wild fish (Cramer xx).

Table 8-4: Summary of fish stocking in Clear Creek Watershed.

Species	Release Years
Brook trout	1949, 61, 65, 66, 67, 69, 71, 78, 81
Chinook salmon	1952, 54
Coho salmon	1980, 1982, 85
Cutthroat trout	1948, 1970, 72, 74, 75
Rainbow trout	1947-1949, 1952-59, 1960-1979
Steelhead	1955, 84, 85, 91

8.4.3 Whirling Disease

Whirling Disease has been found infecting fish up to Metzler Park in Clear Creek. This disease is caused by a parasite, *Myxobolus cerebralis* (Mc), that infiltrates the head and spinal cartilage of fingerling trout where it multiplies rapidly, causing the fish to swim erratically and, in severe cases, die. When an infected fish dies, millions of tiny indestructible Mc spores (each about the size of a red blood cell) are released to the water where they can survive in this “dormant” form for up to 30 years. When Mc spores are ingested by Tubifex worms, the spores change inside the worm are released from the worm in a highly infective form, the Triactinomyxon (Tam). Tams are free-floating in the water until they infect trout, causing spinal deformities and decreased abilities for feed. Whirling disease is most infective to rainbow and cutthroat trout, but can infect all salmonid species (http://www.whirling-disease.org/).

Typical signs of whirling disease include a darkened tail, twisted spine and deformed head (shortened, twisted jaw). Young fish may also swim erratically (whirl). Stocking or natural movement of live, infected fish is the primary route by which whirling disease is disseminated (http://www.whirling-disease.org/).

It is thought the disease may have been introduced to Clear Creek by a stray eastern steelhead (D. Caldwell, ODFW 5-23-02 pers. comm.). ODFW thinks the disease may be persisting at the small hatchery on main Clear Creek off of Ridge Road. The theory is worms in the mud of the hatchery ponds provide a host for the parasite to reproduce, however it has not been found in high enough concentrations to be harmful yet (Dick Caldwell, ODFW 5-23-02 pers. comm.). The current recommendation is to remove the sediments in the hatchery ponds and install liners, in addition more testing is recommended in the lower Clackamas tributaries to determine the distribution.

8.4.4 Aquatic Habitat Condition

- *What is the condition of fish habitat in the watershed (by sub-basin) where habitat data have been collected?*

Field reconnaissance notes and habitat data was collected between 4/4 and 5/29/2002. Sites to be visited were identified by selecting a representative sample of CHT types distributed throughout the subwatersheds. Field checking sites within the anadromous fish zone and tributaries for anadromous fish access was the priority. Sites with features that were difficult to identify on aerial photos were also a priority. Due to limited access no sampling was completed in the Little Clear Creek subwatershed.

Due to all the private lands access was often limited and difficult which slowed down the field sampling effort. However notes and photos were collected at 36 sites and quantitative habitat condition data was collected at 8 sites. Because of the limited access and special interest in the Mainstem of Clear Creek we decided to kayak from Fischer's Mill to the mouth so conditions along the entire reach could be observed. This kayak effort was done on 5/20/2002 and notes and photos were taken at 30 sites. The field notes and photos are compiled in Appendix 1, *CHT and Aquatic Habitat Field Report*, which is an electronic database with clickable map showing the site locations and data summaries.

Key parameters of the quantitative habitat data were compared to the NMFS PFC matrix values in Table 8-2 and rated as properly functioning (PF), at risk (AR), not properly functioning (NPF) or not applicable (na). These results are summarized in Table 8-5. There were some clear patterns in the quantitative habitat data. Substrate conditions were properly functioning at all sites and in general most sites visited in Clear and Foster Creeks had nice gravels with only localized areas of high fines and embedded conditions. Where there were floodplains conditions were in properly functioning condition which means there were frequent active off channel areas and margin side channels. Large woody debris numbers were low at almost all sites visited which can directly influence pool formation and bank stability. At most sites all three parameters were rated as not properly functioning. In addition, most of the large wood that was observed was very old and decadent, it will probably not last in the channel much longer.

Table 8-5: Summary of Habitat Conditions measured in Clear and Foster Creeks during 2002 field sampling effort.

Site	Sub-strate	Large Woody Debris	Stream bank Condition	Off-Channel Habitat	Floodplain Connect-ivity	Pool Freq	Pool Quality
Foster Creek above Bakers Ferry Bridge	PF*	NPF	NPF	PF	PF	NPF	AR*
Swagger Creek above Highland Road	PF	NPF	NPF	Na*	na	NPF	AR
Clear Creek - Shibley Property	PF	NPF	NPF	PF	PF	NPF	AR
Bargefeld Creek - Mace-Childs properrty	PF	PF	NPF	NPF	AR	NPF	AR
Spring Creek - above Matoon Road	PF	NPF	PF	na	na	NPF	AR
Clear Creek - John Foster Property	PF	NPF	AR	PF	PF	NPF	AR
Foster Creek - Simkins Property	PF	NPF	PF	AR	PF	NPF	AR
Little Cedar - Jim Rodins Property	PF	NPF	PF	AR	PF	NPF	AR

Habitat Condition Evaluation Key:

AR – Indicate habitat parameters that fall into the "At Risk" range of values
PF - Indicate habitat parameters that fall into the "Properly Functioning" range of values
NPF - Indicate habitat parameters that fall into the "Not Properly Functioning" range of values
na- not applicable

The observations made during the qualitative surveys were similar to the quantitative data. Except in some cases specific conditions were noted. For example in several locations along main Clear Creek large wood was stacked adjacent to the channel after apparently having been removed from the gravel bars in front of private property. In many locations landscaping extended to the edge of the stream creating smooth mowed grassy banks this did not function to provide much cover. Specific locations of problem areas in Clear and Foster Creeks are identified in Appendix 1: CHT and Aquatic Habitat Field Report with yellow dots on the map.

8.4.5 Potential Barriers to Fish Migration

- *Where are there potential barriers to fish migration?*

There are eleven known natural anadromous fish passage barriers in the Clear Creek watershed, these are indicated on *Map 7: Fish Distribution*. The most significant barriers blocking the greatest areas of potential anadromous fish habitat are located at the confluence of main Clear Creek and the north fork of Clear Creek in the upper Clear Creek subwatershed where there are 15 to 20' falls blocking both forks of the river (D. Roberts BLM pers. comm. 5-23-2002). There is also an approximately 10' tall falls on Swagger Creek below Highland Rd. (*Map 7: Fish Distribution*, and see photo in Appendix 1). The other barriers are typically 10 to 30' falls at the mouths of small tributaries to main Clear Creek. While these prevent access to the tributaries the area of potential habitat is small. The mouths of all larger tributaries were checked during the field reconnaissance effort for barriers to fish passage.

In Foster Creek there are no known natural fish passage barriers. There is a small dam above Gerber Road that appears to be seasonally installed and removed. Depending on the timing and use of the dam it may be a fish passage barrier or possibly have a negative impact on downstream habitat.

There is an in-stream pond that completely blocks potential fish passage up Bargefeld Creek. There is potential quality coho and steelhead habitat above this dam. The operations and logistics of providing fish passage around this pond should be investigated.

There is currently an ongoing assessment of all road crossings. This assessment will provide a comprehensive review of all fish passage barriers associated with roads in the Clear and Foster Creek watersheds.

8.5 CONCLUSIONS AND RECOMMENDATIONS

- There is no central collection point for data that is collected making it difficult to track down and compile any information that has been collected. Creating a central collection point for all data collected including ODFW, and Angler Groups. Also, to better document the extent and areas of concentrated fish use try engaging volunteer groups to do annual spawner surveys.

- Due to limited access no sampling was completed in the Little Clear Creek subwatershed. Habitat conditions should be checked in this area.

- Due to the limited tributary access conditions in the main channel should be evaluated. Continue qualitative sampling of main Clear Creek.

- Large woody debris supply is limited throughout the watershed. Pool frequency and number of pools also low. Continue riparian planting for long term supply of large wood. Investigate opportunities to introduce large wood to the channel. Educate landowners about benefits of large wood and impacts of landscaping to the edge of the creek..

- Incorporate results of ongoing road survey and upstream extent of fish into assessment.

- Several areas of impact due to cattle grazing were noted. The grazing creates impacts to banks and vegetation. Locations of these impacts were noted on Clear Creek Hattan Fork trib. and Bargefeld Creek above Fishers Mill Road.

- The Powerline Crossings of Foster and Clear Creeks were areas of no shade on Clear Creek, and major channel clearing and modification on Foster Creek.

- Pond operations of in-channel ponds potentially blocking anadromous fish passage on Foster Creek above Gerber Road, and Bargefeld Creek above Mace property should be investigated.

8.6 REFERENCES

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9.0 WILDLIFE AND UPLAND VEGETATION

9.1 INTRODUCTION

Wildlife and uplands vegetation section provides an assessment of the type and distribution of uplands vegetation, weeds, vertebrate species, rare plant and animals, special concern species, and pest animals. Existing information was compiled on what species may occur in the watershed. There is little specific information on the rare plants and animals. Information on pest and weed species is not available for much of the watershed because the majority of the land is in private ownership. There are gaps in information and surveys. Wildlife analysis was based on vegetation types. Additional data and/or additional monitoring needs are presented in the recommendation section. The acronyms used in this section are listed below:

ACEC	Area of Critical Environmental Concern
BLM	Bureau of Land Management
CRBC	Clackamas River Basin Council
CWD	Course woody debris
ESA	Endangered Species Act
GAP	Gap Analysis Project
GIS	Geographic Information System
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
ONHIC	Oregon Natural Heritage Information Center
OSU	Oregon State University
OSWB	Oregon State Weed Board
OSWL	Oregon State Wildlife Law
PAG	Plant Association Group
SWCD	Soil and Water Conservation District
TES	Threatened, Endangered and Sensitive Species
TNC	The Nature Conservancy
USFS	United States Forest Service
USFWS	US Fish and Wildlife Service

9.2 CRITICAL QUESTIONS

Question 9-1: Are vegetation maps current, do they cover the entire watershed and are they mapped at a scale appropriate for wildlife and Species of Special Concern impact analysis?

Question 9-2: What species of concern (plants or animals), including any disjunct populations, are present within the watershed? What function does the habitat and conditions within the watershed have on these species conservation?

Question 9-3: What special status (plants or animals) are known to occur or is there potential habitat for these species within the watershed? What function does the habitat and conditions within the watershed have on these species long-term viability?

Question 9-4: What are the noxious weed species and what is their distribution within the watershed?

Question 9-5: What wildlife species and habitats found on the Upper Clear Creek are found in the Lower Clear Creek Watershed? Are there wildlife species found in the Upper Clear Creek Watershed, which are important indicator species for the Lower Clear Creek Watershed?

Question 9-6: What are the key data/information gaps for wildlife, rare species, species of concern, and upland vegetation components?

9.3 METHODS

The wildlife and vegetation analysis is based on existing information only. No fieldwork was conducted. State and federal land management agencies, Metro, Oregon Natural Heritage Information Center, and literature review were the primary sources of information. (*Note: Oregon Natural Heritage Program (ONHIC) has moved from The Nature Conservancy and become a state entity associated with Oregon State University. They are now called the Oregon Natural Heritage Information Center (ONHIC) within the Institute for Natural Resources (INR).)* State and federal agencies identify rare plant and animals as well as pest animal and weed species. Existing vegetation maps developed by the Oregon Biodiversity Project and Oregon Natural Heritage Information Center (ONHIC) were used to identify the historic, potential, and current vegetation patterns. CRBC's cooperators, agency web sites, and the ONHIC databases provided further information.

Rare plant and animal species are classified by several agencies including ONHIC, BLM, ODA, ODFW, and USFWS) to provide protection of these species throughout their range. Noxious weeds are classified and managed under the ODA's Oregon State Weed Board (OSWB). Pest fauna are managed under the ODFW's Wildlife Integrity Act.

Little site specific information on presence/absence, distribution, and abundance of rare plants and animals is documented within the watershed. Information regarding wildlife species, weeds, and pest species is not known because of fragmented ownership and largely private ownership throughout the watershed. Information from the BLM's *Upper Clear Creek Watershed Assessment*, *Clear Creek Ranch Vegetation and Wildlife Inventory* (Aregentea Environmental, *et al*, 1999), and personal communications with CRBC's cooperators was used to characterize the flora and fauna of the watershed.

9.4 VEGETATION TYPES

Critical questions: What vegetation classifications are available for the watershed? What are the map scale and resolution? Are any appropriate for wildlife and Species of Special Concern impact analysis?

A vegetation analysis identifies plant communities or vegetation types and subsequently wildlife habitats in a "big picture" scale. This broad scale view of the watershed vegetation types provides a "course filter" approach to conservation planning. Once the pattern and distribution of the vegetation types are examined the "at-risk species" or rare species can be addressed through site specific surveys or "fine-filter" conservation strategies. This section presents the three broad vegetation classifications conducted within the watershed: potential, historic and current vegetation classification and delineation (e.g., mapping). Each of these mapping efforts provides information addressing different issues and can be used to answers different questions.

9.4.1 GAP Vegetation Types

Gap Analysis Project (GAP) vegetation maps provide information on the ***potential vegetation*** (See box below for information on the Oregon Gap Analysis Project). There are two editions of the GAP vegetation map for Oregon. The original GAP map was published in 1993. Steve Ciacco and Jimmy Kagan (ONHIC) conducted this classification and mapping effort. They provided a very detailed vegetation classification however; the spatial resolution was limited by the technology used. The vegetation types were hand delineated on 1:250,000 images. When these images were linked the distortion at the edge of the images resulted in spatial distortion. Minimum mapping unit was 100 ha and was mapped at a scale of 1:250,000.

Second generation GAP data or GAP 2 was developed by the ODFW (See *Map 8: Predicted Vegetation GAP2*). This provided good spatial resolution but the vegetation classification was at a courser scale. The mapping scale was 1:100,000 with a 100 ha minimum mapping unit. There are five cover types within the study area: open water (38 ac); agriculture (24,238 ac); Douglas-fir, western hemlock, western red cedar (21,628 ac); grass, shrub, sapling or regenerating young forest (8 ac); and mixed conifer-mixed deciduous forest (2,883 ac). These types are not evenly distributed across the subwatersheds. Open water and agriculture is limited by terrain in the upper elevations within the study area (Figure 9-1). In addition, parcel size or polygon size (Table 9-1) is not even across the study area with agricultural lands having greater size in the lower watershed and on private lands. Table 9-1 identifies the cover types across ownership within each of the five subwatersheds.

The Oregon Gap Analysis Project (OR-GAP)

In 1988, Oregon was only the second GAP program started in the US. It commenced after pilot project initiated in Idaho by Mike Scott of the Idaho Cooperative Fish and Wildlife Research Unit of the University of Idaho. OR-GAP was managed by Blair Csuti of the Idaho Cooperative Fish and Wildlife Research Unit until 1997 and was completed by the Oregon Natural Heritage Information Center (ONHIC). It has been a cooperative venture, with the initial vegetation map completed by contract staff and the ONHIC, and the initial wildlife distributions developed cooperatively by Oregon State University, the Biodiversity Research Consortium, ONHIC and the Oregon Department of Fish and Wildlife (ODFW). Oregon was also fortunate enough to have a separate statewide biodiversity assessment managed by the Northwest Office of the Defenders of Wildlife. This was the Oregon Biodiversity Project, which started as an effort to implement the results of the first Oregon Gap Analysis work, but wound up as an independent analysis. A second-generation land cover map was developed by ODFW, and ONHIC developed updated species distribution maps based on the second-generation land cover. Because there was access to a historical vegetation cover, the project was able to model vertebrate species distributions prior to European settlement.

Source: http://www.natureserve.org/nhp/us/or

Table 9-1. GAP2 vegetation types for each subwatershed within the Clear and Foster Creek Watershed. Total acres and number of parcels counted of each vegetation type is presented by ownership category.

		BLM		Private		USFS	
Subwatershed	Vegetation Type	Acres	Count	Acres	Count	Acres	Count
Foster	Agriculture			2,237	1		
	Open Water			17	1		
Upper Clear	Agriculture	74	10	3,075	5	40	1
	Grass-shrub-sapling or Regenerating young forest	5	2			3	1
	Mixed Conifer/Mixed Deciduous Forest	248	11	2,605	7	30	3
	Douglas-fir-W. Hemlock-W. Red Cedar Forest	2,251	19	7,368	32	1,647	8
Middle Clear	Agriculture	196	3	4,667	7		
	Douglas-fir-W. Hemlock-W. Red Cedar Forest	703	1	5,454	3		
Little Clear	Agriculture	54	3	2,160	3		
	Douglas-fir-W. Hemlock-W. Red Cedar Forest	592	6	2,992	5		
Lower Clear	Agriculture	276	3	11,459	1		
	Open Water			21	1		
	Douglas-fir-W. Hemlock-W. Red Cedar Forest			620	1		

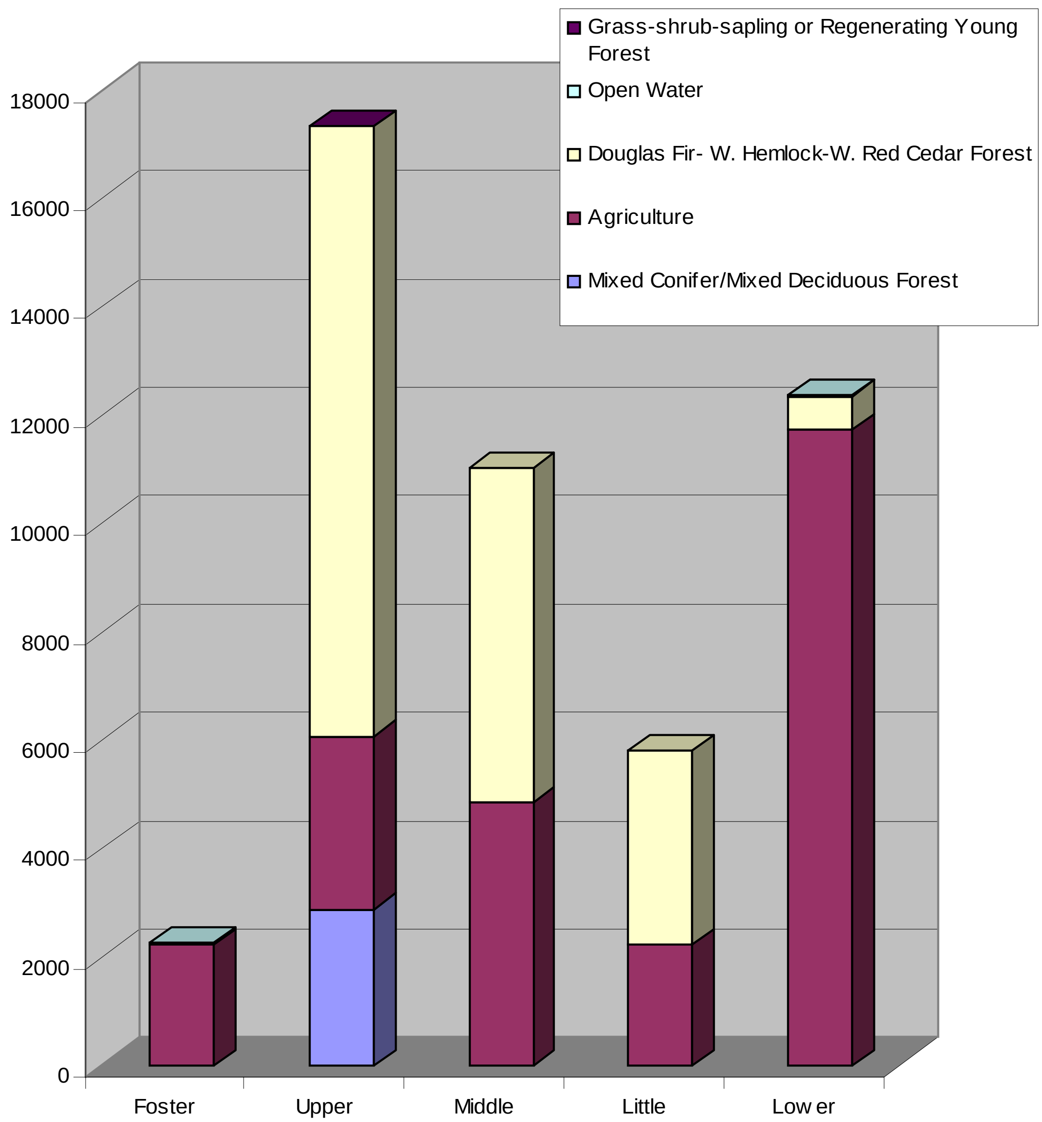

Figure 9-1: GAP2 Vegetation Type Acres by Subwatershed.

9.4.2 Historic Vegetation Types

The Oregon Biodiversity Project classified historic (circa 1850) vegetation. Three vegetation types dominated the landscape. Western Douglas-fir – Mixed Conifer dominated the watershed with over 43,000 acres or 89 % of the watershed. This type dominates all of the subwatersheds and the only type found in Foster and Lower Clear Creek. Mountain Hemlock was found in Upper Clear Creek comprising less than one percent of this subwatershed. The map also shows that Ponderosa pine – White oak was found on south-facing slopes and other drier sites. However, Gilbert Shibley, a Forest Consultant and long time resident of the watershed indicates that it is very unlikely that Ponderosa pine – White oak was located in the upper third of the watershed (Gilbert Shibley, personal communication, 2002). He provides that the community may have been Douglas-fir white oak instead.

Table 9-2. Historic vegetation types for each sub watershed within the Clear and Foster Creek Watershed. Totals number of acres and number of parcels of each vegetation type are provided by land ownership category. (Summarized from ONHIC, historic vegetation map metadata, 2002).

		BLM		Private		USFS	
Subwatershed	Vegetation Type	Acres	Count	Acres	Count	Acres	Count
Foster	Western Douglas-fir Mixed Conifer			2,254	1		
Upper Clear	Mountain Hemlock	217	1	5	1	3	1
	Ponderosa Pine-White Oak	81	6	3,591	2		
	Western Douglas-fir Mixed Conifer	2,279	9	9,453	17	1,718	8
Middle Clear	Ponderosa Pine-White Oak	48	1	1,495	5		
	Western Douglas-fir Mixed Conifer	851	6	8,626	1		
Little Clear	Ponderosa Pine-White Oak	7	2	105	1		
	Western Douglas-fir Mixed Conifer	639	7	5,047	3		
Lower Clear	Western Douglas-fir Mixed Conifer	276	3	12,096	1		

How was the historic vegetation for Oregon (c. 1850, 1936-37) developed?

Various efforts produced GIS data coverage of historic vegetation, vegetation prior to European influence, in parts of Oregon. This effort combines the best available data into a single comprehensive historic vegetation coverage for the entire state. The base coverage was Andrews and Collins 1936-37 vegetation from information in National Forest archives. Oregon Natural Heritage Information Center provided information on Willamette Valley historic vegetation using Surveyors' notes from the 1850's. The remaining data, non-forested lands east of the Cascades, came from the Interior Columbia Basin Ecosystem Management Project's historic vegetation analysis. The purpose of this data layer is to compare historic vegetation to current vegetation patterns.

Source: Defenders of Wildlife, 2002. Oregon Biodiversity Project, Oregon's Living Landscape CD

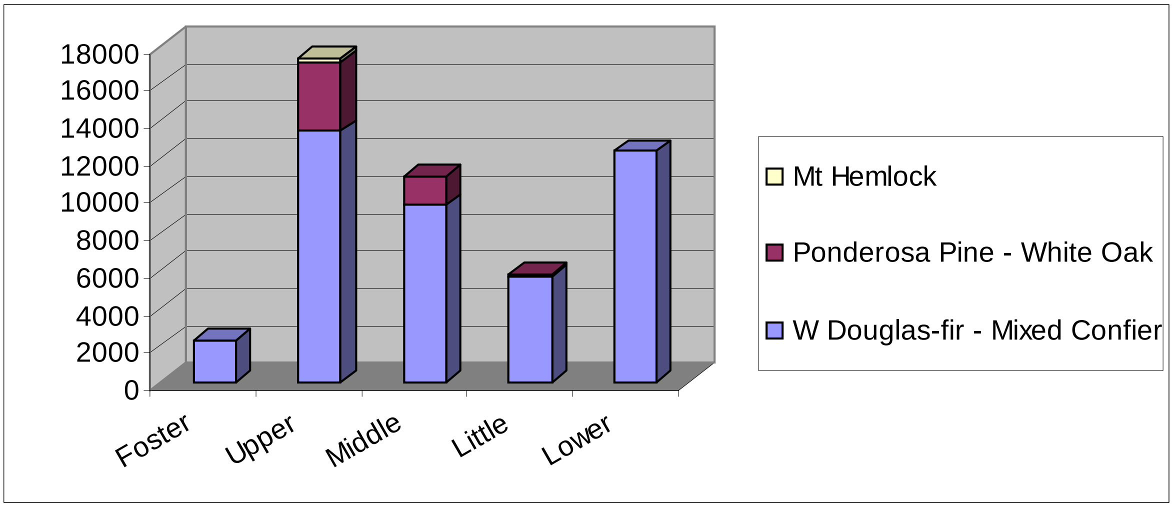

Figure 9-2: Historic vegetation type by subwatershed.

9.4.3 Current Vegetation Types

ONHIC has developed a process to incorporate the most up to date vegetation classification and mapping information. This Best Approximation Map synthesizes classification and mapping efforts from GAP and Plant Association Groups (PAG) (*Map 9: Current Vegetation and Noxious Weeds*, Figure 1-1, and Table 9-3.). The goal of the Best Approximation mapping effort is to revise and update this map as additional information becomes available from agencies' vegetation classification process.

To create this Best Approximation Map two scales and classification types were used. In the lower watershed, Metro's vegetation mapping effort was extracted. The ONHIC and Ecotrust mapped the Metro study area at a scale of 1:100k with 0.5 ac minimum mapping units. In the upper watershed, outside the Metro Analysis study area, Oregon State University (Doug Otter) and ODFW mapped the types on orthophoto quads. The map was ground truthed the delineations and classifications. This upper watershed was mapped using the satellite data at 1:100k scale with 10 ac minimum units. This approach included forest stand ages in its classifications.

Over time the Best Approximation Map by the ORHIC will use PAG data developed by the Forest Service in conjunction with Otter's work to put the tree or species type with the stand age information. For example, forest stands described as younger stand ages but within the PAG area of Douglas-fir – Hemlock will be classified as Douglas-fir while older stands within the same PAG type will be defined as Hemlock providing information on the actual or current vegetation on the site. PAG provides information on the potential natural vegetation of the site. This is useful for land management planning purposes and has been adopted by the BLM and Forest Service. Current vegetation is useful for analysis of current wildlife habitat. Using both tools allows a measure of where we are and where we could go to enhance wildlife habitat.

Today the map has errors or omissions, which requires caution when using this for analysis. Classification for this watershed is poor relative to areas around it because it is outside the Metro analysis area and outside the classification efforts conducted in the upper elevations in the Cascades on Federal lands. Two classification efforts were combined within the watershed each using different categories and each using different mapping scales. These errors could be corrected through a revision of the vegetation map using Orthophoto Quadrangles, natural color stereo-pair photography, and limited on-site vegetation surveys (refer to Recommendations, Section 9.9). In addition, definitions and site verification should be conducted to be sure delineations and definitions are consistent (Figure 9-3: Current vegetation types for Clear and Foster Creek Watersheds.).

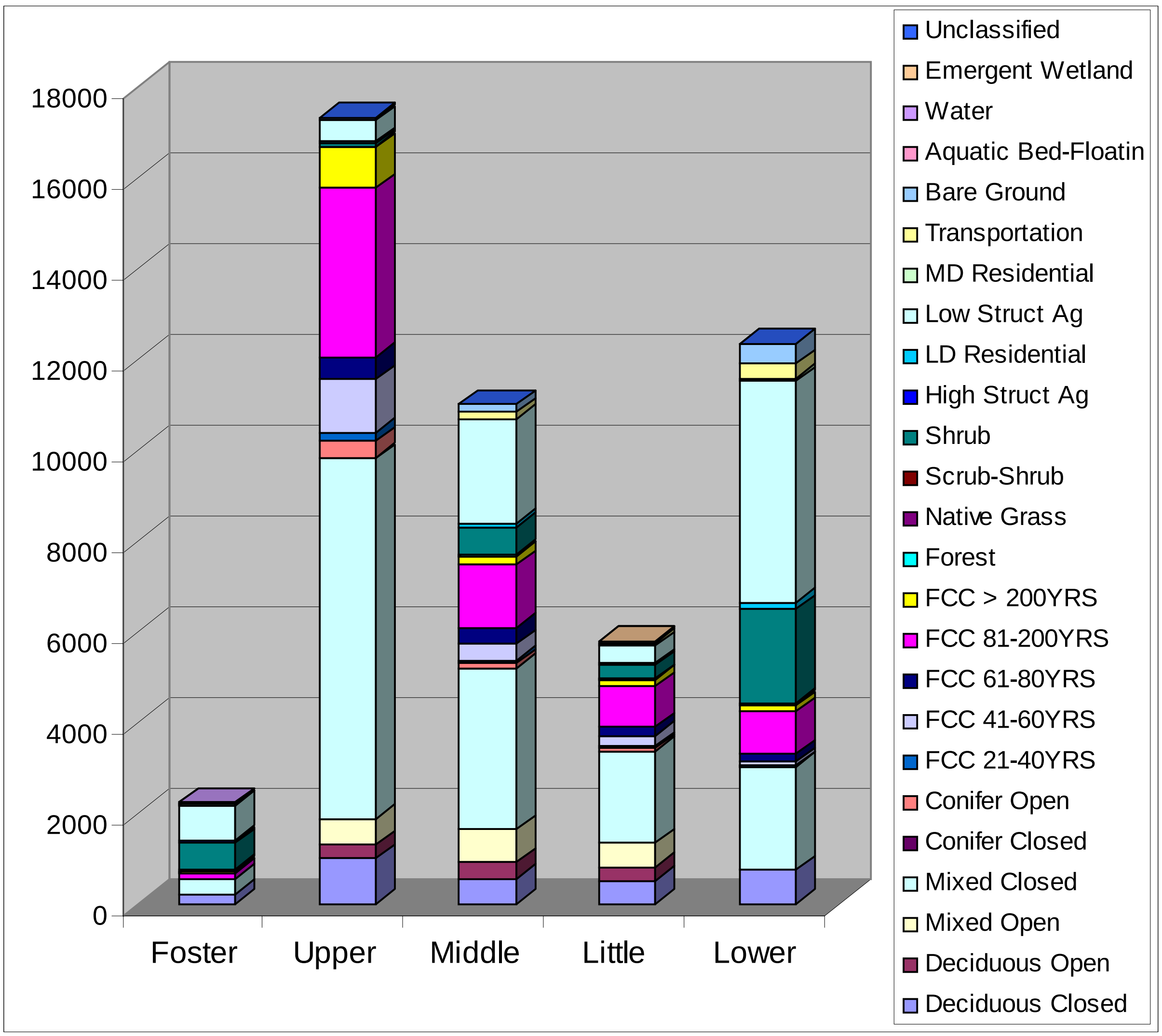

Figure 9-3: Current vegetation types for Clear and Foster Creek Watersheds.

Table 9-3. Current vegetation types or ONHIC Best Approximation Cover Types for each subwatershed within the Clear and Foster Creek Watershed by ownership. Source: ONHIC (Specific definitions for these types are not readily available because this effort pulled together several classification efforts.)

ONHIC Best Approximation	Foster	Upper			Middle		Little		Lower	
Cover Types	Prv	BLM	Prv	USFS	BLM	Prv	BLM	Prv	BLM	Prv
Deciduous Closed	224	54	925	22	74	298	16	500	10	734
	171	56	471	22	21	228	19	309	8	899
Deciduous Open		32	266	10	14	544	1	308		
		39	247	11	21	521	2	162		
Mixed Open	0.2	80	465	22	62	655	1	520		
	1	41	261	8.0	29	191	3	156		
Mixed Closed	333	727	6870	366	301	3265	285	1737	203	2091
	131	183	530	140	69	497	59	374	11	603
Conifer Closed		1	16			4		1		2
		4	58			14		7		7
Conifer Open		12	344	3	9	86		61		
		28	231	7	14	150		112		
Forest Canopy Cover 21-40 YRS		68	59	63	2	68	3	37	0	8
		73	148	87	9	99	15	47	1	27
Forest Canopy Cover 41-60 YRS	1	294	593	293	30	333	61	177	14	84
	5	145	535	122	62	391	72	235	21	172
Forest Canopy Cover 61-80 YRS	3	80	324	79	53	301	51	148	17	137
	10	195	770	159	98	602	96	316	25	287
Forest Canopy Cover 81-200 YRS	130	991	2111	623	288	1108	183	715	31	911
	69	200	806	139	61	638	85	360	28	503
Forest Canopy Cover > 200 YRS	15	237	417	241	17	175	17	123	0	139
	42	173	606	74	34	348	32	264	3	342
Forest	26		16			23	8	22		24
	11		19			22	6	26		16
Native Grass	39					3		1		39
	32					12		3		127
Scrub-Shrub	3							3		
	3							2		
Shrub	579	0	71		13	594	7	286		2052
	230	1	150		23	597	8	220		1300
High Structure Agriculture	34									
	3									
Low Density Residential	32	0	39		1	72	0	40		167
	107	1	140		5	272	2	158		581
Low Structure Agriculture	759		469		34	2281	5	373	0	4875
	279		94		10	265	9	146	1	876
Medium Density Residential	23					4		0		51
	69					15		1		179

ONHIC Best Approximation	Foster	Upper			Middle		Little		Lower	
Cover Types	**Prv**	**BLM**	**Prv**	**USFS**	**BLM**	**Prv**	**BLM**	**Prv**	**BLM**	**Prv**
Transportation	17	29				149	5	53		319
	9	2				8	2	13		29
Bare Ground	36		33		1	157	0	46		462
	98		65		2	219	2	79		702
Aquatic Bed-Floating								0		
								1		
Water	0	1			0	2	0			3
	4	1			1	3	1			4
Emergent Wetland								0		
								1		
Unclassified		1	0		0					0
		3	1		1					1

9.4.4 Plant Species of Concern

Critical question: What are the plant species of concern including any disjunct populations present within the watershed?

For this document, plant species of concern comprises those plant protected by the Oregon State Wildlife Law (OSWL). To protect native plants, the OSWL provides that bulbs, rhizomes, seeds, roots, or native plants shall not be exported from Oregon through sale, offered for sale, or collected with out a permit. This law protects native plants in the following family or genera of plants: *Lilium, Calochortus, Frittillaria, Erythronium, Cypripedium, Calypso, Lewsii, Douglasia, Rhododendron* or *Azalea*. Collection is provided through a permitting process with the State Department of Agriculture.

In addition, federal candidates, federal proposed, state listed and other plants listed by federal agencies as special status plants shall not be exported from Oregon, sold, or offered for sale and are restricted from collection. These plant species with special designations are addressed in Section 9.5. Written permission may be provided by the landowners where research or conservation of the species is involved. The lists are dynamic, changing as additional information is gained on the distribution and abundance of the species. Species may be added to the lists and are immediately subject to the restrictions.

No issues with harvest or use of plant species of special concern were identified within the watershed.

9.4.5 Special Habitats

Special habitats are usually native non-forest types such as meadows, wetlands, rock outcrops, cliffs, and talus slopes and other micro habitat or terrain features. These areas provide additional structure or habitat and contribute disproportionately to the overall biodiversity in a landscape. These areas can be designated with special land management status, such as Area of Critical

Environmental Concern (ACEC) used for these areas on BLM lands. The pond at the headwaters of Moiser Creek in the Little Clear Creek subwatershed does not have specific designation, however it does provide rich habitat for many wildlife species. Habitats such as this pond may be found throughout the watershed.

Other features or elements within the landscape provide microhabitat for wildlife. Standing dead and coarse woody debris (CWD) provides structure (e.g., perches or roost locations for birds) and functional habitat (e.g., cavities for nesting and rodent burrows) conditions for plants and animals in each seral stage. These old, dead trees decay they provide a pool of energy, carbon, and nutrients in ecosystems and have an impact on site productivity. A wide variety of mammals, amphibians, reptiles and ground-nesting and foraging birds use CWD as habitat. The BLM indicates they have a shortage of CWD and snags material within forest cover types according to criteria defined in the resource management plan (J. England, personal communication, 2002).

9.4.6 Weeds

Critical question: What are the noxious weed species and what is their distribution within the watershed?

Noxious weeds are non-native plants that have been legally designated as serious pests because they cause economic loss and harm the environment (ODA 2001). The Oregon Noxious Weed Strategic Plan (ODA 2001) notes that the spread of noxious weeds has been described as a "biological emergency", a "biological wildfire raging out of control", or an explosion in slow motion". Invasive, non-native plants compete with crops, destroy range and pasture lands, clog waterways, affect human and animal health, and threaten native plant communities.

Where do noxious weeds come from and how are they spread?

Noxious weeds, non-native invaders, began to appear and spread with European settlement and continue to arrive today. Most of Oregon's least desirable weeds are Mediterranean, European, and Asian origin. The introduction of non-native invasive plants has increased dramatically in the past decade due to the increase ease and speed of world travel and the expansion of global commerce (Cohen and Carlton 1998). Local spread of noxious weeds can be natural with wind, water and animals; but human activities such as, recreation, vehicle travel, and the movement of contaminated equipment, products, and livestock often greatly increase the distance and rate of dispersal.

Source: ODA 2001, Oregon Noxious Weed Strategic Plan

A lovely example of the mechanism of weed spread is provided by purple loosestrife. Purple loosestrife was originally introduced as an ornamental in the 1880s. It is now a noxious weed in the lower 48 states. Purple loosestrife encroaches on native wetlands, rivers, streams, ponds, and lakes impacting water quality and reducing the population of 44 native plant species as well as impacting song bird, water fowl, amphibian and other wildlife habitat (Blossey, 1999 as cited in ODA 2001). Purple loosestrife invade an area outcompeting native vegetation cause a loss of half of the native vegetation and complete stands of purple loosestrife are not uncommon (Westbrook 1998, as cited in ODA 2001).

In October 2001, an interagency meeting was held to develop a weed list for Northwestern Oregon. Participants at this meeting included: Oregon Dept of Transportation (ODOT), Soil & Water Conservation Districts (SWCD), Forest Service, Counties, and The Nature Conservancy (TNC). A list was developed from this meeting to include those weeds that pose economic (agriculture) as well as ecological risk (*Appendix 4: Appendix 4: Weed List of Northwestern Oregon*). This list has 3 categories of weeds:

- Potential new invaders – species to watch for eradication
- New invaders – have the potential to eradicate these
- Established infestations – too common to map and unlikely to eradicate, control only

Weeds are found throughout the watershed with some elevational and habitat distinction by species (*Refer to Map 9: Current Vegetation and Noxious Weeds*). Few surveys for weeds have been conducted within the watershed. Salem District BLM has conducted roadside inventories for weed species on their parcels (C. Hibler, personal communication, 2002). The most recent systematic roadside inventory of BLM land for noxious weeds was conducted in the late summer of 1998. No high priority species were found. Because gorse (*Ulex europaeus*), a high priority noxious weed species is known on multiple ownerships on private land in the Highland Butte area, BLM conducted an inventory for this species on BLM parcels in this vicinity in 1995. No new sites were found.

Weeds are often dispersed along road corridors so road and highway agencies were contacted. Six noxious weed species identified along Highways 224 and 221 (Bette Coste, ODOT, personal communication, 2002). Eldon Hiller, Vegetation Management Specialist, Clackamas County Road Department, indicated that there was one hogweed location within the Clackamas watershed and Japanese knotweed was located throughout the county (E. Hiller, personal communication, 2002). Table 1-1 lists the high priority noxious weeds known to occur in the watershed.

Although weeds have invaded many parts of the watershed, large tracts remain weed free. The challenge is to protect the weed free areas from invasion, while reducing the impact to areas where weeds have been established. As with tackling weeds in backyards and gardens, vigilance and persistence do count in controlling weeds. Reed canarygrass *(Phalaris arundinacea)* is one example of a common invasive wetland and riparian species, which can be difficult to eradicate. However it can be controlled through habitat modification. This species will not thrive but will persist in shade. Planting trees and shrubs to overtop this species is a reasonable control measure.

Education and cooperation between landowners is a key component of controlling weeds. Weed infestations are commonly shared across land ownership. Effective control can not be obtained if one side of the fence is spraying to control weeds or taking other management action and the neighbor is not participating in weed control.

Table 9-4. Noxious weed species known to occur in the watershed. ***Source: Results of interagency meeting on weeds held on October 10, 2001, Salem BLM.***

Common name	Scientific Name	Comments
Bull thistle	*Cirsium vulgare*	Would like to keep it out of clean areas
Canada thistle	*Cirsium arvense*	Would like to keep it out of clean areas. Thrives in meadows and opening in forests. Spread vegetatively and can become quite dense. Can be a good wildlife species.
English ivy	*Hedera helix*	Common in the lower watershed especially along creeks and residential areas and parks. This species can kill trees.
Himalayan blackberry	*Rubus discolor* (*R. procerus*) & (*R.. armeniacus)*	Common, fungal rusts are potential biocontrol agents in coastal areas. Biocontrol hurdles include: there are about 400 native blackberries in North America of which 70 are Threatened and Endangered species; cane berry industry is very affluent in NWOR; would need an economic analysis which was not included in ODA's economic analysis; good public relations. ODA would only take on this approach if there were a broad support base.
Scotch broom	*Cytisus scoparius*	Established in all counties. On-going aggressive control should occur when densities are low. More difficult to control once established.
*Tansy ragwort	*Senecio jacobaea*	Well established in all counties.

All of these species rank as an ODA "B" designated weed – a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. Where implementation of a fully integrated statewide management plan is not feasible, biological control shall be the main control approach. "B" weeds targeted for biological control are marked with an asterisk. The recommended action for all "B" species is limited to intensive control at the state and county level as determined on a case-by-case basis.

9.5 RARE SPECIES

Critical questions: What rare species are known to occur in the watershed? Are there other similarly ranked species that have the potential to occur in the watershed based on distribution maps and available habitat? What is the long-term viability of these species within the watershed?

It is commonly held that although extinction is a natural process the current rate of extinction has accelerated and is above natural levels. Based on current trends, half of the species on earth will be extinct within the next 100 years (ONHIC, 2001). The major cause of this phenomenon is large-scale destruction of native habitats, which has increased since European settlement began in the mid 1800's - in Oregon and throughout the New World (ONHIC, 2001).

This section provides an overview of the rare plant, fungi, and animals that are known to occur or have the potential to occur. A comprehensive survey has been conducted for the Clear Creek Ranch (Aregentea Environmental *et al*, 1999). BLM lands have also been surveyed for plants and fungi (C. Hibler, personal communication, 2002) and most animals (J. England, personal communication, 2002). A list of potential species that may occur in the watershed was developed through review of the BLM special status list, Clear Creek Ranch report, the ONHIC publication *Rare Threatened, and Endangered Species of Oregon* dated February 2001), and discussion with the staff at the ONHIC and the BLM. Species known to occur in Clackamas County were compared with potential habitat within the watershed. A list of the species, which are known to occur or have the potential to occur in the watershed, is provided in *Appendix 5: Rare Species*. Because much of the land is in private ownership, few surveys have been conducted for these species throughout watershed. Consequently, the distribution and status is largely unknown. Determining trends requires a baseline of information. In all cases, the primary threat is loss of suitable habitat, which leads to fragmentation and isolation reducing species viability.

The USFWS, state, and federal agencies have responsibility for the protection of native flora and fauna. In addition the ONHIC provides a source of information on these species.

Oregon State Endangered Species Programs

In 1987, the Oregon Legislature passed an Endangered Species Act, which gave the Oregon Department of Agriculture responsibility and jurisdiction over threatened and endangered plants, and reaffirmed the ODFW's responsibility for threatened and endangered fish and wildlife. Both of these agencies have entered into cooperative (Section 6) agreements with the United States Fish and Wildlife Service for the purpose of carrying out research and conservation programs for animal and plant species under the auspices of the federal Endangered Species Act. The Oregon Natural Heritage Information Center (ONHIC) has a similar agreement with the Fish and Wildlife Service for invertebrates. ONHIC maintains comprehensive databases for Oregon biodiversity, concentrating on the rare and endangered plants, animals and ecosystems. The program is a partnership between The Division of State Lands, The Nature Conservancy of Oregon and Oregon State University, currently supported primarily by federal natural resource agencies. Biologists working for these agencies, together with the state's herbaria and museums, provide most of the information that comprise ONHIC's databases. A key objective of the ONHIC is to serve as clearinghouse of information regarding site-specific locations of rare, threatened and endangered species in Oregon.

Source: ONHIC 2001

9.5.1 Rare Plants

Rare plants, unlike rare animals, have limited protection on private lands. Systematic rare plant surveys have been conducted on BLM lands and on the Clear Creek Ranch property. Rare plant surveys have not been conducted in most of watershed. As such, knowledge about the presence and distribution of rare plants is very limited.

Three species are known to occur in the watershed: *Latherus holochlorus* (Thin-leaved peavine), *Cimcifuga elata* (tall bugbane), and *Delphinium leucophaeum* (white rock larkspur) (Hibler 2002 and ONHIC). *Montia howellii* (Howell's montia) has a high potential to occur in the watershed but to date has not been found here. Information on these species is provided below. Other species to consider in future surveys are provided in Appendix 5.

***Latherus holochlorus* (Piper) C.L. Hitchc.** Thin-leaved peavine is considered imperiled globally and within Oregon. The FWS has listed this as a species of Special Concern and ONHIC has ranked it as a threatened with extinction. Thin-leaved peavine blooms in June and is found along the Willamette Valley fencerows in loamy, moist soils. This plant was collected in this area in the 1920's.

***Cimcifuga elata* Nutt.** Tall bugbane, a perennial herb, is a Species of Concern found in forested areas of western Oregon, Washington and British Columbia. It is known from two occurrences within moist second growth forests with alder in the study area. Tall bugbane was found sandwiched between private lands on in a rural home site area. The population is not limited to the BLM parcel. It occurs in small populations at moderate to low elevations in forest gaps of moist forests. Deciduous tree species are nearly always present in the local overstory. Tall bugbane is considered rare but not immediately imperiled globally or within Oregon. It is a candidate for listing as threatened by the ODA under the Oregon Endangered Species Act (ESA) and is ranked as threatened with extinction by the ONHIC. Tall bugbane is a BLM Bureau Sensitive category under the BLM's Special Status Species (rare species) Program. To prevent listing of this species the *Conservation Strategy* <u>Cimicifuga elata</u>*: Tall Bugbane* was signed into effect in 1996 by the managers in multiple National Forests, BLM Districts, and COE lands. After implementation of this strategy which included renewed efforts to inventory for this species, numerous new locations of this species were found throughout its range in western Oregon. More than one hundred populations are documented in Oregon.

***Delphinium leucophaeum* Greene.** White rock larkspur was historically found on dry bluffs and open ground. It is now restricted almost entirely to fencerows and protected woodlands. It is a candidate for listing as endangered by the ODA under the Oregon ESA. It is on the ONHIC List 1 that indicates the taxa is threatened with extinction or presumed extinct throughout their entire range. This species was a former Federal Candidate for listing under the ESA. It is known from three sites within the watershed in former prairie, now a roadside strip between fence line and ditch.

***Montia howellii* Wats.** Howell's montia occurs in vernally wet places including seeps, wet grasslands, dirt roads and gravel stockpiles; associated with wetland forbs and grasses. This species has not been found in the watershed to date. It is a BLM Sensitive species, and is on

ODA's candidate. The ONHIC ranks it as a 4, a species which is not currently threatened or endangered, but is rare enough to be conservation concern.

9.5.2 Rare Fungi

Fungi surveys have not been conducted in majority of lands within the watershed. *Sowerbyella rhenana* and *Ramaria araiospora* are two rare fungi, which have been found on BLM lands (Hibler, 2002). Both are on the ONHIC List 3 indicating the more information is needed to determine status, but which may be threatened or endangered in Oregon or throughout their range. Both are BLM Bureau Tracking species in Oregon.

9.5.3 Rare Animals

Information on the presence of rare animal species was largely obtained from the ONHIC, Clear Creek Ranch survey (Aregentea Environmental *et al* 1999) and the Upper Clear Creek Watershed Assessment (BLM 1995). Spotted owl is the only species listed under the ESA known to occur in the vicinity of the watershed. There are eight Special Status species known to occur in the watershed (Table 9-5). Most of these species are affiliated with mature or late successional forests. Nine other Sensitive species may occur in the watershed. In all cases, fragmentation and decreased patch size compromises the species habitat use within the watershed. Corridors and remnants of mature or late successional forests can provide a dispersal mechanism. The habitat fragmentation analysis (Section 9.6) provides an area to consider emphasizing for corridor protection.

Table 9-5. Special Status species known to occur in the watershed or have a reasonable possibility to occur in the watershed.

Species	Federal	OR	ONHIC	BLM	Presence	Habitat
BIRDS						
Northern Spotted Owl *Strix occidentalis caurina*	T	T	1		Known	Mature / late successional
Northern Goshawk *Accipiter gentilis*	XC	C	3	BSO	Possible	Mature forest
Harlequin Duck *Histrionicus histrionicus*	XC	U	2	BSO	Possible	Riparian / uplands
Bufflehead *Bucephala albeola*		U	2	BAO	Known	Riparian / Ponds
Mountain Quail *Oreortyx picus*		U	4	BTO	Possible	Shrub / sapling
Pileated Woodpecker *Dryocopus pileatus*		V	4	BT	Possible	Mature / mixed
Streaked Horned Lark *Eremophila alpestris strigata*		C	3	BSO	Known	Shrub / sapling
Oregon Vesper Sparrow *Pooecetes gramineus affinis*		C	3	BSO	Known	Shrub /sapling
AMPHIBIAN & REPTILES						
Tailed Frog *Ascaphus truei*	XC	V	3	BT	Possible	Riparian / streams
Northern red legged frog *Rana aurora aurora*	XC	V	3	BTO	Possible	Riparian / uplands
Cascade frog *Rana cascadae*	XC	V	3	BT	Possible	Meadows
Clouded salamander *Aneides ferreus*		U	3	BTO	Known	Partial shade
Cascade torrent salamander *Rhyacotriton cascadae*		V	3	BT	Possible	Riparian
Oregon slender salamander *Batrachoseps wrighti*		U	3	BTO	Known	Riparian
MAMMALS						
Long-eared myotis *Mytois evotis*	XC	U	4	BT	Known	Late successional
Fringed myotis *Myotis thysanodes*		V	3	BTO	Known	Late successional
Pacific western big-eared bat *Corynorhinus townsendii townsendii*	XC	C	2	BSO	Known	Late successional
Pacific Fisher *Martes pennanti pacifica*			2		Possible	dry and wet coniferous forest types
INVERTEBRATES						
Oregon megomphix *Megomphix hemphilli*			1	BS	Possible	Moist conifer / hardwood forest, low - mid elevations.

Key to Listing Status

FEDERAL

XC	Former Federal Candidates
FPEO	Federally Proposed Endangered in Oregon
FT	Federally Threatened

OREGON

Animals are administered by the ODFW

SE - State Endangered	A species threatened with extinction with all or a significant portion of its range.
ST- State Threatened	A species that could become endangered within the foreseeable future within all or a portion of its range.
C - Critical	Species for which listing as threatened or endangered is pending; or those for which listing as threatened or endangered may be appropriate if immediate conservation actions are not taken. Also considered critical are some peripheral species, which are at risk throughout their range, and some disjunct populations.
V - Vulnerable	Species for which listing as threatened or endangered is not believed to be imminent and can be avoided through continued or expanded use of adequate protective measures and monitoring. In some cases the population is sustainable and protective measures are being implemented; in other, the population may be declining and improved protective measures are needed to maintain sustainable populations over time.
U - Undetermined Status	Species for which status is unclear. They may be susceptible to population decline of sufficient magnitude that they could qualify for endangered, threatened, critical or vulnerable status, but scientific study will be required before a judgement can be made.

ONHIC

List 1	Taxa that are threatened with extinction or presumed to be extinct throughout their entire range.
List 2	Taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon.
List 3	Species for which more information is needed before status can be determined, but which may be threatened or endangered in Oregon or throughout their range.
List 4	Taxa, which are of concern, but are not currently threatened or endangered.

BLM

BTO - Bureau Tracking Oregon	To enable an early warning for species which may become of concern in the future, districts are encouraged to collect occurrences data on species for which more information is needed to determine status within the state or which no longer need active management. Unless the status of these species changes to federal or state listed or proposed, BT species will not be considered as special status species (rare species) for management purposes.
BSO - Bureau Sensitive Oregon	Includes species that could easily become endangered or extinct in a state. They are restricted range and have natural or human caused threats to survival. BSO are not Federally listed species or listed by the State of Oregon as threatened or endangered. BSO Species are designated the State director and are tiered to the state fish/wildlife/botanical agencies' or ONHIC designations.
BA - Bureau Assessment	Plant and wildlife species, which are not presently eligible for official federal or state status but are of concern in OR/WA, may, at a minimum, need protection or mitigation in BLM activities. These species will be considered as a level of special status species (rare) separate from the BS category.

Source: Oregon and Washington Bureau of Land Management Rare Lists - January 2000 (BLM 2000).

Northern Spotted Owl **–** Three known Spotted Owl sites (KOS) (resident pairs or singles) are known in the vicinity of the watershed (ONHIC). A portion of each of these three KOSs is located in the Upper Clear Creek Watershed. Approximately 50% of the federally managed lands within the watershed have been surveyed for northern spotted owls during the early 90s. No additional surveys are planned. A KOS is established by buffering a site center with the provincial home range radius for the spotted owl. The provincial home range radius in the Western Oregon Province is 1.2 miles.

The Upper Clear Creek Watershed Analysis (BLM, 1995) provides the following analysis for the trends and cumulative effects for this bird. Known populations of northern spotted owls occur to the south and east of the upper watershed in areas of more continuous habitat. The upper watershed provides dispersal habitat, but will not provide significant amounts of suitable nesting, roosting, and foraging habitat (above and beyond the 15% late successional forest required by the Record of Decision). Riparian reserves on federal lands may provide short unconnected dispersal corridors but due to fragmented ownership patterns these corridors, will probably not be adequate for dispersal.

The desired future condition for spotted owls is to provide dispersal and connectivity habitat in the south end of the watershed. This habitat will be complementary to known sites and larger patches of suitable habitat and Late Successional Reserves (LSR's) located to the south and east.

Northern red tree vole is an important forage species for the Spotted Owl. Although the red tree vole is not known to occur in this watershed they are hard to detect and systematic surveys for this species have not been conducted. The BLM survey and manage guidelines for this species require that surveys be conducted for this species prior to management actions. Management guidelines include retention of the largest green conifer trees, maintaining blocks of older forest, and maintaining corridors where possible.

Within the context of other opportunities, timber sales should be designed so as to avoid the removal of remnant older forest patches, avoid fragmentation where possible, and retain older forests.

Oregon Vesper Sparrow **–** Two occurrences of this species are known from the watershed. See Section 9.6.2 Focal Animal analysis for additional information on this species.

Bufflehead **–** This duck nests in woodlands near small lakes and ponds. During winter and migration finds this bird also on sheltered bays, rivers, and lakes. Single female was observed this spring on a pond in the Little Clear Creek subwatershed in April (Bernatas, personal observation, 2002).

Streaked Horned Lark **–** Two occurrences of this species are known from this watershed in the lower watershed. See Section 9.6.2 Focal Animal analysis for additional information on this species.

Long-eared myotis (bat) **–** One occurrence is known from this watershed. Occur in small clusters or individually. Occupies talus and trees and has been found in fir and spruce forests.

Fringed myotis (bat) **–** One occurrence is known from this watershed. This species uses talus and caves.

Pacific Western big-eared bat **–** One occurrence is known from this watershed. This species occupies talus and caves.

Oregon Slender Salamander **–** One occurrence of this species is known from in this watershed. It inhabits closed canopy coniferous forest or conifer/hardwood mixed forest with large, highly decayed down logs. It requires a high level of moisture in down logs for mating and reproduction. All occurrences have been in areas in the Upper Clear Creek drainage that has not been logged. The Oregon slender salamander is thought to spend its entire life cycle within an area of a few square meters.

Other species that could occur in the watershed include:

Pileated Woodpecker **–** This species very likely occurs in this watershed, but no occurrence data was reported from the ONHIC or BLM information. This species is the largest woodpecker in North America. This woodpecker is the most important primary cavity excavator in the northwest, providing large cavities it uses, as well as, cavities being used by other species such as northern flying squirrel and northern spotted owl. This woodpecker forages for carpenter ants requiring a significant number of down logs, snags, and cull trees for foraging and nesting. This bird does not require a closed canopy forest. Previously, logged sites and land clearings that removed most of the snags have had the greatest affect on this species. Large fires that modified a large percentage of the watershed left numerous snags and down logs. Management of privately owned forestlands is regulated by the Oregon Forest Practices Act.

Harlequin Duck **–** This bird found on swift flowing mountain rivers and larger streams where it breeds.

Northern Goshawk **–** Prefers late successional forests at higher elevations such as Goat Mountain in the southern portion of the watershed.

Pacific fisher **–** One was recorded in 1980 north of Estacada near Currinsville. Fishers use both dry and wet coniferous forest types for breeding, feeding and resting as primary and secondary habitats. Fisher has been known to range within the Cascade Mountain in Oregon. Their preferred habitat is widespread continuous canopy forest at relatively low elevations. They feed on a variety of small mammals including rabbits, voles, and mice. They also feed on deer carrion and seasonally on birds, bird eggs, amphibians, fish and insects.

Clouded salamander **–** As with the Oregon slender salamander, this species is dependent on downed logs and inhabits small logs with loose bark in partial shade to sun. It is also more tolerant than the slender salamander to canopy removal. Small down logs are removed for firewood removal and salvage logging. Many private forests within the watershed are highly managed for timber and Christmas trees with little down material remaining.

***Red-legged frog*–** Habitat includes wetlands, ponds, and slow moving streams from the Willamette Valley to about 3,000 ft. Bullfrogs can be competitors with this species. See Section 9.6.2 Focal Animal analysis for additional information on this species.

Oregon megomphix *(Megophix hemphilli)* **–** This invertebrate is a BLM Sensitive. It is found in the duff and leaf litter within moist conifer/hardwood forests with bigleaf maple. Surveys conducted for this species indicate that it is common along the interface between the Willamette Valley and the Western Oregon Cascades.

9.6 WILDLIFE

Critical questions: What wildlife species and habitats found on the Upper Clear Creek are found on the Lower Clear Creek Watershed? Are there wildlife species found on the Upper Clear Creek Watershed, which are important indicator species for the Lower Clear Creek Watershed?

This section provides information on species of concern, pest species, and other wildlife that may occur in the watershed. There have been few studies or surveys for wildlife within the watershed. The BLM has conducted surveys on their lands for some wildlife species. The majority of the watershed has not been surveyed because it is private land. Literature review and discussions with agency personnel did not reveal any wildlife species that were found in the upper watershed that could be used as indicator species in the lower watershed. To evaluate the habitat quality and fragmentation within the watershed focal species analyses were used. These analyses provide a baseline for future surveys to confirm habitat occupation and habitat corridor establishment.

9.6.1 Wildlife Overview

9.6.1.1 Species of Concern

For this document, species of concern are those species that do not have ESA, BLM, USFS or State of Oregon status (protection) but are of local concern or regional importance. Big game (e.g., deer, elk, bear, and cougar), upland game birds (e.g., turkeys and ring-necked pheasants) and non-game species (e.g., most songbirds) are included under this heading. There is little population data available for any of wildlife species either native or non-native game or non-game species (Holly Michael, ODFW, personal communication, 2002). There was a turkey release over 10 years ago, but the success was apparently poor (Tom Thorton, ODFW, personal communication, 2002). Turkeys are not native to this watershed.

9.6.1.2 Pest Species

Pest wildlife species can be viewed much like weed plant species. Both native and non-native wildlife species can be viewed by some as a treasure and by others as a pest. Deer, raccoon, skunk, Canada Geese, and American Crows, although native species, can become "pests" in urban or suburban settings when their population numbers increase. Non-native species or introduced species are more often considered pest species. The impact these introduced species have is competition for limited resources. Starlings, House Sparrows, and bullfrogs are good examples of introduced species, which are typically considered undesirable. Some non-native species such as Ring-neck Pheasants and Chukkar Partridge were introduced for hunting and are considered a welcome addition by upland game bird hunters.

The USFWS animal damage control staff can manage or get rid of Canada Geese or other species, even though Canada Geese are protected under the Migratory Bird Treaty Act. The Oregon Wildlife Integrity Program (See Wildlife Integrity Program box below) provides regulations for importation, possession, confinement, transportation and sale of nonnative wildlife.

Starlings and House Sparrows are widespread throughout the lower watershed and can out-compete native bird species. Two species directly impacting the aquatic fauna include the bullfrog (*Rana catesbeiana*) and nutria (*Myocastor coypus*). Their distribution and abundance in the watershed is not known.

The bullfrog was introduced into the western US to be farmed as a food source (Bury and Whelan, 1984, as cited in Altman 1985). They escaped and spread rapidly. This frog is directly or indirectly responsible for the decline or extirpation of a number of native amphibians and reptiles, particularly other *Rana* frogs (Bury and Whelan, 1984 as cited in Altman 1985). They both out-compete and predate on native species (including non-amphibians such as young turtles and waterfowl) (Adams 1999; Adams 2000; Witmer and Lewis 2001 as cited in Metro 2002). Bullfrogs are relatively insensitive to water quality and habitat fragmentation and can travel long distances overland, unlike most native amphibians (Metro 2002).

The nutria is a semi-aquatic furbearer, which was initially a fur-farm species. They compete with muskrat and beaver using similar habitats. Their burrows can cause erosion on streambanks.

Black-tailed deer are reported as a problem for nursery and Christmas tree plantations (Tom Thorton, ODFW, personal communication, 2002). The seedlings (1-3 year's growth) are especially susceptible to browse damage. Multiple stems can result when the leader growth is removed. ODFW provides permits for harvesting 1-5 deer for damage control. The permit stipulates that meat from this harvest must be provided to charity.

Wildlife Integrity Program

Nonnative, introduced species (sometimes called "exotics") which are brought into Oregon for a variety of reasons are a major concern of the ODFW. The reasons are numerous, but include the following potential problems:

- *competition with native fish and wildlife species for food, cover and space,*
- *spread of diseases to native populations,*
- *destruction of the habitat of native species,*
- *predation (eating) on the eggs, young or even adults of native wildlife, and*
- *breeding with native species, affecting population genetics and the ability of a native species to compete and survive.*

In Oregon, at least 96 introduced fish and wildlife species are known to occur. Sixty-five percent (62 species) have become established in the wild and are believed or known to exist as self-sustaining populations at one or more locations. Not all non-native species would survive in the wild in Oregon if released or if they escaped from captivity. However, many could thrive, and their effect on native species and habitats could be devastating. This could happen even if they survived just a short time.

State law (ORS 496.012) says that it is the policy of the state of Oregon to prevent the serious depletion of any indigenous species and to provide the optimum wildlife recreational and aesthetic benefits for present and future generations. Scientific information clearly demonstrates that importation, possession, confinement, transportation and sale of wildlife regulated by this Commission may result in disease, genetic, ecological, environmental and other threats to Oregon's wildlife resources. Oregon Fish and Wildlife Commission directed the Department to draft administrative rules designed to protect the integrity of Oregon's native wildlife.

A Wildlife Integrity Task Group (Task Group) was appointed to assist the Department as it developed draft administrative rules. The Task Group is comprised of representatives of the Oregon Department of Agriculture, the U.S. Fish and Wildlife Service, veterinarians, wildlife biologists, wildlife breeders, the pet trade industry, conservation organizations, Oregon Fish and Wildlife Commission, Oregon State Police, Oregon Health Division, U.S. Department of Agriculture, Oregon Farm Bureau, the Humane Society, and exotic species clubs. It met six times between 1994 and 1996.

The Task Group recommended that nonnative species be categorized based on their potential to harm native wildlife. Three categories were recommended: Prohibited, Controlled and Noncontrolled. The Task Group placed species or groups of species in one of these categories-
Source: (www.dfw.state.or.us/ODFWhtml/Wildlife/Integrity).

9.6.2 Wildlife Habitat Analysis

Conservation efforts have largely been addressed through the set aside or designation of protected areas, however these relatively small and often isolated parcels are proving insufficient for the long-term maintenance of ecological integrity (Snaith and Beazley 2002). Planning for ecological integrity across the landscape requires both course filter and fine filter levels of analysis. The course filter approach is based on adequate representation of natural feature of habitat types, and the fine filter involves detailed evaluation of landscape-scale processes and the area requirements of viable populations of local species (Noss *et al* 1999). Prioritizing species and evaluating ecological significance is needed where investigating occurrence (presence / absence) and population parameters of every species is not economically possible (Noss 1990; Lambeck 1997). The approach is also useful where private land is the dominant ownership making site-specific surveys logistically difficult.

To address the question of ecosystem integrity and subsequently wildlife habitat, a focal species approach was used to evaluate habitat continuity or corridor needs. "Focal species" refers to individual species selected for monitoring in ecosystem-level management programs (Lambeck 1997). The focal species can include functionally distinct categories including umbrella, keystone, flagship, vulnerable and indicator species; each may provide guidance for conservation planning and management (Snaith and Beazley 2002). Lambeck's (1997) focal species approach lumps species by processes likely to threaten their persistence. His approach selects the species most sensitive to each threat as the focal species. As such, focal species would be those most area-sensitive, dispersal-limited, resource limited and ecological process-limited taxa within the landscape.

To avoid one of the more serious flaws in focal species analysis, the assumption of nestedness (Lindenmayer *et al* 2002), and species from different plant communities or requiring different habitats potentially available within the watershed were selected. The species selected represent different habitats but similar threat mechanisms within the watershed. Selection of the focal species used in this analysis was based on a review of the species of special concern potentially occurring in the watershed and consultation with local biologists. Species were selected with consideration of the available data layers within the project's GIS and the quality of these data.

Three focal analysis were used to evaluate two characteristic habitat types, the dominant cover type, Douglas fir – mixed conifer, and the remnant grassland community. We selected a plant cover type, Douglas-fir – mixed conifer forests, as an "umbrella species" since this habitat type dominated historic vegetation in the watershed. Within this overall forest type, patches of grassland communities were found on dry slopes at lower elevations and within the Willamette Valley (Refer to *Westside Grassland* box below) (Lori Henning, personal communication, 2002; Kagan, personal communication, 2002). Two vulnerable species groups were selected to represent the grassland communities: a grassland bird guild and red-legged frog. The grassland bird guild was formed using two birds, Oregon Vesper Sparrow and Streaked Horned Lark. These two rare birds are known from the watershed. The red-legged frog was selected as the focus for riparian element within the *Douglas-fir* – mixed conifer community. The habitat requirements and habitat element ranks for these species are presented below.

The methods used for the three focal analyses are similar. Habitat variables were identified and ranked to characterize the remnant forest community or to identify suitable habitat for grassland birds and red-legged frog. Suitability is based on habitat parameters (e.g., vegetation cover type, wetlands, stream shade, and slope) and disturbance characteristic (e.g., roads). Only those variables that were available within or could be modeled from the data available within the project GIS database were used. Data layers available included:

Category	**Source**
Vegetation	Best Approximation Map cover type
Patch size	Best Approximation Map cover type
Shade	Shade along the riparian corridor (refer to the Riparian Section)
NWI	National Wetland Inventory types
Ecotone	Best Approximation Map cover type buffer
Road Buffer	Road layer
Riparian Recruitment	Riparian Recruitment (refer to the Riparian Section)

The elements within each variable were ranked (e.g., percent cover with stream shade). Rank was based on characteristic of historic *Douglas-fir* – mixed forest or the species habitat requirements. A habitat suitability model was developed to incorporate these variables for each focal analysis.

We suggest using these analyses as a preliminary assessment based on the best available information. This caution is based on the known problems with the Best Approximation Map of the current vegetation. The ranks used are based on literature and the results have not been field verified. These results provide a reasonably good first approximation of suitable habitat and provide a focus for additional surveys on monitoring efforts.

Umbrella species analysis for Douglas-fir – mixed conifer cover type: Variables used for this analysis included vegetation types, patch size, riparian recruitment, shade, National Wetland Inventory. A buffer was defined around roads to consider disturbance factors. Table 6 shows the criteria used and ranked variables. The model for determining remnant *Douglas-fir* – mixed conifer habitat analysis is presented below:

Habitat quality = shade + riparian recruitment + NWI + vegetation + patch size – road buffer

The results reveal that most of the remnant *Douglas-fir* – mixed conifer cover type is located in the Upper Clear Creek subwatershed. (Refer to Table 7 and *Map 11: Douglas-fir mixed conifer vegetation.*) A corridor of this forest type can be found adjacent to Clear Creek in the Middle Clear Creek subwatershed. Patches of higher-ranking habitat were found within the Little Clear Creek watershed. Few large patches or older age stands of Douglas – fir mixed conifer cover type remains in the Foster Creek or Lower Clear Creek subwatershed.

Oregon Vesper Sparrow and Streaked Horned Lark – These two birds were formerly common breeding birds of open fields in the Willamette Valley. Information on these two bird species is summarized from the *Sensitive, Threatened, and Endangered Vertebrates of Oregon* (ODFW, 1994).

> "As a species, vesper sparrows are widely distributed medium sized, brownish or grayish sparrows with a chestnut-colored patch on the wings. Distinctive features are the white outer tail feathers, which are shown in flight (ODFW 1996). The Oregon Vesper Sparrow is one of three subspecies of vesper sparrows and is found west of the Cascade Range in southern British Columbia, Washington and Oregon. Populations of Oregon Vesper Sparrow are highly fragmented today. It was once found in agricultural areas and hillsides. Pre-European settlement, this sparrow was known from prairie or grasslands that were periodically

disturbed by fire. With settlement these areas became agricultural lands with a mix of cropland, brushy fencerows, and weedy pastures until the late 1940's. After World War II small diverse farms have tended to be converted to large, relatively weed-free fields that lack fencerows. One breeding bird route where this species is still recorded has grasslands devoted to pasture and hay. Other notable habitat is described as having some bare soil or sparse growths of unmowed grasses and weeds. Small trees or shrubs that provide perches must also be present. Gilligan *et al* (1994) described this bird occurring today "primarily on drier, grassy hillsides". The suggested cause of decline is a change in farming practices that result in a reduction of weedy areas, singing perches, weedy pastures, and fencerow vegetation. The habitat has also been lost to urbanization. This bird is susceptible to nest parasitism by brown-headed cowbirds which were not common in western Oregon until the 1950's."

"Streaked Horned Lark is a sparrow-sized, ground-dwelling true lark. This species was formerly very common but now is considered depleted and uncommon (ODFW 1996). In *Birds of Oregon* (Gabrielson and Jewett, 1940) this lark is noted as a "common breeding bird of open fields in suitable localities throughout western Oregon" and "a habitual fence post percher". It uses open fields, particularly those having bare ground or sparse vegetation. Overgrazed pastures and recently plowed areas are used. They feed on the ground. Nests are dug in dry ground with sparse vegetation. Habitat parameters are not fully understood for this species. "

Westside Grasslands

Once widespread in the Willamette Valley, Westside Grasslands are now rare, limited, and currently declining due to fire suppression, conversion to agriculture and urban habitats, and invasion by non-native species. In the Metro region, this habitat in its native form has virtually disappeared. Sometimes referred to as prairie or, in the Oregon Coast Range, grass balds, this habitat occurs near or adjacent to many other habitats. Often used for grazing and recreation, Westside Grasslands may be grassland or savanna, with less than 30 percent tree or shrub canopy cover. Bunchgrasses dominate native sites, with space between vascular plants covered with mosses, lichens and forbs. Rich diversity of native forbs is typical of sites in good condition. When present, tree and shrub species vary widely. Degraded sites tend to be dominated by exotic grasses. Grassland vegetation provides several essential wildlife functions and values. According to Partners in Flight (2000), 44 breeding bird species are highly associated with grassland/savanna areas in the Willamette Valley. Open meadows are also important to raptors, providing vital hunting grounds and in turn, keeping rodent populations in check.

Historically, dry soils and fire (lightning strikes and intentionally set by indigenous inhabitants to maintain food staples) eliminated or thinned invading trees, but fire suppression over the past century has led to Douglas-fir encroachment, converting many grasslands to shrublands and/or forests. Because grasses have rapid generation turnovers and do not block sun from taller plants, this habitat is particularly vulnerable to invasion by non-native species through human-associated disturbances such as vehicular use or grazing. Prescribed fires and other management activities can help control Scot's broom and Douglas-fir encroachment in these grasslands.

Source: Metro 2002, Metro's Technical Report for Goal 5, January 2002 and Johnson and O'Neil 2002.

Based on habitat requirements for these two grassland bird species the following variables were used to develop the habitat suitability model: shade, vegetation type, vegetation patch size, National Wetlands Inventory (NWI) category and ecotone. The ecotone category was developed to capture the effects of adjacent vegetation types. The ecotone category is the 400 ft buffer between grassland and agricultural types. Those shrublands cells within that 400-ft buffer were given a value of a 2. Ranks of the characteristics of the variables are presented in Table 6. Roads were not buffered because these birds use fence post and weedy areas found along road right of ways. Grassland, shrub and scrub-shrub communities were ranked high while closed forest types and coniferous communities of any age class were ranked low because they would not be suitable habitat for these species. Low structure agricultural lands were also ranked high since these birds have been recorded using this type. High structure agricultural communities were ranked low. See text box below for a discussion of wildlife habitat provided by agricultural lands. The habitat suitability model used for this analysis:

Grassland birds = shade + patch size + vegetation type + NWI + ecotone

Very little habitat is available for these species in this watershed (refer to Table 7; *Map 12: Habitat Analysis Upland Birds*). Foster Creek has the largest contiguous habitat for this bird guild. These birds are known from this subwatershed. Little Clear Creek subwatershed provides about four small sites. Lower Clear Creek subwatershed also has some small parcels that may provide suitable habitat. Middle Clear Creek and Upper Clear Creek subwatersheds provide little habitat for these birds. Historically, it was likely that little habitat was available for these birds in the upper watershed because of the dominance of the coniferous forests.

Red-legged frog – This frog is not known from this watershed. Habitat does exist within the watershed and no systematic surveys have been conducted for this species within the watershed. The following is summarized from *The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest* (Blaustin *et al*., 1995). The red-legged frog is a medium to large frog with reddish to olive dorsal surface and considerable flecking. The flecks are small black spots that generally have indistinct edges. The chest and abdomen may be gray or white. The hind leg undersurface and the posterior portion of the abdomen are usually pink to red, although in some individuals they may be yellow. Breeding occurs early in the year and is temperature dependent. For example, in Corvallis, OR, frogs move to breeding areas in January when the air temperature reaches 10^{o} C. They use permanent bodies of quiet water including small ponds, quiet pools along streams, reservoirs, springs, lakes, and marshes. These frogs can be found in forests a considerable distance from water. They have been reported as much as 200 to 300 m from standing water. They inhabit land for most of the day, however when predators approach they escape to water and remain there for long periods of time.

Red-legged frogs inhabit moist forests and riparian areas, typically below 850 m. Although not restricted to old-growth habitat they were reported most abundant in old-growth stands and least abundant in young stands. Abundance was negatively associated with elevation, slope, talus, rocky outcrops, and positively associated with all deciduous and broadleaved evergreen trees. They are notably more abundant at lower elevations with flatter slopes.

Populations of red-legged frog seem to be in decline in areas outside old growth. Threats to this species include bullfrog introductions, pesticides and herbicides. Loss of old-growth forest is indicated as a mechanism for population declines, however this frog was not considered as an evaluation criteria for old-growth.

Habitat variables available were ranked based on habitat requirements for this frog. The characteristics within the variables were ranked according to habitat suitability. The model first developed an area along streams using a buffer of 300 ft (600 ft wide total). All other habitat outside of this buffer is not considered suitable habitat for this frog. The 300-ft buffer was selected as a conservative estimate of habitat use since little is known about buffer width

Do agricultural lands provide wildlife habitat?

This habitat can be diverse, ranging from hayfields and grazed lands, to multiple crop types including low-stature annual grasses to row crops to mature orchards. Hedges, windbreaks, irrigation ditches, and fencerows provide especially important habitat for wildlife (Demers et al. 1995). USDA Conservation Reserve Program lands are included in this category and may provide valuable wildlife habitat. Agricultural lands are subject to exposed soils and harvesting at various times during the year and receive regular inputs of fertilizer and pesticides, thus influencing the quality of water-associated habitats.

The greatest conversion of native habitats to agricultural production occurred between 1950 and 1985, primarily as a function of U.S. agricultural policy (Gerard 1995). Since the 1985 Farm Bill and the economic downturn of the early to mid 1980's, the amount of land in agricultural habitat has stabilized and begun to decline (National Research Council 1989). The 1985 and subsequent Farm Bills contained conservation provisions encouraging farmers to convert agricultural land to native habitats (Gerard 1995; McKenzie and Riley 1995). Clean farming practices and single-product farms have become prevalent since the 1960's, resulting in larger farms and widespread removal of fencerows, field borders, roadsides, and shelterbelts (National Research Council 1989; Gerard 1995; McKenzie and Riley 1995). In Oregon, land-use planning laws prevent or slow urban encroachment and subdivisions into areas zoned as agriculture.

Because this habitat type is human-generated, there is no "natural" disturbance regime. Fire is nearly completely suppressed; in absence of fire or mowing, unimproved pastures become increasingly shrubby. Edges can be abrupt along habitat borders, with important implications for wildlife. Presence of non-cultivated or less intensively managed vegetation such as fencerows, roadsides, field borders and shelterbelts can enhance structural diversity. Integrated pest management plans and similar farming practices can help reduce the impacts of fertilizers and pesticides (Gerard 1995).

Twenty-nine percent of birds and 25 percent of mammals native to Oregon use croplands and pasturelands to meet their habitat needs (ODFW 1993). Agricultural fields left fallow for the winter often provide wintering habitat for migratory birds (ODFW 1993). Many of the species that use this habitat require the nearby associated aquatic habitats to meet their needs. Bird species at risk that depend on this habitat include Oregon Vesper Sparrow and Western Meadowlark. One mammal, the Camas Pocket Gopher, is at risk at the federal level.

Source: Metro 2002, Metro's Technical Report for Goal 5, January 2002 and Johnson and O'Neil 2002.

requirements for amphibians. In western Oregon, 75-100 m (246-328 ft) may be necessary to protect riparian-dependent reptiles and amphibians. The NRCS (1995) recommended minimum 30-m (98-ft) buffers to protect frogs and salamanders, and Rudolph and Dickson (1990) recommended the same buffer width for the full complement of reptiles and amphibians. The dependence of amphibians on LWD suggests a minimum of 30-m buffers.

A road buffer (300 ft) was also established to reflect the potential negative impact of siltation. Connectivity between habitat patches is likely to be of particular importance to this relatively immobile group (Metro 2002). Vegetation types, patch size, and National Wetland Inventory category were included in the model to address overall habitat requirements. Stream gradient, shade, and riparian recruitment attempted to address microhabitat requirements. The ranks used for this model are presented in Table 6. The model used to develop habitat suitability ranks is:

Red-legged frog = shade + riparian recruitment + NWI + vegetation + patch size – road buffer

The model revealed segments of the main stem of Clear Creek has suitable habitat for the red-legged frog (refer to Table 7, *Map 13: Habitat Analysis Frog*). Suitable habitat segments were found along Clear Creek within the Middle and Upper Clear Creek subwatersheds. Upper reaches of Little Cedar Creek within the Upper Clear Creek subwatershed have some potential habitat. Little continuous habitat was found in Lower Clear Creek and Foster Creeks subwatersheds. Little Clear Creek subwatershed provides some continuous suitable habitat for this species.

9.7 HABITAT FRAGMENTATION AND HUMAN DISTURBANCE

"The primary cause of decay of organic diversity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human populations and human activities" (Ehrlich 1988).

Agricultural development, home site development, weed encroachment, and human and domestic animal disturbance have created habitat fragmentation within the watershed. Plant communities and species within the community are adapted to local conditions such as terrain, soils, and moisture regime. As long as conditions remain unchanged, species and communities tend to persist in the same place over time (Primack 1993). Changes in dispersal mechanisms, competition, and predation have changed plant communities and species over the course of thousands of years. Today changes happen quickly. Major threats to biological diversity that result from human activity are habitat destruction, habitat fragmentation, habitat degradation, introduction of exotic species, spread of disease, and over exploitation (Primack 1993).

Results of the *Douglas-fir* - mixed conifer analysis show the remnant section of this forest type. Habitat fragmentation and available corridors (or places for corridor enhancement) can be identified on the resulting habitat quality map. (Refer to Table 7, *Map 11: Douglas-fir mixed conifer vegetation.*) Little remaining vegetation is found in the lower watershed while patches do occur in the upper watershed. A corridor of the *Douglas-fir* forest community follows much of Clear Creek with the exception of the Lower Clear Creek subwatershed. A statistical analysis of habitat fragmentation was not conducted because of the inconsistencies in the mapping scales used across the watershed (refer to Section 10.4.3 – Current Vegetation). Results using these data would reflect the differences in mapping scales rather than a true edge or patch effect.

Effects of habitat loss or fragmentation includes residential development which has been shown to cause an increase in free-ranging dog and cat populations, vehicular traffic, illumination from yard lights, nonnative plants, and the number of people present on the land (Knight *et al* 1995). Rural dog and cat populations result in an increase in predation of small mammals, birds, and larger mammals such as deer fawns (Jurek 1994 as cited in Mitchell *et al*. 2002). Species have different sensitivity to human disturbance in that some avoid humans while others are attracted to them. Increasing housing developments were found to result in a decrease in Black-headed Grosbeaks, Blue-gray Gnatcatchers and Orange-crowned Warblers and increase in Black-billed Magpies, and Brown-headed Cowbirds (Odell and Knight *in press* as cited in Mitchell *et al* 2002). Wildlife management objectives developed for public lands may also be more difficult to implement effectively because of the influence of activities or available habitat on private lands. Changes in vegetation composition and landscape structure may limit animal travel corridors, reduce suitable habitat for sensitive species, and increase predation by domestic pets (Mithcell *et al* 2002).

Increase in human presence is one principal way that wildlife is disturbed (Knight and Gutzweiller 1995 as cited in Mitchell *et al* 2002). Simply by being in the environment humans disturb wildlife. Through attraction of avian nest predators, human activity near nests is known to cause lower nesting success or nest failures in some species. This is a significant conservation issue because many wildlands are subjected to repeated intrusion by recreationists, ecotourists, and other users groups during avian breeding seasons (Gutswiller *et al*. 2002).

One element of human disturbance observed in this watershed is recreational shooting. On one visit in April 2002 to the Upper Clear Creek watershed there were at least six groups of people engaged in recreational shooting. The targets (bottles and cans) were placed on stumps and most folks were shooting from the road. Rifle noise is a known disturbance to wildlife. Disturbance that adversely affects activity budgets reduces time available for more productive activities, such as foraging, and increases energy expenditure (Stalmaster and Kaiser, 1997). This disturbance factor occurring in the spring, during breeding season, may be more harmful than during other seasons.

9.8 INFORMATION GAPS AND MONITORING NEEDS

There is a paucity of information for most upland vegetation and wildlife analyses. No surveys have been conducted for TES species, weeds, pest wildlife species, plant species of concern, or any other wildlife. The BLM has conducted surveys for weeds and TES species and has classified and mapped the vegetation to meet their management needs. These BLM lands comprise a small portion of the watershed and are primarily situated in the Upper Clear Creek subwatershed. Extrapolation of these survey data to the rest of the watershed is problematic since the disturbance mechanisms between the upper watershed and the lower watershed area are very different. The disturbance mechanism in the upper watershed is through timber harvest while the lower watershed has been altered due to home site development and agriculture.

The use of the focal species analysis provides a reasonably good first approximation of habitat fragmentation and patch distribution across the watershed. Native habitat is available in at least small patches throughout much of the watershed. The lower watershed provides the greatest challenges for developing habitat connectivity. The following provides recommendations to close the gaps in data needs and suggested monitoring efforts by topic area.

9.8.1 Weeds

Except on BLM lands there is little data on the distribution and abundance of weed species throughout the watershed. The BLM conducts weed surveys on their lands every five years. Another survey should be completed in the next year or two. Vast areas remain weed free based on a windshield survey of the watershed in April 2002 (Bernatas, unpublished data, 2002). Weeds are an overlooked threat to biological diversity and can degrade habitat quality for many species. Surveys should be conducted throughout out the watershed and control measures implemented.

State, county, and federal governments are responsible for implementing and maintaining control programs. Private land owners also play an essential role in effectively controlling weeds. The Oregon Department of Agriculture (ODA) Noxious Weed Control Program and the Oregon State Weed Board (OSWB) provides statewide coordination and provides leadership. The number of weeds listed by the OSWB has increased 40 % over the last 10 years while the funding has not kept pace (ODA, 2001). The public and land managers have increased their interest in managing weeds requiring additional attention, assistance, and technical support from existing resources. The following identifies the 10 objectives and strategies for effective implementation of the Oregon Noxious Weed Strategic Plan:

- Leadership and Organization
- Cooperative Partnerships
- Planning and Prioritization
- Education and Awareness
- Integrated Weed Management
- Early Detection and Control of New Invaders
- Noxious Weed Information System and Data Collection
- Monitoring and Evaluation
- Policy, Mandates, Law, Compliance and Enforcement
- Funding and Resources

Partners in weed control include ODA, OSWB, Division of State Lands, DOT, ODFW, Parks and Recreation, DOF, USFS, and BLM. There is no weed board in the county. There are some efforts to establish weed boards in the Clackamas, Multnomah, and Washington Counties (a board in each county) (Hibler, personal communication, 2002). Supporting the establishment of these weed boards is recommended. The Agriculture Extension Service personnel are often the first agency contacted by the public to control weeds and other vegetation management issues. It is also poorly funded to meet the increased needs. Control of weeds is likely to remain the responsibility of individual landowners. Identification and active initial control is the key to controlling weed invasion.

9.8.2 TES Species

There are limited data and no comprehensive surveys on the presence / absence, distribution or abundance for rare plants, fungi, and animals on lands outside of BLM managed parcels. Wildlife and critical habitat such as nests are afforded protection on private lands, however TES plants are not afforded the same protection under state and federal laws.

The focal species analysis identifies locations within the watershed, which may provide suitable habitat for grassland birds and the red-legged frog. Surveys should be conducted to verify the habitat suitability and determine presence / absence for these vulnerable species. Based on the results of the focal analysis conducted in this assessment a sampling strategy could be used to conduct surveys for these species. Survey areas should be stratified to include areas of initial or first tier surveys and those to be conducted as second tier surveys. Areas to emphasis surveys are as follows:

9.8.2.1 Focal Species - Streaked Horn Lark And Oregon Vesper Sparrow

These two species are really *very* rare in this region now. Survey should be conducted for these species as indicated below. However, because these birds are so rare these species may not been found in any given year. As such, habitat parameters should be refined and this habitat definition should be used as a surrogate or find a couple of other, more common species, to measure response to changes over time. Another consideration is to use Neotropical migrants as a *focal group*. Many declining grassland species are among them.

- Foster Creek -Upper portion of this subwatershed; however, the entire subwatershed should be sampled within suitable habitat. These birds are known from this subwatershed.

- Upper Clear Creek – Small segments along Little Cedar and Clear Creeks could be surveyed in a second tier survey.

- Middle Clear Creek – The lower section of this subwatershed has appears to provide moderately suitable habitat. Other areas to include in a sampling strategy include the unnamed tributary just above stream mile on Clear Creek and small patches on Swagger Creek.

- Little Clear Creek – Minor patches of habitat were located within this subwatershed. These areas could be included in a second tier survey effort.

- Lower Clear Creek – Both of these birds are known from this subwatershed. Known locations should be resurveyed and additional surveys conducted in suitable habitat identified throughout this subwatershed.

9.8.2.2 Focal Species - Red-legged Frog

- Foster Creek – Small segments were identified throughout this subwatershed. The lowest section of Foster Creek was identified as having several small segments of potentially suitable habitat.

- Upper Clear Creek – Some of the most continuous habitat is found along Clear Creek here. Nearly stream reaches support some habitat. Surveys should be conducted throughout this subwatershed in the habitat identified.

- Middle Clear Creek – Portions of Swagger Creek, Clear Creek and unnamed tributary would be included in a first survey sampling effort for this frog

- Little Clear Creek – Mossier Creek, Clear Creek and their tributaries appear to support habitat for this frog and should be included in a first tier survey effort.

- Lower Clear Creek – Little habitat was identified within this subwatershed. Burgled and segments of and unnamed creek east of Mattoon Road provide potentially suitable habitat.

9.8.3 Upland Vegetation

Historic Vegetation – The Historic Vegetation Map developed by the ONHIC may have an error regarding the delineation of the conifer-oak cover type. This issue should be resolved with the ONHIC to determine if there is a clerical error, a classification or delineation error within the database.

Current Vegetation – The current vegetation map (Best Approximation Map) is a good starting point, but has errors which can alter the habitat analysis outcomes. All habitat fragmentation, patch analysis, and wildlife habitat assessment is based in large part on this vegetation layer to define suitable habitat. The Best Approximation Map has numerous small errors. For example, there is a community type category defined as Forest. This category overlaps with one or more of the other forest categories. Other forest type categories also probably over lap. For example, Mixed Open could also refer to a younger age stand of a coniferous forest and therefore overlap with Forest Canopy Cover 21-40 years. Much of this watershed lies between the Metro Analysis Area in the Willamette Valley and the Upper Cascades where federal land managers, particularly the Forest Service have developed vegetation classifications. Because most of the watershed is private, there has been little incentive to update the classification and delineation in this watershed until now. The actions developed from this Watershed Assessment and other Basin wide decisions are based on vegetation data that lack accuracy and precision. Tools and additional information are readily available to revise this map. Jimmy Kagan, Director, ONHIC, indicated that the Forest Service developed a Potential Natural Vegetation map for Northwestern Oregon. This used Plant Associations, a finer resolution of mapping than Alliance. They used Ecoplot and other forest data plots for their initial delineation. This first approximation map was verified using belt transects to determine ecological gradient to refine the delineation. This information along with the Metro data, and Northwest Habitat Institute, and other classification efforts in the vicinity could be used to readily update the current vegetation map in this watershed.

9.8.4 Habitat Fragmentation

The Douglas-fir mixed conifer habitat quality analysis provides for a first approximation of habitat fragmentation. The map developed as a result of this analysis provides a good visual display of potential corridors. The lower watershed is more fragmented because of home site development and agriculture. Forest roads supporting timber harvest fragment the upper watershed. A statistical analysis is problematic because of the mapping scale. A fragmentation analysis conducted for this watershed using the current vegetation map reveals the disparity in mapping scale used in the upper and lower watershed. Comprehensive analyses of this issue may best be addressed once the Best Approximation Map is revisited, however.

9.9 RECOMMENDATIONS AND POSSIBLE COUNCIL ACTIONS

- The most important step in addressing upland vegetation, habitat fragmentation and connectivity, and wildlife habitat is to revise the Best Approximation (Current) Vegetation map for the watershed. Because all wildlife analysis is based on habitat suitability, an up-to-date vegetation map forms the foundation of this analysis.

- After the vegetation classification has been revised, perform a habitat connectivity and habitat fragmentation analysis to identify potential habitat corridors. Metro has developed Wildlife Habitat Criteria Matrix (draft June 4, 2002) which could be used in part to revise the wildlife habitat quality measures.

- Sample appropriate habitat for TES species on willing landowners parcels. Sites for survey are identified in Section 1.8.

- Other species to develop for monitoring include Neotropical migrants particularly in riparian areas. Bureau of Land Management (1998) provides a list of species to consider for an evaluation of riparian condition.

- Weeds are a major contribution to the health of the watershed. All roads within the watershed should be inventoried for weed species. Encourage private landowners to identify and control weed species on their lands. Support the formation of a county weed board to coordinate weed information and control measures.

- Areas along Clear Creek's main stem and tributaries within the Little Clear Creek provide the most continuous habitat. Leaving some remnant patches during harvest activities is encouraged. Developing corridors with in the Lower and Foster Creek watershed is encouraged.

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Web Sites

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